

Appendix A for the Objection Filed Against the Lost Creek Boulder Creek Landscape Restoration Project Draft Record of Decision on August 5, 2019 by NEC, AWR and ISC.

Appendix A contains relevant portions of literature and/or reports cited in the Objection and/or in the Declaration provided by Dr. Sara Johnson, including:

Bull, E., M. Henjum, and Rl. Rohweder. 1988. Nesting and foraging habitat of great gray owls. *Journal of Raptor Research* 22:107-115.

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NESTING AND FORAGING HABITAT OF GREAT GRAY OWLS

EVELYN L. BULL, MARK G. HENJUM AND RONALD S. ROHWEDER¹

ABSTRACT.—During 1982-1986, 46 Great Gray Owl (*Strix nebulosa*) nests were located in northeastern Oregon. Twenty-five of these nests were on stick platforms, 11 were on artificial platforms, and 10 were on broken-topped dead trees. Mean dbh and height of trees containing stick nests were 58 cm and 30 m, respectively, and the majority (76%) of nests were in live western larch (*Larix occidentalis*). Broken-topped dead trees with nests averaged 78 cm dbh and 11 m tall. Forest types in which nests were found included: Douglas-fir (*Pseudotsuga menziesii*)-grand fir (*Abies grandis*) (50%); western larch-lodgepole pine (*Pinus contorta*) (29%); ponderosa pine (*Pinus ponderosa*)-Douglas-fir (15%); and ponderosa pine (7%). Nesting males foraged primarily in mature, open stands (11-59% canopy closure) of ponderosa pine or Douglas-fir.

The Great Gray Owl (*Strix nebulosa*) is the largest strigiform found in North America and is an impressive owl of great interest to bird enthusiasts. This circumpolar species is widespread and occurs in boreal forests from Alaska, east to Ontario, south to Idaho, western Montana, northwestern Wyoming, northern Utah, northern Minnesota, northern Wisconsin, and the Sierra Nevada in California; in Eurasia, this owl occurs in northern portions of Scandinavia, Russia and Siberia (American Ornithologists' Union 1983).

Surprisingly little is known about the Great Gray Owl, making management difficult. To manage for the species, information on the habitat used for nesting and foraging is essential. If foraging habitat is lacking and prey densities are low, the owls will not nest even if nest sites are available. If prey is adequate and nest sites are lacking, again there will be no nesting.

Because these owls depend on existing nest platforms such as old raptor nests, broken-topped dead trees, and artificial platforms (Nero 1980; Mikkola 1983; Winter 1986; Bull et al. 1987; Franklin 1987; Forsman and Bryan 1987), managers have a good opportunity to manage the species by providing nest platforms where they want the owls—provided there is adequate prey and habitat to support them. It is therefore essential to know what habitats are suitable for nesting and foraging.

Our objectives were to determine habitat used for nesting and foraging of Great Gray Owls during the breeding season in northeastern Oregon. Nesting habitat included the nest tree and the area surrounding the tree, in addition to the habitat used by ju-

veniles after fledging who were still dependent on the adults. Foraging habitat included areas used by males who were feeding females and offspring.

STUDY AREA

During March-May 1982 we surveyed for Great Gray Owls in 2 large areas: the area within a 60-km radius around La Grande, Oregon and a 50 km² area 47 km north of Enterprise, Oregon. During 1983-1986 survey efforts were confined to 4 areas where Great Gray Owls were located in 1982—the Spring, Bowman, Sheep and Thomason study areas.

Forest types in each area were categorized using a modification of Burr's (1960) classification by tree species in the dominant and codominant crown classes. Dominant trees were defined as those with crowns extending above the general level of the crown, and codominant trees were those whose crowns formed the general level of the crown (Smith 1962:33). Each of the 4 study areas contained 4 different forest types: 1) ponderosa pine (*Pinus ponderosa*), 2) ponderosa pine-Douglas-fir (*Pseudotsuga menziesii*), 3) Douglas-fir-grand fir (*Abies grandis*), and 4) western larch (*Larix occidentalis*)-lodgepole pine (*Pinus contorta*).

Successional stages in each area were classified based on tree size and stand structure as subclimax, mature, over-mature and remnant. In subclimax stands all trees were <30 cm dbh; in mature stands the largest trees were 30-50 cm dbh; over-mature stands were unlogged and larger trees were ≥50 cm dbh; remnant stands were typically logged and had 1-3 trees/ha ≥50 cm with the remainder of trees <30 cm. The remnant stage identified stands that did not resemble unlogged over-mature stands but contained a few large-diameter trees.

The Spring study area (44 km²) was 17 km west of La Grande at 930-1140 m elevation. Cover types included conifer forest (63% of area), shallow-soiled grasslands (32%) and clearcuts (5%). During the previous 10 yrs, 66% of forested stands within the Spring study area had been selectively logged. As a result most forests in this area consisted of open, park-like stands dominated by ponderosa pine. These stands were on deep soils with a dense cover of grasses. Isolated stands of unlogged, large trees (≥50 cm dbh) comprising 22% of this study area remained. Isolated stands contained Douglas-fir, lodgepole pine,

¹ Deceased.

110- one study area
had 141 ac/ pair
- another = 320 ac/ pair

Table 1. Characteristics of 3 types of Great Gray Owl nest structures at 46 nest sites in northeastern Oregon, 1982-1986.

CHARACTERISTIC	NEST STRUCTURE					
	STICK	BROKEN-TOPPED TREE	WOODEN PLATFORM			
No. nests in Spring	16	1	4			
No. nests in Bowman	3	2	2			
No. nests in Sheep	5	1	—			
No. nests in Thomason	1	6	5			
Nest tree species						
Western larch	76%	10%	45%			
Douglas-fir	20%	20%	—			
Ponderosa pine	4%	70%	36%			
Lodgepole pine	—	—	18%			
	\bar{x}	S.D.	\bar{x}	S.D.	\bar{x}	S.D.
Nest height (m)	17	5.05	11	3.88	12	3.01
Tree dbh (cm)	58	17.16	78	15.24	58	17.20
Tree height (m)	30	4.98	11	3.65	29	8.73
Bole height (m)	10	5.00	8	4.24	13	6.59
Tree age	151	35.07	173	25.40	129	51.73

78 cm =
= 30.7"

western larch, and occasionally grand fir. A total of 52 artificial nest platforms were erected in 1984 in the Spring area.

Bowman (27 km²) was 50 km west of La Grande at 1380-1500 m elevation. Cover types included coniferous forest (68%), shallow-soiled grasslands (20%) and clearcuts (12%). Dense stands of lodgepole pine or mature and over-mature stands of grand fir and Douglas-fir with some western larch and ponderosa pine dominated the Bowman area. About 60% of the forested area had been logged in the 15 yrs prior to our study; lodgepole pine stands had been clearcut, and ponderosa pine and Douglas-fir stands had been selectively logged. Fifty-four artificial nest platforms were erected in this area in 1984.

Sheep (78 km²) was 37 km southwest of La Grande at 1290-1500 m elevation. Cover types included coniferous forest (68%), clearcuts (12%), wet meadows along streams (12%) and shallow-soiled grasslands on ridges (8%). Ponderosa pine forests occurred on south-facing slopes, and lodgepole pine stands or mixed stands of Douglas-fir, western larch and grand fir occurred on north-facing slopes. Greater than 80% of the forested area had been logged (40% clearcut and 60% selectively logged) during the 15 yrs prior to this study.

Thomason (34 km²) was 47 km north of Enterprise at 1350-1470 m elevation. Cover types included coniferous forest (71%) and wet meadows (29%). Forest stands were lodgepole pine and ponderosa pine or mixed stands of Douglas-fir, western larch and grand fir. About 80% of the area had been selectively logged in the 10 yrs prior to this study. There were 38 artificial nest platforms in Thomason at the onset of this study.

METHODS

Locating Birds and Nests. Owls were located after dark in February, March and April by imitating the territorial call of a male Great Gray Owl every 0.1 km while walking through each study area. Areas containing owls were searched for active nests during the day.

Radio Telemetry. Adult Great Gray Owls were captured with bal-chatri traps, noose poles and mist nets (Bull 1987). Radio transmitters (AVM Instrument Co.—SM1, L Module) were placed on 10 males and 13 females and 35 post-fledging juveniles. Transmitters were attached to the bird with a back-pack harness of 6 mm tubular teflon ribbon. The entire package weighed 25 g and lasted 242-505 d. A Telonics TR-2 receiver with a hand-held 2-element Yagi antenna was used for locating owls.

Adult radio-tagged owls were located each spring at their nests. Juveniles were located every 1-3 d for 7 d after fledging. Eight nesting males were followed in the morning (first light until roosting) and evening (departure from roost until dark) 1-2 times/wk from the time transmitters were put on until 2 mo after fledging, or until the radio failed or the nest was abandoned.

Habitat Quantification. Variables recorded at nests included nest type (stick, broken-topped dead tree, or artificial platform), nest height (m), tree species, dbh (cm), height (m), age (increment bore used), and bole height (height of lowest live branch) (m) (Table 1). Stick nests were classified as natural platforms created by dwarf mistletoe (*Arceuthobium* spp.) or as vacated nests built by Northern Goshawks (*Accipiter gentilis*) or Red-tailed Hawks (*Buteo jamaicensis*). At 4 sites we saw hawks con-

Surveys,

Table 2. Habitat characteristics in circular 0.1-ha plots centered on 46 Great Gray Owl nests in north-eastern Oregon, 1982-1986.

CHARACTERISTIC	\bar{x}	S.D.	FRE- QUENCY
Forest type			
Douglas-fir-grand fir			50
Lodgepole pine-western larch			29
Ponderosa pine-Douglas-fir			15
Ponderosa pine			7
Successional stage			
Mature			26
Over-mature			41
Remnant			33
Logging			
None			72
Partial cut			19
Adjacent to clearcut			9
Canopy closure (%)			
0-10			7
11-59			30
≥60			63
Live trees/0.1 ha ≥50 cm dbh	3.2	2.51	
Dead trees/0.1 ha ≥50 cm dbh	1.0	2.10	
Live trees/0.1 ha <50 cm dbh	26.7	14.70	
Dead trees/0.1 ha <50 cm dbh	9.2	7.80	
Leaning trees/0.1 ha <10 cm dbh	5.1	14.45	
Regeneration (trees/0.1 ha)	41.8	55.47	
Distance to water (m)	231.6	209.98	
Distance to clearing (m)	77.1	70.13	

structing nests in prior years; at the remainder, a nest below the canopy in a dense forested stand was classified as an old Goshawk nest, and a nest high in the canopy of a more open forest was classified as an old Red-tailed Hawk nest.

In a circular 0.1-ha plot centered on each nest, we recorded the variables listed in Table 2. Regeneration included all trees ≤10 cm dbh. We also recorded landform (flat, draw, or slope), slope aspect and gradient, number of canopy layers and height (m) of tallest canopy. With aerial photos (scale 1:24 000) and a planimeter, we determined the percent area in forest, grassland, clearcut and selectively logged forest within a 500-m radius of each nest. The linear distance in edge between forest and grassland within the 500-m radius was calculated with a map measure. Edge was defined as a 60-m wide band where forests and openings met.

Juvenile owls were located every 1-3 d during the week after fledging. Each time a juvenile owl was located, we recorded type of perch used (branch, leaning tree, or top

of a broken-off dead tree) and perch height. Tree species, condition (live or dead), dbh, and height of the tree used for perching were measured. In addition we noted the presence of leaning trees that provided owlets access to perches in upright trees. For the next 2 mo, juveniles were located every 1-2 wks and locations recorded on aerial photographs.

While following radio-tagged males, activity and habitat use data were recorded at 15-min intervals and each time an owl hit the ground when pursuing prey (hereafter referred to as a foraging site). Activity categories were hunting or roosting. Birds actively searching for prey, flying from perch to perch, and staring intently at the ground were classified as hunting. Birds quietly perched in a tree next to the trunk and not watching the ground intently were classified as roosting.

Every 15 min we recorded location of the bird on an aerial photo, estimated canopy closure over the bird and recorded forest type, successional stage, physiognomy of the stand (open or dense forest or edge), logging activity, number of stand layers, type of perch and tree species supporting perch. If a bird was roosting when first located, we recorded the data once and waited until the bird left the roost before continuing.

At each foraging site we recorded percent, height and type of ground cover within a 1-m radius, presence or absence of downed wood within a 1-m radius, diameter (at largest point) of the downed wood, distance owl flew to prey, height of perch, diameter of perch tree and distance to nest. Home range of hunting males was delineated by connecting the outermost radio locations to form minimum convex polygons which were then measured with a planimeter.

LANDSAT data (Isaacson et al. 1982) were used to determine forest canopy closure classes (0-10%, 11-59% and ≥60%) available in 3 of the study areas and in the home range of 5 of the 8 males. The 0-10% class comprised openings; the 11-59% class contained relatively open stands, many of which had been selectively logged; the ≥60% class was primarily unlogged, overmature forest stands.

Density. We calculated density of active nests of Great Gray Owls in Spring and Thomason by counting the number of nests within a polygon defined by the outermost nests in 1984. We chose 1984 because we believe all nesting pairs within the polygons were located that year. We did not present the density as number of nests/study area because we believe all nests in the study areas were not found.

Analysis. Chi-square analyses were used to compare the observed number of foraging locations in each canopy closure class and in edge with the expected number of locations based on the percent edge and canopy closure classes in the home range of each radio-tagged male. We compared habitat characteristics of hunting birds in Spring with those in Bowman and Sheep using a Chi-square analysis. Habitat used by 3 birds studied in Sheep and Bowman were combined because of the small sample size and because the 2 areas had similar habitat and logging activity. We used $P < 0.05$ as the level of significance. We could not test for preference for nest type or nest habitat because we did not determine the number or distribution of available nest sites.

RESULTS

Nest Sites. During 1982–1986, we located 46 nests, 14 of which were used more than once (Table 1). Of the 14 nests used more than once, 6 were used 2 years, 6 were used 3 years, 1 was used 4 years, and 1 was used twice in the same year, so we observed 69 nesting attempts on 46 nest structures. Fifty-four percent of the nests were stick platforms, 24% were artificial platforms and 22% were natural depressions on broken-topped dead trees (Table 1). Of the stick nests, 68% were originally made by Northern Goshawks, 12% were made by Red-tailed Hawks and 20% were natural platforms created by dwarf mistletoe infections.

All 3 types of nests were commonly used, although nests in broken-topped trees and wooden platforms had a lower rate of nest failure (20%) than did nests in stick platforms (34%), suggesting that the latter was a less stable structure because young or eggs fell through on at least 4 occasions. The majority of stick nests were in large diameter (≥ 50 cm dbh) live western larch (Table 1). The majority of nests in broken-topped dead trees were in large diameter ponderosa pine at least 7 m tall. Nests in wooden platforms were at least 9 m above the ground in live trees.

The mean size of 11 stick nests was 74 cm (SD = 17.32) long, 65 cm (S.D. = 11.97) wide, 27 cm (S.D. = 14.04) high, with a depression 7 cm (S.D. = 2.70) deep. The only nest on a broken-topped dead tree that was measured had a circular depression in the top of the tree that was 56 cm in diameter and was 26 cm deep.

The majority of the nests occurred in Douglas-fir–grand fir forest types and in over-mature and remnant stands (Table 2). Sixty-nine percent of nests occurred on slopes, 22% on flat ground, and 9% in draws; mean slope gradient at nests was 13% (S.D. = 9.28). Sixty-five percent of nests were on north-facing slopes. Northern aspects are preferred by Northern Goshawks (Reynolds et al. 1982), the primary builder of nests used by Great Gray Owls.

Western larch comprised the dominant crown class at 52% of nest sites, ponderosa pine 28%, and Douglas-fir and grand fir the remainder. Ponderosa pine comprised the dominant crown class at nests in Thomason, and western larch comprised the dominant crown class in the other study areas. The co-dominant crown class was comprised of lodgepole pine at 51% of the nests, Douglas-fir at 31% and ponderosa pine at 18%.

Seventy-two percent of nest sites had not been logged, but 60–80% of stands in each study area had been logged. Forty-four (96%) of 46 nest sites had ≥ 2 canopy layers, the tallest layer having a mean height of 34 m (S.D. = 4.90). Density of live trees < 50 cm dbh at nest sites ranged from 5–64 stems/0.1 ha, and of live trees ≥ 50 cm dbh ranged from 0–10 stems/0.1 ha. Density of dead trees ranged from 0–36 stems/0.1 ha at nest sites. Regeneration ranged from 0–290 stems/0.1 ha.

Area in forest within a 500-m radius of each nest ranged from 52–99%, and forested area that had been logged ranged from 0–97%. The amount of edge between forests and openings within 500 m of the nest averaged 4.2 km (range = 0.7–8.3 km). The amount of area in natural openings within 500 m of the nest ranged from 0–40%. Nests in Thomason contained the greatest amount of natural opening (\bar{x} = 25%), and nests in the other 3 study areas contained 13–15%. Bowman contained the greatest amount of clearcut area (13%) within 500 m of nests; nests in the other 3 areas contained $\leq 6\%$. Total area in openings (natural and clearcut combined) ranged from 18–26%.

Nest Site Fidelity. We observed 18 nesting attempts by 9 pairs where at least 1 member of each pair was radio-tagged. Of the 18 nesting attempts, 39% were on the same nest the next year, 39% were within 1 km of the nest used the previous year, and 22% were farther than 1 km away from the nest used the previous year. Average distance between alternate nests was 1.3 km (range = 0.2–4.5 km, Fig. 1). In 4 cases in which a bird or a pair moved farther than 1 km from their previous year's nest, we found previous nest sites occupied by new pairs.

Density. Shortest distance between 2 active nests was 430 m; 2 other nests were 460 m apart. In 1984 the minimum density of owls was 7 pairs/9.4 km² (entire study area was 44 km²) at Spring and was 5 pairs/2.9 km² (entire study area was 34 km²) at Thomason. At Spring, 2 different females used the same nest in 1984 and were counted as 2 pairs.

Perches Used by Juveniles. Owlets left the nest before they could fly but were capable climbers, using talons, bills and wings to claw and flap their way up tree trunks. For the first few days, leaning trees with bark were easiest for the young to climb. After several days, juveniles could climb up some vertical trees, particularly those with branches or deeply fissured bark (characteristic of large-diameter trees). As owlets aged, they perched higher in the

$$\begin{aligned} 5 \text{ pr} / 2.9 \text{ km}^2 \\ = 1 \text{ owl} / .58 \text{ km}^2 \\ = .22 \text{ sq mi} \\ = 141 \text{ acres} \end{aligned}$$

$$\begin{aligned} 7 \text{ pr} / 9.4 \text{ km}^2 &= 1.3 \text{ km}^2 / \text{pr} \\ &= .5 \text{ sq mi or } 320 \text{ acres} \\ \text{Shortest distance nests} &= .22 \text{ mi} \end{aligned}$$

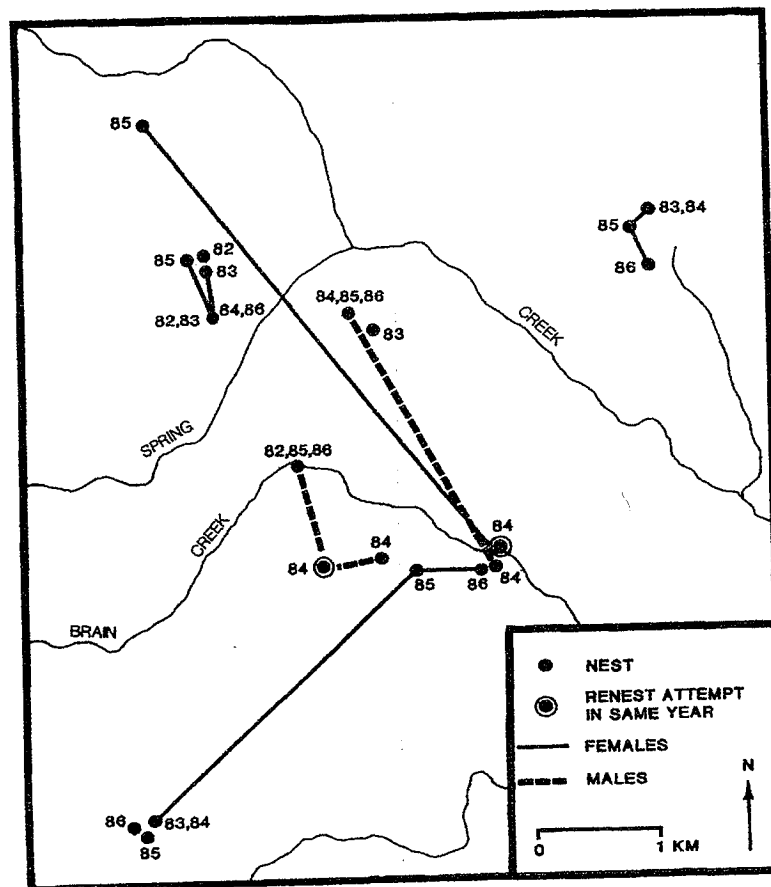


Figure 1. Locations of nests of radio-tagged Great Gray Owls in Spring area 1982-1986. Lines connect nests used in successive years by the same bird.

canopy. Perches used the first week after the young left the nest averaged 6.2 m (S.D. = 4.13) above the ground, had an average canopy closure of 50% (S.D. = 22.16) and were all within 200 m of the nest.

Of 116 perches used by juveniles, 67% were leaning trees or trees which could be reached by climbing a leaning tree; the remainder were branches or broken-topped trees. Leaning perch trees were typically small-diameter (\bar{x} = 16 cm, S.D. = 7.82) lodgepole or ponderosa pine, with an average of 87% (S.D. = 23.80) of the bark remaining. Branches used as perches were typically in live ponderosa pine or Douglas-fir trees with a mean dbh of 37 cm (S.D. = 20.10).

After leaving the nest, juveniles typically moved toward dense forest cover (if the nest was not in a

dense stand). Within 2 wks after fledging juveniles gradually became more mobile but generally stayed within forest stands with $\geq 60\%$ canopy closure (Fig. 2). Family group C ranged the farthest and roosted less frequently in stands with dense canopies than did other family groups (Fig. 2).

Foraging Habitat. During 229 hrs of radio-tracking 8 male Great Gray Owls, we recorded 223 foraging sites and 622 hunting locations at 15-min intervals. Males usually hunted in open forested stands from perches close to the ground. Hunting perches averaged 5.5 m (S.D. = 6.65) high and were in trees with mean dbh of 27 cm (S.D. = 14.06). Mean distance males flew from perches to prey was 10.5 m (S.D. = 9.39). Vegetative ground cover at foraging sites averaged 88% with an average plant

67%
perches
= leaning
tree

perches =
close to
ground
18'

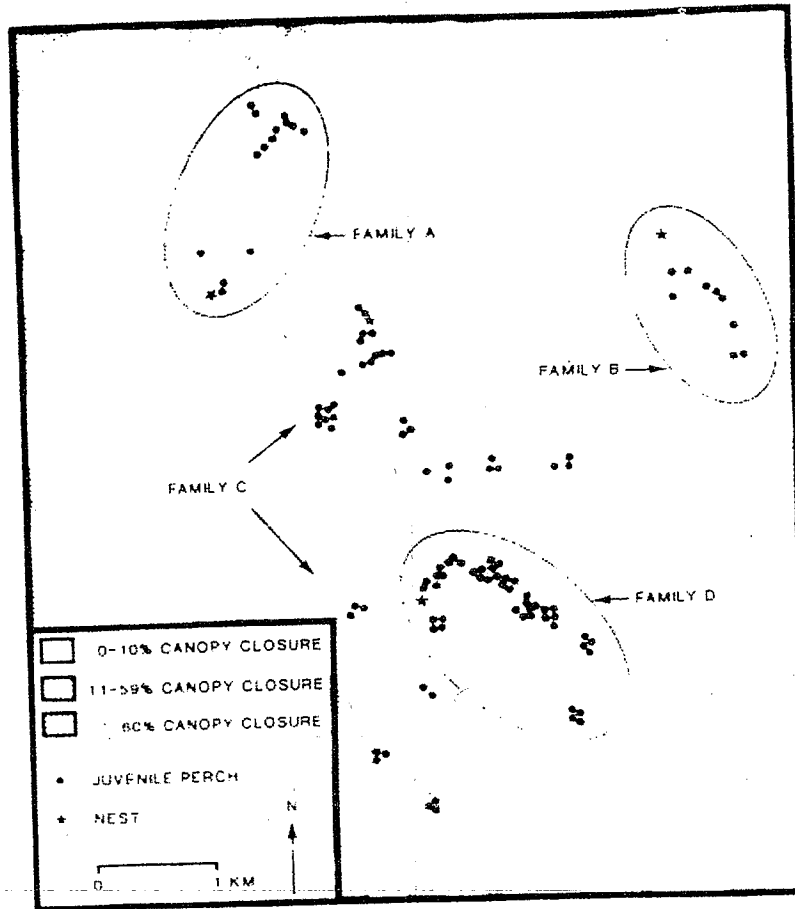


Figure 2. Location of nests and perches used by juveniles of 4 Great Gray Owl family groups in Spring study area. Juveniles were located during 2 mo after fledging. Family groups A and B nested in 1983, and family groups C and D nested in 1985.

height of 21 cm. Grasses dominated in 96% of the sites. Downed wood with a mean diameter of 20 cm was present within 1 m in 77% of the sites.

Mean distance the 8 males moved from the nest when hunting was 0.62 km. One male foraged no further than 0.7 km from his nest, whereas the greatest distance foraged by a male was 3.2 km. Home range of 5 males with ≥ 90 foraging locations averaged 4.5 km² (range = 1.3–6.5 km²).

There was a significant difference in canopy closure of stands used for foraging by 5 males compared to expected use based on availability (χ^2 values for 5 males: 48.1, 41.1, 37.3, 109.8, 58.4; 2 df, $P < 0.01$). Males preferentially foraged in stands with

11–59% canopy closure and avoided clearings. Four of the males avoided stands with $>60\%$ canopy closure, while 1 male used such stands in proportion to their occurrence. Use of edge was significantly greater ($P < 0.05$) than expected with 2 males, less than expected with 2 males, and not different than expected with 1 male.

There were significant differences between 5 foraging males at Spring and 3 at Sheep and Bowman in all habitat variables measured except canopy closure (Table 3). Males at Spring hunted more often in stands that were open, logged, younger, with 1–2 canopy layers and containing more ponderosa pine than did males at Sheep and Bowman (Fig. 3). Males

$$\text{Home Range} = 1.3 \rightarrow 6.5 \text{ km}^2 =$$

$$= 0.5 \text{ m}^2 (320 \text{ ac}) \rightarrow 2.5 \text{ m}^2 (1600 \text{ ac})$$

$$\text{Area used while nesting} = \text{avg}$$

at Sheep and Bowman hunted more often in stands that were unlogged, older, with 2-3 canopy layers and containing more Douglas-fir and lodgepole pine.

Males roosted during the day in stands with 11-59% canopy closure (71%) and stands with 60% or more canopy closure (29%). Eighty-three percent of 62 roost sites were in mature or older stands with 2 or more canopy layers. Sixty-eight percent of roosts were in unlogged stands. Owls roosted at least 7 m above the ground 56% of the time, 3-6 m above the ground 38% of the time and lower than 3 m 6% of the time.

DISCUSSION

Great Gray Owls are versatile in their use of nest structures and readily use artificial nests. In Finland Mikkola (1981) observed the species using nests on branches, on stumps, on the ground, on a cliff and on a barn. Great Gray Owl use of artificial nest structures has been reported by Nero et al. (1974), Nero (1982) and Helo (1984) and provides opportunities for management. Owls may prefer artificial structures over natural platforms; 3 females in our study nested on platforms even though stick nests were available nearby.

Great Gray Owls are flexible in their use of habitats as well. Nero (1980) and Servos (1986) found Great Gray Owl nests in poplar (*Populus* spp.) and tamarack (*Larix laricina*) trees adjacent to muskeg in Canada. Winter (1986) found nests on dead trees in conifer forests only within 260 m of meadows in California. Harris (1984) described nests in forests of tamarack and black spruce (*Picea mariana*) in Canada, and Mikkola (1981) reported nests in dense spruce and pine forests, deciduous stands, wet spruce moors, and swamps in Finland and Sweden. Mikkola (1981) suggested that the owls preferred edges of older stands rather than the interior of large, dense forests. In Oregon we found Great Gray Owl nests in all forest types available within the study areas; however, the majority of nests were in over-mature or remnant stands of Douglas-fir and grand fir forest types on north-facing slopes.

Although the majority of each study area had been logged within 15 yrs of our study, 72% of nests occurred in unlogged stands. Either owls preferred unlogged stands or there was a disproportionate number of potential nest sites in stands, as logging activities often remove large-diameter live and dead trees that could support nests.

Leaning trees and dense cover near nests are im-

Table 3. Foraging site characteristics of 8 nesting male Great Gray Owls in northeastern Oregon, 1985 (data in percent).

CHARACTERISTIC	SPRING (N = 357)	SHEEP/ BOWMAN ^a (N = 265)
Forest type ($\chi^2 = 264.2$, 3 df, $P < 0.01$)		
Ponderosa pine	62	3
Ponderosa pine-Douglas-fir	25	5
Douglas-fir-grand fir	11	60
Lodgepole pine-western larch	2	32
Successional stage ($\chi^2 = 12.1$, 3 df, $P < 0.01$)		
Subclimax	23	17
Mature	61	58
Over-mature	6	6
Remnant	10	19
Physiognomy of stand ($\chi^2 = 82.6$, 2 df, $P < 0.01$)		
Open forest	84	51
Edge	14	30
Dense forest	2	19
Logging ($\chi^2 = 54.2$, 2 df, $P < 0.01$)		
Unlogged	25	49
Partial cut	74	46
Clearcut	1	5
No. stand layers ($\chi^2 = 130.6$, 2 df, $P < 0.01$)		
1	46	13
2	52	54
3	2	33
Perch location ($\chi^2 = 28.3$, 2 df, $P < 0.01$)		
Branch	68	55
Trunk	27	25
Leaning tree	5	20
Tree species of perch ($\chi^2 = 318.2$, 3 df, $P < 0.01$)		
Ponderosa pine	82	7
Lodgepole pine	9	55
Douglas-fir	7	25
Other	2	13

^a The 3 birds in Sheep and Bowman were combined due to sample size.

portant habitat components for fledglings. Owlets left the nest before being able to fly, but leaning trees enabled owlets to climb to perches above the ground. Without leaning trees owlets would be vulnerable to terrestrial predators.

Male Great Gray Owls foraged in a variety of habitats; partially logged stands did not appear to be detrimental, as 62% of foraging locations occurred

preferred habitat

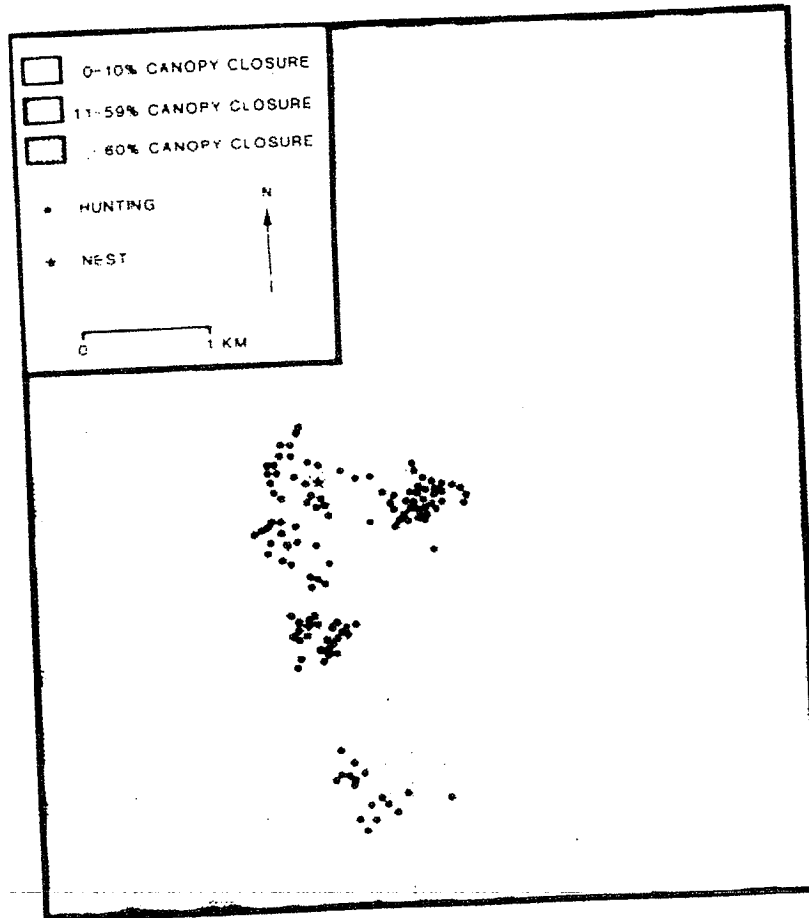


Figure 3. Locations at 15-min intervals of a hunting male Great Gray Owl in Spring study area during daylight. Observations were made on 10 d from 1 April–22 July 1985.

there. Open stands of mature forests were used most for foraging, while subclimax and dense over-mature stands and clearcuts were used less frequently. Winter (1986) reported that Great Gray Owls foraged primarily in or along meadow edges; Franklin (1987) found them foraging in clearcuts. Factors that are important in foraging habitats include high prey density, perch availability and forests that are open enough to allow birds to move freely.

Relatively close spacing of some nesting pairs in Oregon support the belief that Great Gray Owls defend only the immediate vicinity around a nest (Bull and Henjum 1987). Höglund and Lansgren (1968) reported pairs within 100 m of each other in

Sweden; Mikkola (1976) reported 3 nests within 400 m of each other in Finland; and Wahlstedt (1974) reported 5 pairs within 3 km in April. More recently, Lehtoranta (1986) found 2 nests in Finland only 49 m apart, but since only 1 male was seen, polygamy seems possible.

Because the species does not generally maintain mutually exclusive territories, fairly high densities can be obtained. Mikkola (1981) reported 8 nests in 100 km² in Finland, and Wahlstedt (1974) found 5 nests and an additional 4 pairs that he believed were nesting in a 100 km² area in Sweden. In Oregon we found the highest density of nesting Great Gray Owls reported for either North America or Europe.

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HABITAT USE AND MANAGEMENT OF PILEATED WOODPECKERS IN NORTHEASTERN OREGON

EVELYN L. BULL, USDA Forest Service, Pacific Northwest Research Station, 1401 Gekeler Lane, La Grande, OR 97850
RICHARD S. HOLTHAUSEN, USDA Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208

Abstract: We determined home range size and habitats used by pileated woodpeckers (*Dryocopus pileatus*) to provide essential information for proper management of the species in northeastern Oregon. Twenty-three pileated woodpeckers fitted with transmitters were followed for 5–10 months (Jun–Mar) during 1989–90. Mated pairs ($n = 7$) ranged over smaller areas ($\bar{x} = 407$ ha) than birds ($\bar{x} = 597$ ha) whose mates had died ($n = 9$). Habitat use within home ranges was not random. Stands with old growth, grand fir (*Abies grandis*), no logging, and $\geq 60\%$ canopy closure were used more ($P < 0.01$) than expected, and all other types of stands were used less than expected. From June until March, 38% of the observations of foraging were on downed logs, 38% on dead trees, 18% on live trees, and 6% on stumps. We recommend that management for pileated woodpeckers in northeastern Oregon include increasing density of snags for nesting and foraging, increasing density of downed logs in foraging areas, and increasing management areas from the existing 121 ha to 364 ha of forest. Within these areas, we recommend that 75% be in grand fir forest type; 25% be old growth; and the remainder be mature stands; at least 50% have $\geq 60\%$ canopy closure; and at least 40% be unlogged with the remainder in mature stands.

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The pileated woodpecker was selected as a management indicator species for older forests by some regions in the U.S. Forest Service because it nests and roosts in large-diameter dead trees or snags (Hoyt 1957, McClelland 1977, Harris 1982, Bull et al. 1992b), and is largely dependent on dead wood (standing and down) for foraging (Bull 1987). These habitat components are most common in older forests.

Management for pileated woodpeckers on public lands in the western United States has been based on guidelines that recommend leaving specified densities of snags for nesting and roosting to provide for different population levels of woodpeckers (Thomas et al. 1979, Brown 1985). In addition, 121-ha patches of older forests have been maintained for nesting pairs on National Forests in the Pacific Northwest Region. Neither of these management approaches has been tested, however, to ascertain whether it supports the woodpecker in eastern Oregon.

Research conducted elsewhere suggests that the 121-ha management areas are inadequate in coniferous forests. Radio-tagged pileated woodpeckers in western Oregon had home ranges of 257–1,056 ha (Mellen et al. 1992). In contrast, radio-tagged birds in Missouri used only 53–160 ha during April–August (Renken and Wiggers 1989). However, this research was conducted in deciduous forests that are typically more diverse than coniferous forests, so a comparison of home range sizes is not valid.

We felt it necessary to determine population density of pileated woodpeckers in 9 study areas with different snag densities to test the snag guidelines currently in use, and to test the existing guidelines for 121-ha management areas maintained in old-growth conditions in the Pacific Northwest Region.

We are grateful to M. A. Bishop, H. D. Cooper, R. D. Dixon, J. E. Hohmann, S. M. Lindstedt, and A. L. Wright for their assistance with

Table 2. Habitat characteristics (averages) within the home ranges and within 4 size classes of home ranges of pileated woodpeckers, northeastern Oregon, 1989–91.

Characteristic	All pairs	Home range size class (ha)			
		<300	300–499	500–799	>800
n (home ranges)	7	3	6	6	1
Home range (ha)	407	220	370	647	1,464
Home range (forested ha only)	364	208	345	566	1,324
Forest type series (%) ^a					
Ponderosa pine ^b	3	2	2	13	68
Douglas-fir	23	27	19	34	26
Grand fir	74	71	79	53	5
Successional stage (%) ^a					
Young	6	0	5	4	8
Mature	70	59	71	67	88
Old growth	24	41	22	29	4
Logging activity (%) ^a					
None	43	81	38	64	9
Partial	49	19	53	34	81
Shelterwood	8	0	9	2	10
Canopy closure (%) ^a					
<10%	8	1	7	4	15
10–59%	41	24	43	52	68
≥60%	51	75	50	44	17

^a Values are percentage composition of the home ranges.^b Best predictor ($R^2 = 0.78$; $P < 0.01$; stepwise multiple regression) of home range size.

Douglas-fir, and western larch snags were preferred ($F = 7.48$; 5, 75 df; $P < 0.01$). Snags ≥ 38 cm dbh also were preferred ($F = 63.05$; 3, 45 df; $P < 0.01$).

Dead-standing trees and logs were particularly important for foraging, yet their use changed over the year (Fig. 3). When we compared foraging strata without snow (≤ 5 cm) with foraging strata with snow (> 5 cm), we noted an increase in use of live trees (17–22%), an increase in use of dead trees (35–55%), a decrease in use of logs (41–18%), and a slight decrease in use of stumps (7–5%).

DISCUSSION

We believe that home ranges did not overlap a great deal except in situations when birds had lost mates. Birds whose mates had died usually had more overlap and larger home ranges than did pairs. These birds may have expanded their ranges to search for mates, or to forage over larger areas because of poorer habitat.

We were unable to predict size of home range very accurately with the habitat variables. However, the birds did not use habitat within their home ranges at random and selected for stands with old growth, grand fir, no logging, and $> 60\%$

canopy closure. Similarly, Conner (1980) reported that pileated woodpeckers in Virginia used the oldest stands with the highest basal area and density of stems available for foraging.

The snag densities in the study areas were variable, and while we did not consider some areas (Spring and Wallowa) capable of supporting self-sustaining pileated populations, we felt others (Bear and Syrup) were self-sustaining and capable of acting as sources for other areas because of the high density of pairs (7 and 5 pairs, respectively) and successful reproduction (75% of nesting pairs fledged young). We estimated that 16% of the snags ≥ 51 cm in Bear and Syrup had resulted from activity of spruce budworm or Douglas-fir beetle, so 16% of the snag density can be subtracted from the total to yield a density without the influence of an insect outbreak. We were unable to judge the ability of the remaining areas to support self-sustaining pileated populations because of only 1 year of observations and very variable reproduction.

Our observations of foraging differed somewhat from observations in the eastern United States. Conner (1980) reported more snags (49%) and live trees (45%) and fewer downed logs (1%) used by pileateds for foraging in Virginia. Con-

Table 3. Characteristics of available logs

Characteristic
Tree species
Grand fir
Douglas-fir
Ponderosa pine
Western larch
Other ^b
Dbh (cm) ^c
<25
25–37
38–50
≥ 51
Decay class
Recent-dead
Intermediate
Long-dead

n

^a Species of local availability.^b Primarily local.^c Diameter class to availability.^d Limited to 1.^e Long-dead.

of home ranges of pileated

a)	>800
19	1
	1,464
	1,324
	68
	26
	5
	8
	88
	4
	9
	81
	10
	15
	68
	17

Table 3. Characteristics of foraging strata (%) where pileated woodpeckers were observed foraging, and characteristics of available logs and snags that were measured at 240 plots (20 × 20 m) in 12 home ranges, northeastern Oregon, 1989–91.

Characteristic	Downed log		Snag		Live tree observed
	Observed	Plots	Observed	Plots	
Tree species ^a					
Grand fir	23	28	47	75	41
Douglas-fir	25	6	21	9	21
Ponderosa pine	30	27	16	5	16
Western larch	20	14	14	7	21
Other ^b	2	25	2	4	1
Dbh (cm) ^c					
<25	26	46 ^d	8	59 ^d	9
25–37	34	33	26	27	27
38–50	24	12	30	9	29
≥51	16	8	36	5	35
Decay class ^e					
Recent-dead	1	18	24		
Intermediate-dead	23	66	61		
Long-dead	76	16	15		
n	995	2,779	1,030	558	484

^a Species of logs ($F = 5.98$; 5, 45 df; $P < 0.01$; Friedman's) and snags ($F = 7.48$; 5, 75 df; $P < 0.01$; Friedman's) not used in proportion to availability.

^b Primarily lodgepole pine.

^c Diameter classes of logs ($F = 3.28$; 3, 33 df; $P = 0.03$; Friedman's) and snags ($F = 63.05$; 3, 45 df; $P < 0.01$; Friedman's) not used in proportion to availability.

^d Limited to 15–24 cm dbh.

^e Long-dead logs preferred ($F = 47.67$; 2, 22 df; $P < 0.01$; Friedman's).

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ner (1979a) also reported a variety of foraging strategies for pileateds with the majority of excavation occurring in winter, and more pecking and scaling occurring during the spring and summer. Excavation involved gaining access to interior wood where the woodpeckers fed primarily on ants, probably carpenter ants (*Camponotus* spp.) and some thatching ants (*Formica* spp.) (Bull et al. 1992a). Pecking the bark may have uncovered some ants (*Lasius*, *Leptothorax*) and beetles that occurred under the bark rather than in the interior wood (T. R. Torgersen and E. L. Bull, unpubl. data). Tree gleaning occurred primarily in June and July on live Douglas-fir and grand fir when the birds were probably feeding on larvae of western spruce budworm. We found budworm mandibles in woodpecker scats (Bull et al. 1992a).

We observed pileated woodpeckers gleaning branches of live Douglas-fir and grand fir that were infested with western spruce budworm larvae in June and July. This timing coincided with the highest use of live trees (42%) that we observed and also coincided with the greatest abundance of the large, late-instar budworms (Fellin and Dewey 1986). Use of live trees again increased from November to January when we observed woodpeckers frequently excavating at

the base of live western larch. We think they were feeding on carpenter ants in these larch because ant galleries were evident in some of them. Conner (1981) also noted pileateds feeding on carpenter ants near the base of live trees in winter.

Use of snags was greatest in the winter, presumably because logs became inaccessible when snow covered them. Shallow snow apparently did not preclude use of logs because we observed birds wiping snow off logs with their bills and then feeding in the log.

MANAGEMENT IMPLICATIONS

Past management for pileated woodpeckers followed guidelines presented by Thomas et al. (1979) that were based on providing specified snag densities in 121-ha territories. These guidelines were based on the best knowledge available at the time. From our findings, we now know that 121-ha areas are much smaller than observed pair home ranges, and habitat components other than snags are important in managing for pileated woodpeckers in northeastern Oregon. Management plans for pileated woodpeckers should be revised to incorporate this new information.

We recommend using an average home range

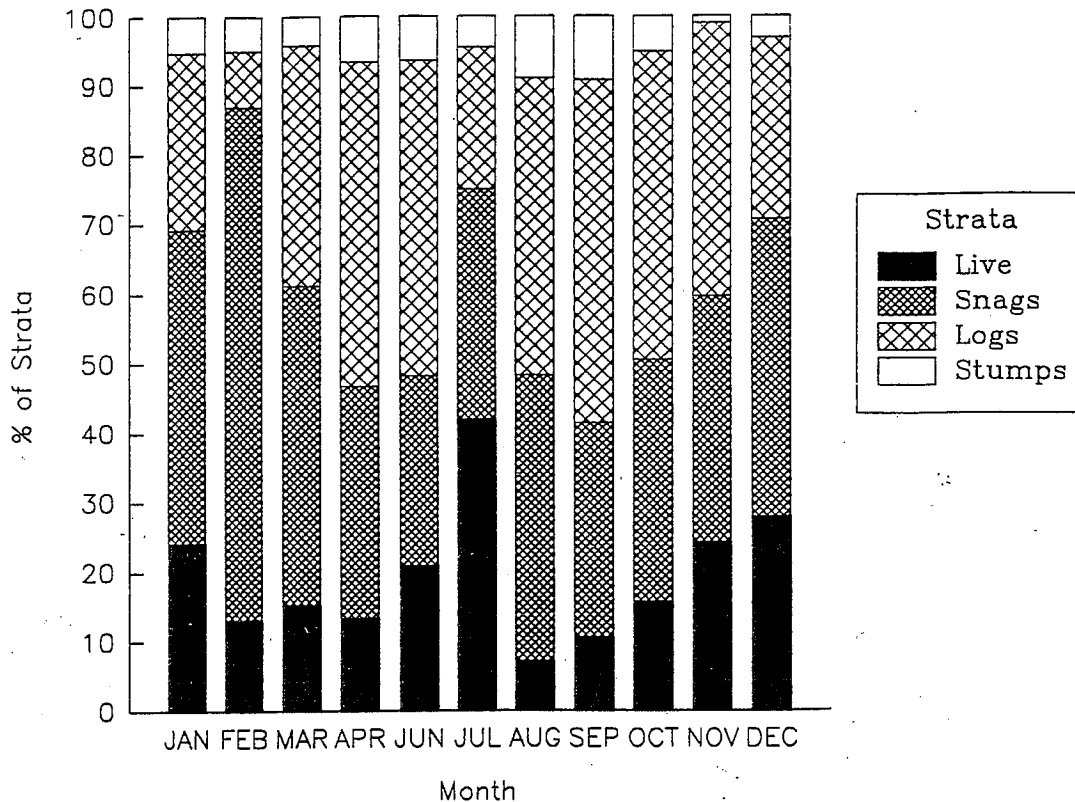


Fig. 3. Monthly foraging strata used by radio-tagged pileated woodpeckers, northeastern Oregon, 1989–91.

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size of 364 ha of forest, more than 3 times the size of current prescribed management areas. Within those home ranges, we recommend that about 75% be in the grand fir forest type; at least 25% be old growth and the remainder be mature; at least 50% of the area should have $\geq 60\%$ canopy closure; at least 40% of the area should remain unlogged, with the remainder having no more than partial overstory removals so mature stands are retained after logging.

40/100
Downed logs were a critical component of the foraging habitat, but only 37% showed evidence of pileated woodpecker feeding. We recommend leaving ≥ 100 logs/ha in management areas, with a preference for logs ≥ 38 cm in diameter (long-dead logs) and for all species except lodgepole pine. We also recommend leaving ≥ 8 snags/ha for nesting, roosting, and foraging; at least 20% of these snags should be ≥ 51 cm dbh.

The existing pileated management areas (121 ha) on National Forests are about 8 km apart. If only 1 pair of pileateds occurs in each management area, and there is 1 management area

for every 4,860 ha, then only 2% of the total forest is being managed for pileated woodpeckers. Additionally, our observations indicate that isolated pairs in marginal (i.e., minimum standard) habitats are unlikely to sustain a population. This information suggests that larger blocks of habitat (for >1 pair), in closer proximity, should be managed for pileateds to provide self-sustaining populations. Such management action is similar to that recommended for the northern spotted owl (*Strix occidentalis*) (Thomas et al. 1990), and would increase the probability of birds finding new mates because if 1 member of a pair dies, the surviving mate does not leave the territory.

Managing for minimum levels of a species is risky (Conner 1979b). Consequences can be unfortunate when new data reveal that current recommendations are inadequate to provide the population levels desired, because other options often have been eliminated. Therefore, we recommend managing clusters of 3 or more pairs in 1 block of habitat with blocks distributed across the landscape through time. This man-

agement types, such as copy closure, trees, and home range.

LITERATURE

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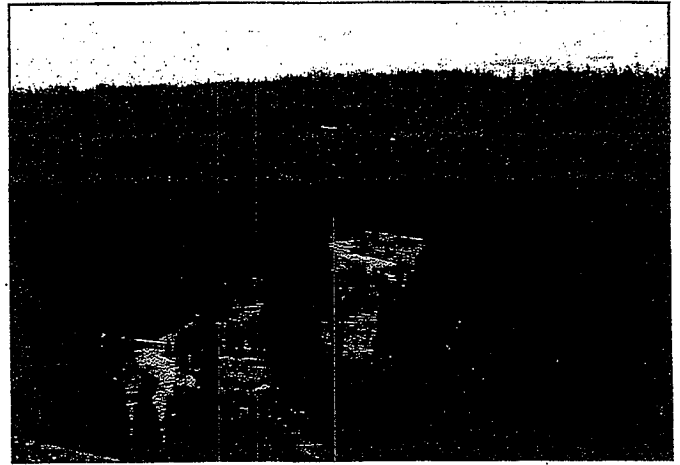
Trees and Logs Important to Wildlife in the Interior Columbia River Basin

Evelyn L. Bull, Catherine G. Parks, and Torolf R. Torgersen

Companion to General Technical Report
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INTRODUCTION



More than 80 species of birds, mammals, reptiles, and amphibians use living trees with decay, trees with brooms, hollow trees, snags, and logs in the interior Columbia River basin. Animals use these structures for foraging, nesting, denning, roosting, and resting. Most notable of these wood-using wildlife species are the primary cavity nesters, the woodpeckers and nuthatches, that excavate nest cavities in decayed wood in standing trees. Their vacated cavities are subsequently used by many other birds and mammals. About 25 percent of the bird species nesting in the northern Rocky Mountain forests are cavity nesters (McClelland and others 1979). Many of the primary and secondary cavity-nesting birds eat forest insects and thus play an important role in regulating their populations. Machmer and Steeger (1995) provide a thorough review of the effect these birds have in reducing numbers of tree-feeding insects.

Tree decay is an important ecological process affecting wildlife habitat. Once begun, the decay process can take hundreds of years as a tree dies, falls to the ground, and decomposes into the forest floor. As it decays, the tree supports many different wildlife groups that use it for foraging substrate, for nesting, and for shelter. The group of wood decomposers is diverse. It includes many arthropods, but in this publication, we focus on decay fungi as the primary organisms in decay. Decay fungi are an essential resource to forest ecosystems in storing and retaining nutrients and in soil development.

This publication provides managers with a description of the ecological processes that create wildlife trees, snags, and logs. It provides qualitative and quantitative information on five distinct structures: living trees with decay (such as internal decay), hollow trees, trees with brooms (misshapen branches), dead trees (snags), and down woody material (logs). We describe the value of these structures to wildlife, the decay or infection processes that produce each type of structure, principles to help in selecting the best structures to retain, and management implications. Although this document cannot prescribe the amount of landscape to manage

for a particular species or a specific, desired population size, it does present information managers can use to make informed decisions regarding the conservation and enhancement of dead wood structures most valuable to wildlife. Forest management practices that fail to properly manage wood components may adversely affect wildlife, soil and stream quality, and forest ecosystem functions.

The information included here applies to coniferous forest lands in the interior Columbia River basin: the area east of the crest of the Cascade Range in Oregon and Washington, all of Idaho, and a portion of western Montana (fig. 1). Tree species characteristic of high-elevation forests, (such as whitebark pine [*Pinus albicaulis*], alpine larch [*Larix lyallii*], mountain hemlock [*Tsuga mertensiana*], and Pacific silver fir [*Abies amabilis*]) are excluded because they typically grow where active management for wildlife trees is seldom needed; these areas are seldom logged. Most of the tree species we deal with here are conifers, although black cottonwood (*Populus trichocarpa*), quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) are

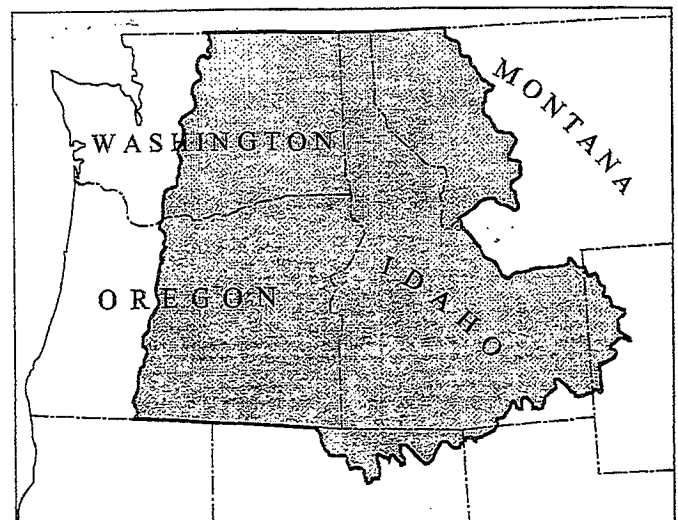


Figure 1—The interior Columbia River basin.

Snag distribution—Snags can either be left in clusters or scattered across the landscape, although where to retain them depends largely on where they currently are. Typically, snags are in clumps naturally because the agents of disease, insects, fire, or flooding that kill many trees act in a localized area. Clusters of snags may be easier to protect during management activities than snags evenly distributed across the landscape. Worker safety is an issue when harvesting adjacent to snags. Retaining snags in clusters, as well as the live trees between the snags, keeps workers away from snags and provides canopy cover for wildlife using the snags.

Two studies on woodpecker use of snag clusters reported different results. No difference was found between woodpecker use of snag clusters versus scattered snags in western Oregon (Chambers 1997). In areas where stand-replacement fires had burned in ponderosa pine/Douglas-fir stands in Idaho, Saab and Dudley (1997) found that cavity nesters as a group select clusters of snags for nest sites instead of evenly spaced trees.

5-25 Most studies recommend managing snags in every 5- to 25-acre patch (Bate 1995, Evans and Martens 1995). Because woodpeckers are territorial, only one pair of each species occupies the same territory; therefore, to attain the maximum density of cavity nesters, snags need to be distributed across the landscape.

In addition, retaining snags on all aspects and on all positions of the slope ensures habitat availability for wildlife species with different preferences. For example, pileated woodpeckers tend to roost in draws during summer but roost higher on slopes in winter (Bull and others 1992). Martens rest or travel in riparian areas a third of the time in summer but only half that often in winter; upper slopes are used half the time in winter but only a third of the time in summer (Bull 1995).

Retaining snags close to living trees provides cover for cavity users. If snags are retained in the middle of a clearcut, species like northern flickers, Lewis' woodpeckers, bluebirds, and American kestrels (*Falco sparverius*) will use them for nesting, but most other woodpeckers will not nest in open areas.

In many areas, fuel-wood cutters are likely to remove snags along roads. This potential problem can be remedied by not leaving snags in areas that are accessible to fuel-wood cutters or by not counting snags left adjacent to accessible roads toward the number retained for a particular stand.

In summary, wherever the objective is to provide viable populations of primary and secondary cavity nesters, prudent managers will provide large-diameter snags when available, snags in a variety of structural classes, snags in every 5- to 25-acre stand and in clusters if available, and snags on all slope aspects and positions of the slope, and adjacent to green trees.

Snag densities—Limited information is available on numbers of snags to retain for wildlife species in the interior Columbia River basin (Bate 1995, Bull and Holthausen 1993, Dixon 1995, Evans and Martens 1995) (table 1). The guide most widely used in the past, Thomas and others (1979), prescribed the number of nest and roost trees to leave for specified woodpecker populations, but the number was based on a hypothetical, untested model and did not include any snags for foraging. Three studies (Bate 1995, Bull and

Holthausen 1993, Dixon 1995) conducted in eastern Oregon have shown that retaining foraging structure is essential, in addition to nest and roost trees in managed landscapes. The Thomas model provided only two roost trees per pair per year, yet research has shown that individual pairs of pileated woodpeckers and white-headed woodpeckers use considerably more than two per year (Bull and others 1992, Dixon 1995). Radio-telemetry studies have shown that home range sizes of pileated woodpeckers (Bull and Holthausen 1993), white-headed woodpeckers (Dixon 1995), and three-toed and black-backed woodpeckers (Goggans and others 1988) are considerably larger than those used in the Thomas model. Raphael and White (1984) found that the relation between numbers of snags and cavity nesters is not linear, which was assumed in the Thomas model. The substitution factor used in the Thomas model is variable and largely a function of snag density. Neitro and others (1985) thought allowing substitution of snags that reduced the number retained was not appropriate. The Thomas model did not take into account the habitat needs of some of the secondary cavity nesters, like bats and brown creepers, that use such snag features as loose bark. In addition, Bull and Holthausen (1993) found lower densities of pileated woodpeckers in nine study areas than predicted by Thomas and others (1979) based on the number of snags present. The above studies present new data suggesting that some of the assumptions and data used in the Thomas model are not valid, and that the prescribed snag densities need to be revised upward.

We know of only three studies in the interior Columbia River basin that have calculated both the density of snags and woodpeckers in managed and unmanaged landscapes. Bate (1995) used six study areas in ponderosa pine stands and found woodpecker abundance was best predicted by hard snag density, large green tree density, canopy height, and number of canopy layers. Of the nine study areas, only one represented a relatively unmanaged forest with the number of snags that probably approximated historical ones. In this stand, Bate found 3.8 snags greater than 10 inches d.b.h., and 60 percent were larger than 20 inches d.b.h. These snag numbers supported 32.3 woodpeckers per 247 acres and represented the study area that most likely supported viable populations of cavity nesters. Dixon (1995) found similar results in some of the same study areas Bate used.

Another study relating woodpecker density to snag density was conducted in northeastern Oregon (Bull and Holthausen 1993). The two study areas that contained viable populations of pileated woodpeckers had an average of 4.2 and 3.8 snags (10 inches or larger d.b.h.) per acre and 0.5 and 0.4 nesting pairs per 247 acres, respectively. The two study areas were in lightly managed landscapes predominated by mixed-coniferous stands with a high density of logs.

Evans and Martens (1995) recommended densities of snags for retention on the Payette National Forest based on their ecological value, encompassing soil health, seedling regeneration, moisture retention, nutrient recycling, and wildlife use (table 1). The numbers that they recommended were derived from actual snag numbers identified during

timber inventory and vegetation plots but were scaled down to the lower ranges of the snag numbers for the recommendations and include snags 10 inches d.b.h. and larger.

Ideally, data would be available on the exact number of snags required to support specific populations of primary and secondary cavity nesters. Unfortunately, this kind of information is not available. We do know, however, that the snag numbers presented by Thomas and others (1979) are not adequate to support the populations intended because of a lack of foraging strata and invalid assumptions used in the model. If management agencies have an objective to manage for viable populations of woodpeckers, providing numbers of snags that have been shown to support viable populations in the recent studies would be prudent.

Although snags are the key structure typically focused on for cavity nesters, realizing the importance of the forest surrounding the snags also is essential. Some species like the pileated and white-headed woodpeckers and American martens are associated with older forests. For white-headed woodpeckers, the snags must be in association with large-diameter ponderosa pines. For pileated woodpeckers and martens, logs, large-diameter green trees, and a dense canopy are needed. Leaving large-diameter snags or green trees in younger forests, also has value as providing biological legacies.

Snag retention in burns—The above management implications apply to healthy green stands. With vast areas of Oregon, Washington, and Idaho burned by wildfires in the 1990s, there is much interest in determining numbers of snags to retain in burned areas after harvesting. Saab and Dudley (1997) reported that woodpeckers selected nest sites with snag densities greater than those measured at random sites in ponderosa pine/Douglas-fir forests with stand-replacing fires. From 10 to 14 snags per acre were retained in burned stands that were harvested; about 38 to 42 snags per acre were in the unharvested burned stands. Seven species of cavity nesters using the burned stands selected nest sites with more than 20 snags per acre, where snags were distributed in clumps. Lewis' and white-headed woodpeckers, and American kestrels selected the largest, most heavily decayed snags available for nesting. Evans and Martens (1995) presented recommendations for numbers of snags to leave in burned stands.

Green tree replacements—Snags are a dynamic resource; old snags fall and living trees die to become new snags. Snag-dependent wildlife need a continuous supply of snags over time. To provide a continuum of snag habitat, future snags must be planned for by leaving green trees to eventually become snags in managed stands. To determine the number of green tree replacements, information on fall rate of standing snags, snag density, live stem density, and mortality rate of live stems is required. Various models have been developed to calculate the number of green trees to provide for recruitment when specific stand inventory information is available (Bull and others 1980, Cimon 1983, Schommer and others 1993). If snags are to be created by killing green trees when the stand becomes snag deficient, the number of green trees required is less because the manager does not have to rely on natural mortality to replace

those snags that fall. Creating snags is costly, however, and stands are seldom monitored to determine when trees need to be killed.

Snag Longevity

Snag longevity, or the amount of time a snag stands, is essential information for managing the snag resource. The length of time snags stand is a primary factor in determining the number of green tree replacements needed to maintain a specific snag density over time. Snag longevity is a function of many factors including species, diameter and height, percentage of heartwood, cause of death, soil type and moisture, forest type, and prevalence of windstorms. Because so many factors influence how long a snag stands, fall rates should be determined by species and size class on each management area. Listed below are studies that report snag fall rates. When possible, the amount of time when 50 percent of snags in a particular study have fallen will be reported.

Several studies have reported fall rates of beetle-killed ponderosa pine. Keen (1955) reported that 50 percent of the ponderosa pines in southern Oregon and northeastern California fell 9 to 10 years after death on pumice soils and 6 to 7 years after death on loam soils. The percentages of snags that fell after 7 years by diameter class, are presented in the following tabulation:

Diameter class (inches)	Percentage
10-18	75
20-28	65
30-38	50
40-48	35
> 50	30

Most of the beetle-killed ponderosa pines in Colorado fall between 7 and 10 years after infestation (Schmid and others 1985). Trees were 7 to 22 inches d.b.h.

In northeastern Oregon, half the ponderosa pines less than 10 inches d.b.h. fell 7 to 8 years after death and half those 10 to 19 inches d.b.h. fell after 8 to 9 years (Bull 1983). Beetle-killed lodgepole pines have similar fall rates, with half of those less than 10 inches d.b.h. falling within 6 to 7 years and half of those 10 inches and larger falling after 7 to 8 years (Bull 1983). In a second study in northeastern Oregon (Bull and Partridge 1986), half of the ponderosa pine snags less than 20 inches d.b.h. fell after 6 years; half of the ponderosa pine snags 20 inches and larger fell after 9 years.

Beetle-killed spruce in Colorado stood much longer than ponderosa pines reported in the studies above. Mielke (1950) found that 84 percent of beetle-killed spruce remain standing after 25 years. Hinds and others (1965) found that 72 percent of beetle-killed spruce remain standing after 20 years.

Fire-killed snags may or may not stand longer than beetle-killed snags, depending on the area. Dahms (1949) reported that a little over half the ponderosa pine snags are down 10 years after a fire in central Oregon. In Montana, nearly half of all lodgepole pine snags fall by the fifth season (Lyon 1977). In California, Kimmey (1955) described the

breakup of a fire-killed stand, although specific fall rates were not presented. In the fourth and fifth year after the fire, many ponderosa and Jeffrey pine (*Pinus jeffreyi*) broke off at the ground or up to 50 feet above the ground. By the fifth year, the general breakup continued until only scattered barkless snags and stubs remain.

In northeastern Oregon, different methods of killing ponderosa pines were investigated (Bull 1996c, Bull and Partridge 1986). Trees that had been topped stand the longest; half of those less than 20 inches d.b.h. are down after 10 to 12 years; half of those 20 inches or larger are down after 12 to 17 years. Half the trees injected with a silvicide are down 7 years after treatment. Half the girdled trees are down 9 years after treatment.

Fall rates of snags that have been created differ. Ponderosa pines infected with dwarf mistletoe were frilled and poisoned with an herbicide in the Southwest; after 10 years, 95 percent of those trees are down (Fairweather 1995).

All of these studies suggest that most ponderosa pine and lodgepole pine that died from fire or beetles in the interior Columbia River basin have fall rates of less than 10 years. Small-diameter snags fall sooner than do larger ones.

Sampling Techniques

Knowledge of snag density is essential for managing forest stands effectively, as well as for complying with standards and guidelines. Various methods have been used to determine snag densities: area-wide counts, fixed-radius circular plots, variable-radius plots using prisms (Bull and others 1990), and variable-strip transects (Bate and others, in press). Total counts of snags over large areas are very time-consuming but yield the most accurate density information. Fixed-radius plots typically need to be at least 1 acre because snags are usually scarce and variance is high. Many plots are usually required to accurately estimate snag density.

Bate and others (in preparation) have developed a more efficient method of sampling snags than either area-wide counts or fixed-radius plots: data are collected from a pilot sample transect and used in a computer program. The program determines the optimal length and width of a strip transect within a given area; the optimal size is that which minimizes the cost and variance. The program then provides the necessary sample size to obtain a snag density within the desired statistical bounds. Transect lengths are either 164 or 328 feet; transect widths range from 33 to 131 feet. The

Table 1—Density of snags reported or recommended in four areas; numbers are snags per acre larger than 10 inches d.b.h. (unless otherwise stated), and the percentages represent snags larger than 20 inches d.b.h.

Forest type	Locality			
	Western Idaho ^a	Central Oregon ^b	Northeast Oregon ^c	North-central Idaho ^d
Ponderosa pine:				
Open canopy ^e	1.6(75%)			
Closed canopy ^f	4.8(44%)	4(60%)		
Mixed conifer:				
Open canopy	2.5(72%)			
Closed canopy	9.0(39%)		3.8(29%)	10-48
Lodgepole pine:				
Open canopy	4.5			
Closed canopy	7.7			
Spruce/fir	9.5(21%)			

^a Recommendations for snag densities selected from the lower ranges of snag numbers on timber inventory plots and fixed-radius plots on the Payette National Forest; different snag levels recommended for burned and unburned stands (Evans and Martens 1995).

^b Snag numbers based on variable-width transects conducted in an unmanaged stand of old growth in central Oregon where woodcutting was prohibited (Bate 1995).

^c Numbers based on density of snags in two 4,000-acre study areas in northeastern Oregon that supported viable numbers of pileated woodpeckers; areas had some timber harvest but no woodcutting (Bull and Holthausen 1993).

^d Densities based on timber inventory plots in unmanaged stands of large saw timber. The snag density varied depending on what snags were included in the count. The 10 snags per acre included only snags 15 inches d.b.h. or larger and 50 feet or taller. The 48 snags per acre included all snags 15 inches d.b.h. or larger of any height. Western white pine snags were not counted (Craig 1995).

^e Stands with less than 30 percent canopy closure.

^f Stands with more than 30 percent canopy closure.

program also provides a "distribution index," which is an estimate of the percentage of the sampled landscape supporting target snags or trees.

Creating Wildlife Trees

In managed stands, retaining existing snags is the most ecologically sound and economical approach to providing wildlife trees. If stands are devoid of snags, however, an option is to alter or kill living trees. Depending on the method used, killing trees can be costly and may not produce the desired decay conditions. Years may pass before the decay is sufficiently advanced to promote cavity-nester excavations.

Bull and Partridge (1986) investigated six methods of killing ponderosa pine. They determined that topping trees with either a chainsaw or explosives produced snags that stood the longest and received the greatest nest use by woodpeckers (figs. 48 and 49). In this study, girdling, fungal inoculation, and beetles attracted by pheromones did not consistently kill the tree. Trees killed by girdling or silvicides fell over too quickly to provide wildlife nest trees.

In a study in New Mexico, all of the ponderosa pines killed by girdling were used for foraging by woodpeckers. Most of the trees greater than 16 inches d.b.h. were standing after 7 years, and about 30 percent contained woodpecker nest sites (Parks 1996b). Because the climate in the New Mexico sites is drier than in the Oregon study area used by Bull and Partridge (1986), basal decay of killed trees may have been less, so the trees stood longer.

Recent work by Parks and others (1996a, 1996b) documents a new method of inoculating live trees with decay fungi. Six years after inoculation of 60 living western larch, 14 percent contained woodpecker cavities near the point of inoculation. These trees may remain alive for decades with a pocket of decay that woodpeckers can use for nesting. Trees may be logged next to these trees without safety concerns, and live trees are less likely than dead trees to be lost to fuel-wood cutters. These preliminary results for western larch suggest that inoculation produces desirable wildlife trees at a lesser cost than killing trees to create snags.

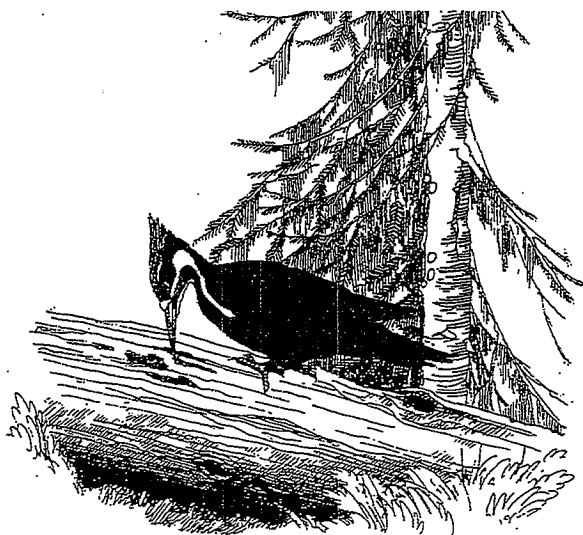
A variety of wildlife tree structures can be created with a chainsaw in standing, living trees. Trees can be topped leaving a horizontal branch structure on which ospreys (*Pandion haliaetus*) can build nests (fig. 50). A depression can be cut into the top of a tree that has been topped to produce a nest site for great gray owls (fig. 51). Artificial cavities and hollows can be cut into standing and downed trees (figs. 52, 53, and 54). Slits can be cut into trees to create roosting habitat for bats (fig. 55). These techniques and others are described by Brown (1996).

Three primary considerations in creating wildlife trees are the target wildlife species for which the structure is being created; the tree species, size of tree, and habitat locality most likely to be used by the targeted wildlife species; and the method of altering or killing trees that is most likely to produce long-standing trees in a given geographic area. Rainfall, snowfall, incidence of windstorms, and prevalent decay organisms all must be considered.

Thousands of trees have been killed to create snags in the interior Columbia River basin in the last 15 years. Few of them have been monitored, however, to determine whether long-lasting, quality snags were actually produced. Because climate and decay organisms differ with area, results of management activities, such as snag creation, must be monitored to ensure that results warrant the cost of these treatments. We include a data form to monitor wildlife use of created snags in appendix A.

Review

- Ponderosa pine, western larch, quaking aspen, and paper birch are favored tree species for nest sites of woodpeckers in many areas in the interior Columbia River basin.
- Large-diameter snags provide nest habitat for the greatest variety of cavity nesters and stand longer than smaller snags.
- Snags can be classed into three structural classes that are a simplified version of past decay class categories.
- Snags should be provided in every 5- to 25-acre stand in clusters if available, on all slope aspects and positions of the slope, and adjacent to green trees.
- Recent studies have shown that the snag model developed by Thomas and others (1979) did not accurately predict woodpecker abundance based on snag abundance. New information suggests that foraging strata (snags and other structures) must be incorporated into any snag model, and that snag numbers need to be revised upward.
- Published data suggest that populations of cavity nesters were viable in stands of ponderosa pine and mixed-conifer forests that contained about four snags per acre, a large component of old-growth stands, and abundant logs.
- Snags can be retained over time by using models for green tree replacements.
- Snag longevity depends on cause of death, tree species, diameter, height, amount of heartwood, geographic area, and site conditions.
- Creating snags and other wildlife structures can mitigate the loss of natural habitat, but retaining existing structures is most cost effective and ecologically sound.



NESTING HABITAT SELECTION AND PRODUCTIVITY
OF NORTHERN GOSHAWKS
IN WEST-CENTRAL MONTANA

By

Lorraine T. Clough

B.S. University of Montana, 1994

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GNO-31, 32
Prey = 34, 69, 82, 78
Log = 35, 47, 67, 71, 75
Narrow zone = 68
Past log = 71, 72
managed =
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C77 = 67, 75

Nesting chronology.— The overall estimated mean onset of incubation was 5 May ± 1.42 days (range from 21 April to 14 May); hatching date, 6 June ± 1.42 days (22 May to 15 June); and fledging date, 12 July ± 1.42 days (29 June to 23 July).

Nesting chronology differed between years (Mann-Whitney $U = 5.0$, $P = 0.002$). Onset of incubation occurred 10 days earlier in 1998 than in 1997, perhaps due to mild weather. In 1997, mean onset of incubation was 10 May ± 1.53 days (range from 4 to 14 May); hatching, 11 June ± 1.53 days (5 to 15 June); and fledging, 17 July ± 1.53 days (13 to 23 July). In 1998, mean onset of incubation occurred on 30 April ± 1.93 days (range from 21 April to 9 May); hatching, 1 June (22 May to 10 June); and fledging, 7 July (29 June to 18 July).

Banding effort and band returns.— In 1997, 11 goshawk chicks (6 females, 5 males) from five of the six monitored nests were banded in the nest 19 to 28 days posthatching. In 1998, 12 chicks (6 females, 6 males) from five of the 12 monitored nests were banded. On 23 November 1998 (approximately 139 days postfledging), #1807-69220, which I banded as a nestling female on 23 June 1998, was captured and released by a falconer near Belgrade, Montana, approximately 160 km south/southeast from its natal nest.

GOSHAWK DIET

For 1997 and 1998 combined, I identified 101 prey items, 8 mammal and 10 bird species, from the prey remains collected at nests (Table 2). In 1997, the three most common prey species were, in descending order of abundance, snowshoe hare (*Lepus*

Table 2. Prey species frequency distribution. Table shows mammalian and avian prey species, the frequency (%) of each prey item for 1997 and 1998, and the percent of total biomass (1997 and 1998 combined) for each prey item.

Prey species	1997 Frequency (%)		1998 Frequency (%)		Total Biomass (%)
Mammals					
Snowshoe hare (<i>Lepus americanus</i>)	12	(32)	3	(5)	53.39
Mountain cottontail rabbit (<i>Sylvilagus nuttalli</i>)	1	(3)	0	(0)	1.11
Columbian ground squirrel (<i>Spermophilus columbianus</i>)	6	(16)	11	(17)	9.45
Golden-mantled ground squirrel (<i>Spermophilus lateralis</i>)	1	(3)	0	(0)	0.55
Red squirrel (<i>Tamiasciurus hudsonicus</i>)	7	(19)	26	(41)	14.27
Northern flying squirrel (<i>Glaucomys sabrinus</i>)	1	(3)	2	(3)	0.95
Northern pocket gopher (<i>Thomomys talpoides</i>)	1	(3)	1	(2)	0.57
Vole (<i>Microtus</i> sp.)	1	(3)	4	(6)	0.39
Total number of mammal prey items	30	(82)	47	(73)	80.69
Birds					
Blue Grouse (<i>Dendragapus obscurus</i>)	1	(3)	4	(6)	11.57
Ruffed Grouse (<i>Bonasa umbellus</i>)	0	(0)	2	(3)	2.56
Northern Flicker (<i>Colaptes auratus</i>)	0	(0)	3	(5)	0.94
Gray Jay (<i>Perisoreus canadensis</i>)	1	(3)	4	(6)	0.79
Clark's Nutcracker (<i>Nucifraga columbiana</i>)	1	(3)	2	(3)	0.90
Common Raven (<i>Corvus corax</i>)	0	(0)	1	(2)	1.95
Townsend's Solitaire (<i>Myadestes townsendi</i>)	1	(3)	0	(0)	0.08
American Robin (<i>Turdus migratorius</i>)	1	(3)	0	(0)	0.18
Dark-eyed Junco (<i>Junco hyemalis</i>)	1	(3)	0	(0)	0.06
Unknown small bird sp.	1	(3)	1	(2)	0.24
Total number of bird prey items	7	(18)	17	(27)	19.27
Total number of prey items	37		64		

americanus), red squirrel (*Tamiasciurus hudsonicus*), and Columbian ground squirrel (*Spermophilus columbianus*). In 1998, the three most common prey species included red squirrel, Columbian ground squirrel, and an equal number of voles (*Microtus* sp.), Blue Grouse (*Dendragapus obscurus*), and Gray Jays (*Perisoreus canadensis*). Overall, mammals contributed 81.0% of the total prey biomass and birds the remaining 19.0% (Table 2). In terms of biomass, the most important prey species were snowshoe hares, red squirrels, Blue Grouse, and Columbian ground squirrels.

Biomass

HABITAT ANALYSIS

Goshawk distribution patterns.— In general, goshawks nested in either Douglas-fir (57.9%) or lodgepole pine (42.1%) forest cover types with overstory trees comprised of pole-sized or larger size classes (Table 3). Although we surveyed nearly 70.0% of the interior forest across the entire northern half of the Flint Creek Range (25 km² of which was in a roadless area), all goshawk responses were received and all nests found around the periphery of the study area within 1 to 5 km of the grassland/timber interface (Fig. 3). Nests were distributed 2 to 5 km apart at elevations from 1,524 to 2,012 m, with 82.6% of nests located on north aspects. Nests in lodgepole pine cover types were located at the lower elevational extent where lodgepole pine occurs, whereas nests in Douglas-fir were found throughout the elevational range of Douglas-fir. The forested lands that goshawks occupied, adjacent to the grassland/forest interface, have been heavily influenced by timber harvest, associated road building, land exchanges, and livestock grazing (USFS 1995, 1996, 1997) relative to habitats at higher elevations in the forest interior.

log

NORTHERN REGION
USDA FOREST SERVICE
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OLD-GROWTH FOREST TYPES OF THE NORTHERN REGION

by

P. Green, J. Joy, D. Sirucek, W. Hann, A. Zack, and B. Naumann*

R-1 SES 4/92; USDA Forest Service, Northern Region, Missoula, MT 59807; For additional information phone 406-329-3045 (FTS 585-3045).

* Authors are: Pat Green, Ecologist/Soil Scientist, Nezperce National Forest, Grangeville, ID; John Joy, Ecologist, Deerlodge National Forest, Butte, Montana; Dean Sirucek, Ecologist/Soil Scientist, Flathead National Forest, Kalispell, MT; Wendel Hann, Ecologist, Northern Region USDA Forest Service, Missoula, MT; Art Zack, Ecologist, Idaho Panhandle National Forests, Coeur d'Alene, ID; and Bob Naumann, Regional Silviculturist, Northern Region USDA Forest Service, Missoula, MT

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The criteria for inclusion of a plot in the analysis were:

1. Plots were survey type 45 and 46, which meet full standard exam procedures.
2. Plots were selected from stands with no evidence of logging.
3. Plots had an identified habitat type.
4. The largest tree on the plot was greater than 100 years old and greater than 9 inches dbh.
5. The plot basal area for trees greater than 5" dbh was greater than 40 sf/acre.

A total of 680,000 plots were screened for the Idaho Panhandle, Clearwater, and Nezperce National Forests in northern Idaho. A total of 1,068,000 plots were screened for the Kootenai, Flathead, Lolo, and Bitterroot National Forests in western Montana. A total of 388,000 plots were screened for the Lewis & Clark, Helena, Deerlodge, Beaverhead, Gallatin, and west side of the Custer National Forests in eastern Montana.

Habitat types are a land classification system based on the potential plant associations that will dominate a site at the end point of plant succession (climax). Habitat types are ideal for stratifying site conditions in order to predict the type of old growth forest they will produce. The plot data was sorted into groups of similar habitat types. Before a site reaches climax condition, it may be dominated by several different conifer tree species (with some associated structural differences), so plots in each habitat type group were subdivided by forest cover type (based on plurality of tree species basal area).

Within each habitat type group and forest cover type group, plots containing large trees over 100 years of age were selected for further analysis. The guiding principle was to select plots containing large, old trees that would represent the latter stages of stand development. These plots with large old trees were then further analyzed to determine the characteristics typical of old growth. These plots with old trees were analyzed for significant differences in tree ages, sizes, and forest stand structures and composition. Based on groupings of the data, and on professional judgment of the foresters, ecologists, and wildlife biologists, the following ages were selected as minimums:

>

North Idaho

All types except lodgepole pine	150
Lodgepole pine	120

Western Montana

Ponderosa pine, Douglas-fir, western larch	170
Lodgepole pine	140
Other types	180

Eastern Montana

Douglas-fir types 1 and 2	200
Limber pine	120
Lodgepole pine	150
Subalpine fir type 10	135
Subalpine fir other types	160
Whitebark pine type 11	150

Whitebark pine type 12	135
Ponderosa pine	180
Douglas-fir type 3	180

The other minimum criteria -- tree size, and number of large trees per acre -- were selected to distinguish those stands where the old trees were dominating the stand structure. The number of trees over a given age and size (diameter at breast height) were used as minimum screening criteria for old growth. Associated characteristics (such as number of snags, down woody material, dead tops and decay, and diameter variation) represent the means, values, and ranges for structural characteristics found in the data for plots that met the old growth minimum criteria.

Three broad old growth stand structures were recognized in the analysis:

1. *Late Seral, Single-Story* -- these stands are still dominated by the tree species and tree canopy layer that first captured the site after a stand replacing disturbance. The upper canopy is relatively closed. If understory trees are present, they are generally small, exhibit little growth, and do not form an apparent canopy layer. Other understory vegetation may be sparse. Ages and sizes of dominant trees are significantly beyond what may be found at culmination of mean annual increment of tree stand volume growth, growth rates are slowing, and tree crowns are showing signs of maturity or old age (flat, wide tops with slow main leader growth). This stage may have moderate amounts of tree decay, but little mortality, and few snags or pieces of down woody material.
2. *Late Seral, Multi-Story* -- the initial seral trees and canopy layer have lost control of the site. Disturbance or the natural mortality of age has produced holes in the the upper canopy; shade tolerant understory vegetation and trees are increasing in crown volume; and shade tolerant understory tree species are growing towards the main canopy, and may have occupied part of it. Two or more canopy layers are obvious, the canopy may be irregular, and broken tops, bole rot, snags, and large down woody debris may be common. The stand may have small openings dominated by shrubs or understory forbs. Although there may be some very large or old individual trees, stand average diameter and age may be either greater or less than in the previous Late Seral, Single-Story stage. There is often great variation in average tree diameter.
3. *Near Climax* -- this stage is dominated by shade tolerant (possibly climax) tree species that captured the site after the initial seral stand has been largely replaced. A few remnant shade intolerant, early seral trees may persist, but they represent a small part of total live canopy. Depending upon overstory structure, there may be great variation in understory characteristics and tree diameter distributions. If the shade tolerant tree species are relatively short lived (such as subalpine fir), or only moderately long lived (such as grand fir), the canopy will be multi-storied, and contain significant numbers of snags and down woody debris. If the shade tolerant tree species is very long lived (such as cedar), there may be 1 dominant canopy layer, with relatively few snags or pieces of down woody debris.

The above 3 stages are generalities useful for explaining why an individual old growth stand may be expected to have, or not have, various structural characteristics sometimes identified with old growth in forest ecology literature. Individual old growth stands may combine various elements of the above 3 stages, or may have some other unique characteristics as the result of particular site and stand history.

The plot data base was stratified by habitat type groups and forest cover types. The forest cover type was assigned to the tree species with plurality of basal area for trees greater than 9" dbh. Data from these plots on numbers of trees by 4" diameter size class, basal area, layers, snags, decay, broken tops, age, and crown ratio were graphed in various combinations, analyzed in frequency diagrams, and displayed in tables. Interdisciplinary team members from the zone committees and Forests then reviewed the output and identified minimum screening criteria for old growth for each habitat type group and forest cover type by Forest. Zone committees then met and grouped this data into minimum criteria for screening stands for old growth.

TABLE 1 NORTHERN IDAHO ZONE OLD GROWTH TYPE CHARACTERISTICS

OLD GROWTH TYPE	HABITAT TYPE GROUP	MINIMUM AGE OF LARGE TREES	MINIMUM NUMBER TPA/DBH	DBH VARIATION 2/	PER-CENT DEAD/BROKEN TOP 1/	PROBABILITY OF DOWN WOODY 2/	PER-CENT DECAY 1/	NUMBER CANOPY LAYERS 3/	SNAGS 1/	NUMBER OF SAMPLES
1 - PP, DF, L	A,B	150	8 > 21"	M	0-30	M	0-8	SNGL/MLT	0-7	815
2 - LP	B,C,D,G,H,I,J	120	10 > 13"	M	0-19	M	2-13	SNGL/MLT	1-37	875
3 - Y	C,C1	150	3 > 21"	M	7-10	H	9-34	SNGL/MLT	5	26
4 - DF,GF,L,SAF,WH,WP	C,C1,D,E,F,G,G1,H,I	150	10 > 21"	M	0-28	M	1-4	SNGL/MLT	1-3	14,421
5 - SAF,MAF	F,G,H,I	150	10 > 17"	H	5-36	H	5-28	MULTIPLE	6-36	4,275
6 - WBP	I,J	150	5 > 13"	M	0-17	M	6-17	SNGL/MLT	11-42	43
7 - C	F,G,G1	150	10 > 25"	M	5-36	M	6-55	SNGL/MLT	6-47	5,865
8 - DF,L,SAF,MAF,WP	J	150	10 > 17"	M	1-14	M	1-15	SNGL/MLT	3-40	890
9 - SAF,MAF	K	150	5 > 13"	H	21-23	M	13-35	MULTI	11-13	26

1/ These values are not minimum criteria. They are the range of means across plots within forests, forest types, or habitat type groups.

2/ These are not minimum criteria. They are Low, Moderate, and High probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.

3/ Number of canopy layers can vary within an old growth type with age, relative abundance of different species and successional stage.

TABLE 2 WESTERN MONTANA ZONE OLD GROWTH TYPE CHARACTERISTICS

OLD GROWTH TYPE	HABITAT TYPE GROUP	MINIMUM AGE OF LARGE TREES	NUMBER TPA/DBH	DBH VARIATION 2/	PERCENT DEAD/BROKEN TOP 1/	PROBABILITY OF DOWN WOODY 2/	PERCENT DECAY 1/	NUMBER CANOPY LAYERS 3/	SNAGS 1/	NUMBER OF SAMPLES
1-PP, DF, L	A-1, B-1	170	8 > 21*	M	12 3-32	L-M	5 0-11	SNGL	6 0-22	4,847
2-DF, L	C-1	170	8 > 21*	H	11 0-21	M	5 2-12	MLT	7 2-37	2,505
3-LP	C-1,D-1,E-1, F-1, G-1, H-1	140	10 > 13*	L	11 5-22	H	6 2-15	SNGL	19 0-92	2,648
4-SAF, DF, GF, C, L	D-1, E-1, F-1	180	10 > 21*	H	95 0-19	H	9 0-19	MLT	15 2-43	13,867
5-SAF, DF, GF, L	G-1, H-1	180	10 > 17*	M	9 1-18	H	6 0-12	MLT	12 3-36	4,053
6-SAF, WSL	I-1	180	10 > 13*	M	11 2-31	M	10 2-17	MLT	25 5-38	255
7-LP	I-1	140	30 > 9*	L	87 3-14	H	5 0-11 9-22	MLT	17	95
8-SAF, WSL	J-1	180	20 > 13*	M	12 10-14	M	5 0-8	SNGL	37 33-40	14

1/ These values are not minimum criteria. They are the range of means across plots within forests, forest types, or habitat type groups.

2/ These are not minimum criteria. They are Low, Moderate, and High probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.

3/ Number of canopy layers can vary within an old growth type with age, relative abundance of different species and successional stage.

TABLE 3 EASTERN MONTANA ZONE OLD GROWTH TYPE CHARACTERISTICS

OLD GROWTH TYPE	HABITAT TYPE GROUP	MINIMUM AGE OF LARGE TREES	NUMBER TPA/DBH	DBH VARIATION 2/	PER-CENT DEAD/BROKEN TOP 1/	PROBABILITY OF DOWN WOODY 2/	PER-CENT DECAY 1/	NUMBER CANOPY LAYERS 3/	SNAGS 1/ 29 4	NUMBER OF SAMPLES
1 - DF	A	200	4 > 17"	M	4 >	L	4 >	SNGL/MLT	4-18	989
2 - DF	B,C,D,E,F,H	200	5 > 19"	M	2 >	L	3 >	SNGL/MLT	3-29	3,439
3 - DF	G	180	10 > 17"	M	2 >	M	6 >	SNGL/MLT	15-50	18
4 - PP	A,B,C,K	180	4 > 17"	M	5 >	L	3 >	SNGL/MLT	5-10	92
5 - PF	A,B	120	6 > 09"	M	0 >	L	0 >	SNGL/MLT	6-24	24
6 - LP	A,B,C,D,E,F,G,H,I	150	12 > 10"	L	0 >	L	0 >	SNGL/MLT	3-56	9,633
7 - SAF	C	160	12 > 17"	M	1 >	H	18 >	SNGL/MLT	50	8
8 - SAF	D,E	160	7 > 17"	M	0 >	L	1 >	SNGL/MLT	0-44	664
9 - SAF	F,G,H,I	160	10 > 13"	M	0 >	M	0 >	SNGL/MLT	20-59	1,360
10 - SAF	J	135	8 > 13"	M	2 >	L	0 >	SNGL/MLT	8-84	38
11 - WBP	D,E,F,G,H,I	150	11 > 13"	M	0 >	L	2 >	SNGL/MLT	0-65	953
12 - WBP	J	135	7 > 13"	M	0 >	L	3 >	SNGL/MLT	0-34	173

1/ These values are not minimum criteria. They are the range of means across plots within forests, forest types, or habitat type groups.

2/ These are not minimum criteria. They are Low, Moderate, and High probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.

3/ Number of canopy layers can vary within an old growth type with age, relative abundance of different species and successional stage.

CORRELATION WITH ADJACENT REGIONS

Old growth types were correlated across regional boundaries with Region 6 (Washington and Oregon) and Region 4 (southern Idaho and Wyoming). Meetings were held with regional representatives on June 11, 1991 in Spokane, Washington and on October 4, 1991 in Missoula, Montana. Most definitions correlated fairly well. Region 6 will use R1's definitions for seral cover types in eastern Washington and Oregon. A summary of the notes is given in Appendix B.

USE OF OLD GROWTH TYPE DESCRIPTIONS

Forest stand composition and structure is a function of site physical characteristics (soil, climate, topography), the particular history of that site, the characteristics of the species that occupy the site and their interactions, and the physical and biological forces that affect the site during successional development. The rugged, mountainous topography of the Northern Region is overlain with a complex climate produced by the west to east intersection of the Pacific Marine climate with the Great Plains Continental climate. There is great annual variation in both temperature and moisture, and there is a large amount of variation from year to year around the long term averages for any given date or month. There is also great variation in type and severity of disturbance mechanisms, both natural and man caused. The result of this variety of forces that shapes individual stands, is a wide variation in the resulting stand structures. No set of generated numbers can capture all the variation that may occur at any given age or stage in forest development.

Because of the great variation in old growth stand structures, no set of numbers can be relied upon to correctly classify every stand. In addition, the uncertainties of sampling and statistics introduce another need for caution in using stand data. The minimum criteria in the "tables of old growth type characteristics" are meant to be used as a screening device to select stands that may be suitable for management as old growth, and the associated characteristics are meant to be used as a guideline to evaluate initially selected stands. They are also meant to serve as a common set of terms for old growth inventories. Most stands that meet minimum criteria will be suitable old growth, but there will also be some stands that meet minimum criteria that will not be suitable old growth, and some old growth may be overlooked. **Do not accept or reject a stand as old growth bases on the numbers alone; use the numbers as a guide.**

A stand dominated by trees of the age and size listed under minimum criteria is generally good potential old growth. The number of trees is meant as a guideline for how many trees it takes to produce older stand characteristics, and should not be used as an absolute. The large tree age listed under minimum criteria is meant to define the minimum age which we will consider old growth, but that age is difficult to measure because some of the oldest trees may be too rotten or too large to accurately age. For this and other reasons, although age is the single most valuable guide for determining when a stand is old growth, age is often the least reliable data in an inventory. Tree size generally increases as a tree ages, but stand density and mortality affect tree size. The associated characteristics listed in Table 1 through 3 are meant to be guidelines in evaluating stands. A stand should not be accepted or rejected as old growth simply on the basis of associated characteristics. The predominance of minimum criteria and associated characteristics, rather than a single number, generally will be an excellent guide. Be aware that the associated characteristics of "DBH variation" and "tree canopy layers" were only provided as a descriptor of what was most common in existing inventory data, and should not be used to decide whether a stand is really old growth. Use these numbers and descriptions as guides in applying the basic principle that old growth is a "late stage of stand development" . . . "dominated by old trees and related structural attributes."

Where stand examination data is available, this data may be compared to the old growth minimum criteria in Tables 1 through 3, by habitat type group and forest cover type. Run Code 22 on the Forest Service Region 1 "R1EDIT Menu" (available in all Forest Service Region 1 Data General computers in the R1EDIT Program Package) is designed to extract potential old growth stands from the R1EDIT stand exam data base. Run Code 22 is an interactive program that allows a user to specify a group of habitat types and forest cover types, and specify the minimum criteria of number of trees, minimum age, and minimum diameter. The program will then return a list of stands from the R1EDIT data base that meets the specified characteristics, and will give some summary data for each stand. A separate Run code 22 extract will be needed for every combination of habitat types and forest cover types that has unique characteristics.

The minimum criteria are used to determine if a stand is potentially old growth. Where these values are clearly exceeded, a stand will usually be old growth. The associated structural characteristics may be useful in decision making in marginal cases, or in comparing relative resource values when making old growth evaluations.

In a few cases of multi-species stands, the forest cover type automatically assigned by the stand exam system, may be misleading when trying to make an old growth determination. For example, in a multi-species stand, cedar may only have 25% of the stand basal area, and still be assigned the forest type, because it has more basal area than any other single species. The old growth cedar forest type requires diameters larger than other species, and even a very old stand, with only 25% cedar, may not have enough large cedar to meet the cedar minimum old growth criteria. However, if the same stand was assigned a cover type of any of the other species that make up 75% of its basal area, the stand would meet old growth minimum criteria. For this reason, if the forest cover type has an old growth minimum criteria that's different from the majority of species for that habitat type, it is recommended that this forest type not be assigned for old growth determination, unless it represents 50%+ of the stand basal area. This adjustment will have to be made manually, on a stand-by-stand basis for the cedar, lodgepole, and SAF-MAF forest types.

In addition to using old growth minimum criteria with the stand exam data base R1EDIT Menu, Run Code 22 for extracting potential old growth stands, additional Run Code 22 extracts with stepped down standards are recommended. These step down runs are useful to extract stands that are either close to being old growth, or are actually old growth, with an inclusion of younger or smaller trees that skews the data. This step down procedure may also identify old growth blocks within larger stands. Step down runs can be done with the minimum criteria backed off slightly (use 1" smaller minimum diameter, or 10 year lower age, or 1-2 fewer trees per acre; possibly do several iterations, each backing down 1 more step).

Because old trees are often rotten and difficult to age, it is recommended that 1 step down version of Run Code 22 be done with a zero age criteria to extract stands where this may be a factor. Careful further evaluation will be needed for any stands extracted with a zero age criteria, since many of these stands will not be old growth.

Where no in-place stand exam data exists, but a site was visited by a professional interdisciplinary team in previous environmental analysis, the notes and determinations of that interdisciplinary team may be used in deciding whether to consider the stand old growth. Be aware that some interdisciplinary teams may have allocated young stands of old growth to meet predetermined acreage targets, and some of their stands may not meet the type descriptions.

These old growth minimum criteria, associated characteristics, and descriptions were developed to apply to individual stands. When applying these standards, 3 things need to be remembered. First, these numbers represent averages and ranges that either existed in the inventories, or were assigned by professional judgement. While they are good guides, they are not absolute. Because of the innumerable combinations of site characteristics and historical factors that can occur, no set of numbers will correctly define every possible situation. The basic concept is that old growth should represent "the late stages of stand development . . . distinguished by old trees and related structural attributes."

The second point is that old growth is valuable for a whole host of resource reasons such as habitat for certain animal and plants, for aesthetics, for spiritual reasons, for environmental protection, for research purposes, for production of unique resources such as very large trees, unusual natural communities, etc. The resource values associated with potential old growth stands need to be considered in making allocations.

The third point to bear in mind when evaluating old growth, is that a stand's landscape position may be as important, or more important than any stand old growth attribute. The landscape is dynamic. We need to do more than draw lines to manage this dynamic system. Consider the size of old growth blocks (large blocks have special importance), their juxtaposition and connectivity with other old growth stands, their topographic position, their shapes, their edge, and their stand structure compared to neighboring stands. Stands are elements in dynamic landscape. We need to have representatives of the full range of natural variation, and manage the landscape mosaic as a whole in order to maintain a healthy and diverse systems.

At the same time, there may be some stands with trees so large or so old, that they are unique. We should always maintain a good representation of these very old unique and outstanding stands, because they are irreplaceable within human life spans. Remember to value the truly unique and outstanding, wherever it may be.

Appendix B - Old Growth Definition Correlation Notes

Old Growth Correlation Meeting Notes -- June 11, 1991; Spokane, WA
with Additions from October 4, 1991 meeting in Missoula, MT.

Attendees

Wendel Hann	R1-RO-Missoula	W.HANN:R01A	FTS 585-3214
John Joy	R1-Deerlodge NF	J.JOY:R01f09D02A	406-287-3223
Ernie Meisenheimer	R6-Olympic NF	E.MEISENHEIMER:R06F09A	FTS 390-2354
Dick Shaffer	R6-RO-Portland	R.SHAFER:R06C	FTS 423-2953
Doug Eggers	R4-Bridger-Teton NF	D.EGGERS:R04F03A	307-739-5519
Glen Jacobsen	R4-Payette NF	G.JACOBSEN:R04F12A	208-634-1421
Dean Sirucek	R1-Flathead NF	D.SIRUCEK:R01F10A	406-755-5401
Jack Losensky	R1-Lolo NF	J.LOSENSKY:R01F16A	FTS 329-3819
Dwane Van Hooser	INT Res. Sta. Ogden	D.VANHOOSER:S22L02A	FTS 586-5388
Paul Harrington	R1-Idaho Panhandle	P.HARRINGTON:R01F04A	208-765-7411
Tom High	R6-Mt. Hood NF	T.HIGH:R06F06A	503-666-0670
Ron Hamilton	R4-RO-Ogden	R.HAMILTON:R04A	FTS 586-5525
Bob Naumann	R1-RO-Missoula	B.NAUMANN:R01A	FTS 585-
Jay Berube	R6-Colville NF	J.BERUBE:R06F21A	509-684-3711
Len Volland*	R6-RO-Portland	L.VOLLAND:R6/PNW	
Clint Williams*	R6-RO-Portland	C.WILLIAMS:R6F	

* Attended meeting in Missoula, MT with Wendel Hann and Bob Naumann to follow up on Spokane Meeting.

Objective - to correlate old growth definitions and explain differences for types with the same name relative to ecosystem characteristics.

Old growth types are named using the standard SAF types as directed by the Washington Office.

Standard elements for correlation of types:

- a) live trees in main canopy
 - number of trees per acre greater than a specified DBH
 - age of largest trees in main canopy
 - variation in tree diameter
- b) number of standing dead trees per acre
- c) number of down pieces of wood per acre
- c) trees per acre with decadence or decay
- c) number of tree canopies (layers)

Old Growth Type Correlations

Mountain Hemlock-Alpine Larch Type (SAF 205) - R1/R6

R6 hasn't completed analysis yet. Western Washington mountain hemlock old growth is in a very different environment and disturbance regime from that in eastern Washington and northern Idaho. R6 will zone this type into westside and eastside types. R6 will use R1's definition for their eastside mountain hemlock.

Western Larch Type (SAF 212) - R1/R4/R6

Minor type in R6. R4 and R6 will use R1 definition.

Lodgepole Pine Type (SAF 218) - R1/R4/R6

R6 only described this type where it is climax. R1 described as old growth where it was both seral and climax. Wallowa-Whitman NF probably doesn't have much old growth lodgepole. R4 will go with R1 definition. R6 will use the R1 definition for seral lodgepole in eastern Washington and eastern Oregon.

Western Yew Type (SAF ---) - R1/R6

R6 hasn't described the western yew type yet. R6 will use the R1 definition.

Ponderosa Pine Type (SAF 237) - R1/R4/R6

R1, R4, and R6 are all close on definition criteria so will use the R1 definition.

Spruce and Subalpine Fir Type (SAF 206) - R1/R4/R6

R1, R4, and R6 are all close on definition criteria so will use the R1 definition.

Douglas-fir Type (SAF 210) - R1/R4/R6

R1 and R4 definitions correlate. R6 only developed a coastal and interior definition for climax Douglas-fir and did not deal with seral Douglas-fir. R6 will use the R1 definition for seral Douglas-fir in eastern Washington and eastern Oregon.

Grand Fir Type (SAF 213) - R1/R4/R6

R1 and R6 agree for the R6 low site definition, which we could explain by R1 sites being comparable ecologically to R6 low sites. However the disagreement could also be related to the difference between climax and seral old growth grand fir. R1 and R4 don't agree, but this can be explained by differences in environments in R4. R6 will use the R1 definition for grand fir in eastern Washington and eastern Oregon.

Western Hemlock Type (SAF 224) - R1/R6

R6 will zone this type into westside and eastside and use R1's definition for their eastside.

Western Redcedar-Western Hemlock Type (SAF 227) - R1/R6

R6 will zone this type into westside and eastside and use R1's definition for their eastside.

Western Redcedar Type (SAF 228) - R1/R6

R6 will zone this type into westside and eastside and use R1's definition for their eastside.

Western White Pine Type (SAF 215) - R1/R6

This type is not significant in either R1 or R6 due to blister rust.

Whitebark Pine Type (SAF 208) - R1/R4/R6

R4 and R6 will use the R1 definition.

Aspen Type (SAF 217) - R1/R4

R1 will use the R4 definition.

Cottonwood-Willow Type (SAF 235) - R1/R4

R1 will use the R4 definition.

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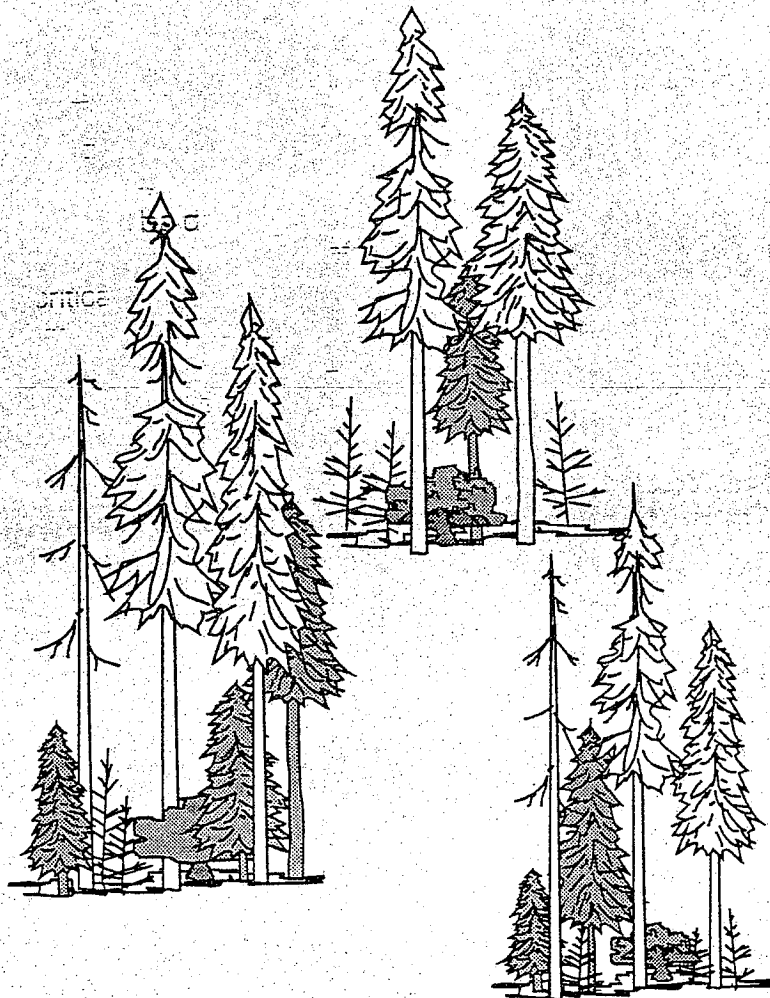
Forest
Service

Intermountain
Region

Ogden, Utah



Characteristics Of Old-Growth Forests In The Intermountain Region



1993

CHARACTERISTICS OF OLD-GROWTH FORESTS
IN THE INTERMOUNTAIN REGION

COMPILED BY

RONALD C. HAMILTON
REGIONAL GENETICIST

APRIL 1993

U.S.D.A. - FOREST SERVICE

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Each old-growth definition and description conforms to a western forest cover type described between pages 80 to 128 of the publication *Forest Cover Types of the United States and Canada*; F.H. Eyre, Editor, published by the Society of American Foresters, 1980. The old-growth definitions comply with the indexing used in the above publication for the 12 cover types. The index is found on Table 2, page 80 of the publication. The 12 cover types are indexed as follow:

HIGH ELEVATIONS

- Engelmann spruce - subalpine fir (206)
- Whitebark pine (208)
- Bristlecone pine (209)

MIDDLE ELEVATIONS

- Interior Douglas-fir (210)
- Grand fir (213)
- Blue spruce (216)
- Aspen (217)
- Lodgepole pine (218)
- Limber pine (219)

LOW ELEVATIONS, INTERIOR

- Interior ponderosa pine (237) (North Plateau Race)
- Interior ponderosa pine (237) (Rocky Mountain Race)
- Pinyon juniper (239)

Forest Successional Stages

SUCCESSION: Plant communities evolve through a general series of conditions as they progress from bare ground to the final stage (climax). This gradual process is called succession and is subdivided into various stages that are known as successional stages.



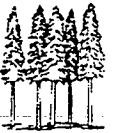
1. **GRASS-FORB** - the vegetation is dominated by grasses and forbs. Many times remanent snags and downed logs are present in the stand. This stage is usually short-lived in most forest successions.



2. **SHRUB-SEEDLING** - the brush may be low brush (e.g. snowberry) or tall brush (e.g. willow) depending on the habitat type. Tree seedlings/saplings are usually under 10 feet tall. Remnant snags and downed logs may still be present in this stage.



3. **POLE-SAPLING** - the trees are usually taller than 10 feet, but are usually less than 8 inches in diameter. An occasional dead tree, or a few remaining snags, may be present.



4. **YOUNG** - trees are usually greater than 8 inches in diameter and in a vigorous stage of growth. Few snags are present and most down material is small limbs and twigs.



5. **MATURE** - trees have reached their height growth and their crowns start to widen, but stand conditions do not meet all the old growth characteristics. Climax (shade tolerant) tree species are becoming evident in the understory, but large snags and down woody materials are uncommon.



6. **OLD-GROWTH (early phase)** - has seral species as the overstory canopy (if seral species are present), with climax tree species of various sizes in an understory. Snags are starting to develop with some large down woody material present. Only occasional small openings are present.



6. **OLD-GROWTH (late phase)** - some describe this stage as "Stage 7." All seral species in the overstory have been replaced by climax vegetation. The understory contains various sizes of climax tree species. Usually large amounts of down woody materials are present, and most of the seral species snags have fallen to the ground. The stand may appear very patchy with many small opening containing seedlings/saplings and tall brush.

APPENDIX C

SUB-REGION DEFINITION TEAMS

To provide some idea about what the teams' make up was and how the zones were divided, the following is provided:

Team Name:

Southwest Idaho (Boise, Challis Payette, Salmon, and Sawtooth National Forests (NFs)).

Mentor:

Chuck Wildes - Forest Supervisor - Challis NF

Technical Team:

Glenn Jacobsen, Silviculturist (Leader)
Floyd Gordon, Wildlife Biologist
Lynette Morelan, Forester
John Erickson, Wildlife Biologist
Sharon Bradley, Silviculturist
Doug Basford, Silviculturist
Dave Reeder, Wildlife Biologist
Richard Wenger, Wildlife Biologist
Roy London, Forester
Howard Hudak, Wildlife Biologist
Bob Steele, Research Ecologist
Susan Reinhard, Public Affairs Specialist

Public Members:

Roger Rosentreter, State Botanist
Dave Van De Graff, Forester (Private Industry)
Mike Medberry, Idaho Conservation League
Dave Gruenhagen, Forester State of Idaho
Dotty Douglas, Boise State University, Biology Department
Ron Mitchell, Idaho Sportsman Coalition
Bob Moseley, Idaho Fish and Game Department
Dallas Olson, Salmon International

Team Name:

Southeastern Idaho/Western Wyoming (Bridger-Teton,
part of the Caribou, and Targhee NFs)

Mentor:

Brian Stout, Forest Supervisor, Bridger-Teton
National Forest

Technical Team:

Doug Eggers, Silviculturist (Leader)
Bruce Padian, Silviculturist
Bill Noblitt, Wildlife Biologist
Ron Walker, Wildlife Biologist
Dee Session, Silviculturist
Hal Gibbs, Wildlife Biologist
Bob Steele, Research Ecologist

Team Name:

Northern Utah (Ashley, Uinta, part of the Caribou,
and Wasatch NFs)

Mentor:

Duane Tucker, Forest Supervisor, Ashley National Forest

Technical Team:

Darrell Johnson, Silviculturist (Leader)
Sherel Goodrich, Range Ecologist
Ken Timothy, Wildlife Biologist
Chip Sibbersen, Forester
Mary Clough, Wildlife Biologist
Dr. Dave Roberts, Professor Forestry/Ecologist -
Utah State University

Public Members:

George Roether, Forestry Consultant
Dick Carter, Coordinator, Utah Wilderness Association
Ralph Miles, Utah State Division of Wildlife Resources
Dr. Dave Roberts, Professor Forestry/Ecologist -
Utah State University

Team Name:

Southern Utah (Dixie, Fishlake, and Manti-LaSal NFs)

Mentor:

Hugh Thompson, Forest Supervisor, Dixie National Forest

Technical Team:

Brian Ferguson, Silviculturist (Leader)
Ron Sanden, Silviculturist
Ron Rodriguez, Wildlife Biologist
Bert Lowry, Wildlife Biologist
Bob Thompson, Range Ecologist
Brent Spencer, Silviculturist
Richard Williams, Wildlife Biologist
Mark Van Avery, Public Affairs Specialist

Public Member:

Merlin Esplin, Forester, Forest Industries
Bill Patric, Utah Wilderness Coalition
Bruce Bonebrake, Utah Division of Wildlife Resources
Dr. Kim Harper, Professor, Ecology -
Brigham Young University
Chris Goslin, Student Volunteer

Team Name:

Nevada (Humboldt and part of Toiyabe NFs)

Mentor:

John Inman, Forest Supervisor, Humboldt National Forest

Technical Team:

Gary Schaffran, Forester (Leader)
Elizabeth Bergstrom, Silviculturist and Wildlife Biologist
Steve Anderson, Wildlife Biologist
Charles Bowey, Wildlife Biologist
Robin Tausch, Research Ecologist

Team Name:

Toiyabe-Sierra (Part of Toiyabe NFs)

Mentor:

Jim Nelson, Forest Supervisor, Toiyabe National Forest
Tied in with Region 5's definition development groups.

Coordinator:

Ann Martin

Technical Team:

**Roland Shaw, Silviculturist (Leader)
Elizabeth Bergstrom, Silviculturist - Wildlife Biologist
Tina Mark, Wildlife Biologist**

Regional Team

Team:

**Bob Cottingham, Resource Analyst (Leader)
Dr. Dave Winn, Wildlife Ecologist
Ronald C. Hamilton, Regional Geneticist
Doug Myers, Inventory Team Leader
Duane VanHooser, Forest Survey Leader**

ORIGINAL RESEARCH

Multiscale habitat relationships of snowshoe hares (*Lepus americanus*) in the mixed conifer landscape of the Northern Rockies, USA: Cross-scale effects of horizontal cover with implications for forest management

Joseph D. Holbrook^{1,2} | John R. Squires¹ | Lucretia E. Olson¹ | Rick L. Lawrence² | Shannon L. Savage²

¹USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, USA

²Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, USA

Correspondence

Joseph D. Holbrook, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, USA.
Email: jholbrook03@gmail.com

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Abstract

Snowshoe hares (*Lepus americanus*) are an ecologically important herbivore because they modify vegetation through browsing and serve as a prey resource for multiple predators. We implemented a multiscale approach to characterize habitat relationships for snowshoe hares across the mixed conifer landscape of the northern Rocky Mountains, USA. Our objectives were to (1) assess the relationship between horizontal cover and snowshoe hares, (2) estimate how forest metrics vary across the gradient of snowshoe hare use and horizontal cover, and (3) model and map snowshoe hare occupancy and intensity of use. Results indicated that both occupancy and intensity of use by snowshoe hares increased with horizontal cover and that the effect became stronger as intensity of use increased. This underscores the importance of dense horizontal cover to achieve high use, and likely density, of snowshoe hares. Forest structure in areas with high snowshoe hare use and horizontal cover was characterized as multistoried with dense canopy cover and medium-sized trees (e.g., 12.7–24.4 cm). The abundance of lodgepole pine (*Pinus contorta*) was associated with snowshoe hare use within a mixed conifer context, and the only species to increase in abundance with horizontal cover was Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Our landscape-level modeling produced similar patterns in that we observed a positive effect of lodgepole pine and horizontal cover on both occupancy and use by snowshoe hares, but we also observed a positive yet parabolic effect of snow depth on snowshoe hare occupancy. This work is among the first to characterize the multiscale habitat relationships of snowshoe hares across a mixed conifer landscape as well as to map their occupancy and intensity of use. Moreover, our results provide stand- and landscape-level insights that directly relate to management agencies, which aids in conservation efforts of snowshoe hares and their associated predators.

KEYWORDS

gradient modeling, habitat selection, habitat use, occupancy, quantile regression, Random Forest

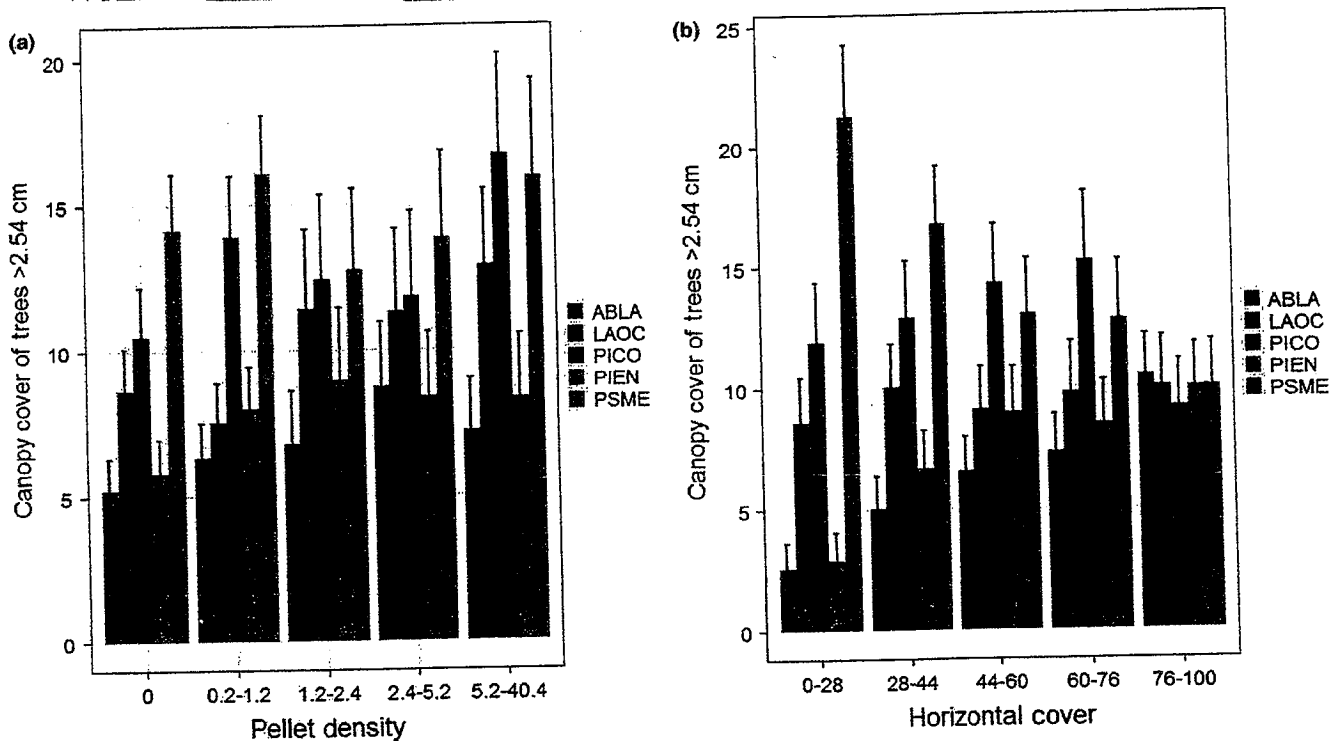


FIGURE 6 Mean ($\pm 95\%$ CI) canopy cover across the distribution of snowshoe hare (*Lepus americanus*) pellet density (a) and horizontal cover (b). Codes ABLA, LAOC, PICO, PIEN, and PSME indicate subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and Douglas-fir (*Pseudotsuga menziesii*), respectively. We estimated percentage canopy cover (i.e., the upper canopy only) along a 5×5 m grid using a vertically projected moosehorn reading for trees ≥ 2.54 cm (i.e., 1 inch) in DBH

We used our top models characterizing occupancy and intensity of use by snowshoe hares to spatially map these responses across our study area (Figure 11). We found that the area of predicted occupancy and absence of snowshoe hares within Glacier National Park and wilderness areas was 4,032 km² (37%) and 6,896 km² (63%), respectively. The area of predicted occupancy and absence on multiple-use lands was 14,868 km² (59%) and 10,236 km² (41%), respectively. These results suggested that protected areas captured more area of predicted absence, and less predicted presence, of snowshoe hares compared to multiple-use lands. Similarly, the predicted pellet density was 1.26 pellets/subplot for protected areas relative to multiple-use lands, which was 2.23 pellets/subplot.

4 | DISCUSSION

Snowshoe hares are an ecologically important herbivore and prey species in northern forests of North America (Krebs, 2011), and therefore, understanding their habitat relationships will help guide ecosystem-level conservation and management. Because of our gradient and multiscale approach, we advanced the understanding of snowshoe hare habitat relationships on multiple levels. First, we demonstrated that both occupancy and intensity of use by snowshoe hares increased with horizontal cover, and highlighted that the influence of horizontal cover becomes stronger with increasing use (and likely density) of snowshoe hares. Second, our work indicated that

subalpine fir and Engelmann spruce are the species that provide the high horizontal cover that is important for snowshoe hares, as well as identified a species-specific association between hares and lodgepole pine across scales. Previous work has highlighted that lodgepole pine is more nutritious than other common conifers and that browsing by snowshoe hares is consistent with nutritional quality (Ellsworth, Wirsing, Shipley, & Murray, 2013). The association we documented between snowshoe hares and lodgepole pine provides support for the hypothesis that high-quality nutrition substantively influences patterns of habitat use and that use is not simply driven by predation risk (e.g., Ellsworth et al., 2013; Hodges & Sinclair, 2003, 2005). In the mixed conifer forests of the Northern Rockies, the abundance of horizontal cover (e.g., subalpine fir and Engelmann spruce) and lodgepole pine, arranged in a multistoried and dense structure, appear to be the important aspects of habitat for snowshoe hares. Lastly, we observed a parabolic association between snow depth (positive between ~0.2–1 m) and occupancy of snowshoe hares, and snow depth ranked as our most important covariate characterizing occupancy (Table 1). Snow extent and, by extension, snow depth are projected to decrease within the Northern Rockies (e.g., Klos et al., 2014; McKelvey et al., 2011), which will likely have substantial implications for the distribution of snowshoe hares (e.g., Mills et al., 2013; Sultaire, Pauli, Martin, Meyer, & Zuckerberg, 2016; Sultaire, Pauli, Martin, Meyer, Notaro, et al., 2016; Zimova, Mills, & Nowak, 2016) as well as the predators that rely on them (e.g., Canada lynx). Collectively, our work provides a new, multiscale and gradient-based lens on habitat relationships of

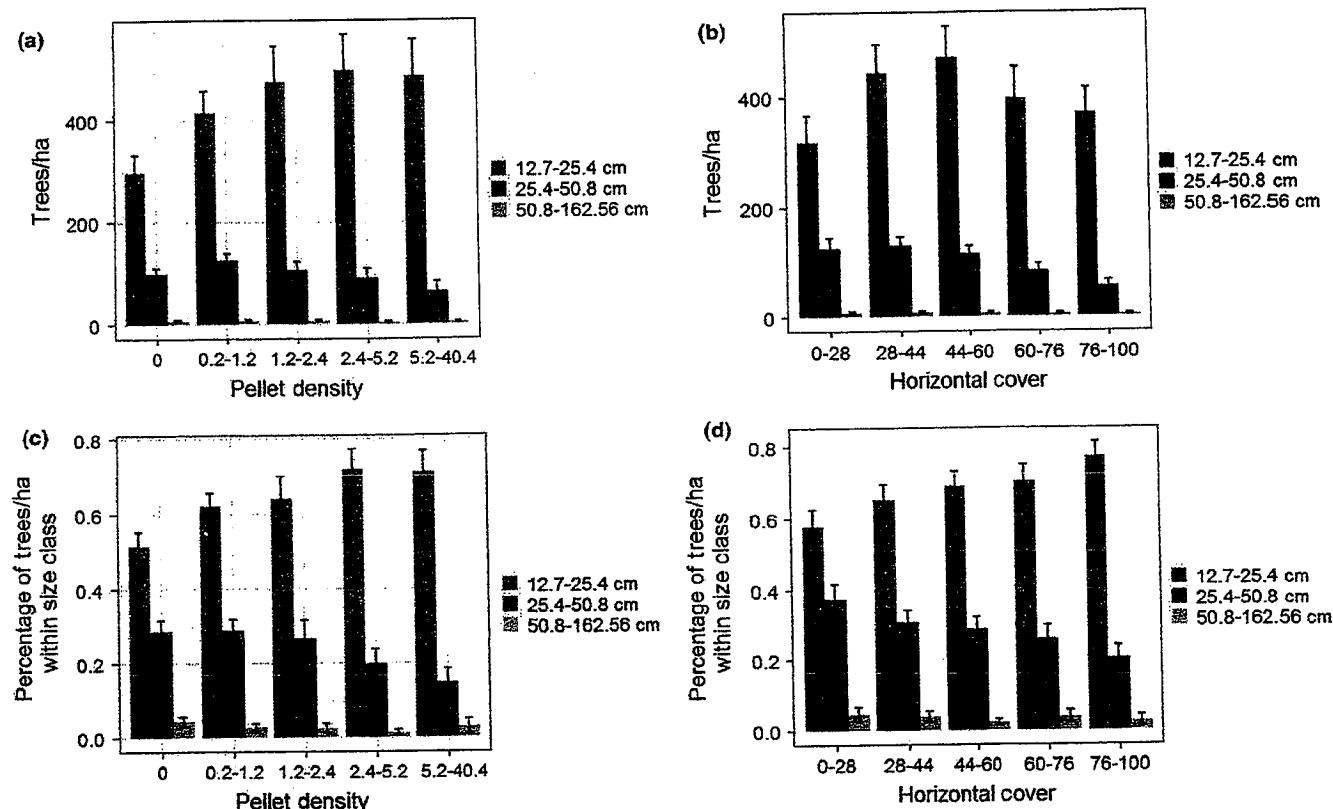


FIGURE 7 Mean ($\pm 95\%$ CI) trees/ha within size classes across the distribution of snowshoe hare (*Lepus americanus*) pellet density (a) and horizontal cover (b). Mean percentage ($\pm 95\%$ CI) of trees/ha within size classes across the distribution of pellet density (c) and horizontal cover (d). All metrics were calculated using the Forest Vegetation Simulator (Crookston & Dixon, 2005) from data collected using a 10 basal area factor prism, and only included trees ≥ 12.7 cm (i.e., 5 inches) in DBH

snowshoe hares and offers specific insight for forest management and snowshoe hare conservation.

4.1 | Plot-scale patterns

Previous work has identified a positive relationship between snowshoe hare density and horizontal cover as well as spruce-fir and lodgepole pine forests (Berg et al., 2012; Cheng et al., 2015; Hodges et al., 2009; Ivan et al., 2014; Koehler, 1990). Our data support these conclusions; however, the interpretation of our results is more nuanced. Our analyses highlighted that the abundance of spruce-fir is more associated with horizontal cover than any other species of conifer (Figures 6 and 8), and we found that horizontal cover was strongly associated with occupancy and intensity of use by snowshoe hares (Figure 4). However, we did not discover any consistent relationship between snowshoe hare occupancy or intensity of use and spruce-fir per se (although see parabolic relationships in Figure 5). Thus, our data suggest that horizontal cover is an important attribute influencing snowshoe hares and that this attribute is associated with forests that have a substantial spruce-fir component (relative to those without a spruce-fir component). Preserving the horizontal cover that spruce-fir trees provide within the mixed conifer context of the Northern Rockies will likely be important for the conservation of snowshoe hares.

Moreover, we found a species-specific association between snowshoe hares and abundance of lodgepole pine, which we attributed mostly to nutritional mechanisms. Ellsworth et al. (2013) discovered that lodgepole pine produced higher levels of digestible protein than other common conifers in the Northern Rockies (e.g., Douglas-fir, subalpine fir, Engelmann spruce, western larch) and that overwinter depletion of biomass and browsing by snowshoe hares was most associated with lodgepole pine. Although our data indicate that areas with high use by snowshoe hares are indeed highly mixed conifer forests (e.g., Figure 5), forest managers within our study region could use lodgepole pine as well as spruce-fir, or more specifically horizontal cover, as initial indicators of potential snowshoe hare habitat.

Our results reinforced previous studies highlighting the importance of dense forests for snowshoe hares (e.g., Berg et al., 2012; Griffin & Mills, 2007; Hodges et al., 2009; Hodson et al., 2011; Ivan et al., 2014; Lewis et al., 2011). Our data indicated that dense horizontal cover within multistoried forests with a substantial component of medium-sized trees (i.e., 12.7–25.4 cm) produced the highest use by snowshoe hares, which was also found in previous studies within Montana (Griffin & Mills, 2007), Washington (Koehler, 1990; Lewis et al., 2011), Wyoming (Berg et al., 2012; Hodges et al., 2009), and Colorado (Ivan et al., 2014). Results from our data support conclusions similar to previous studies in that disturbing (e.g., cutting or burning) multistoried forests with high stem densities (particularly in the

5-10"

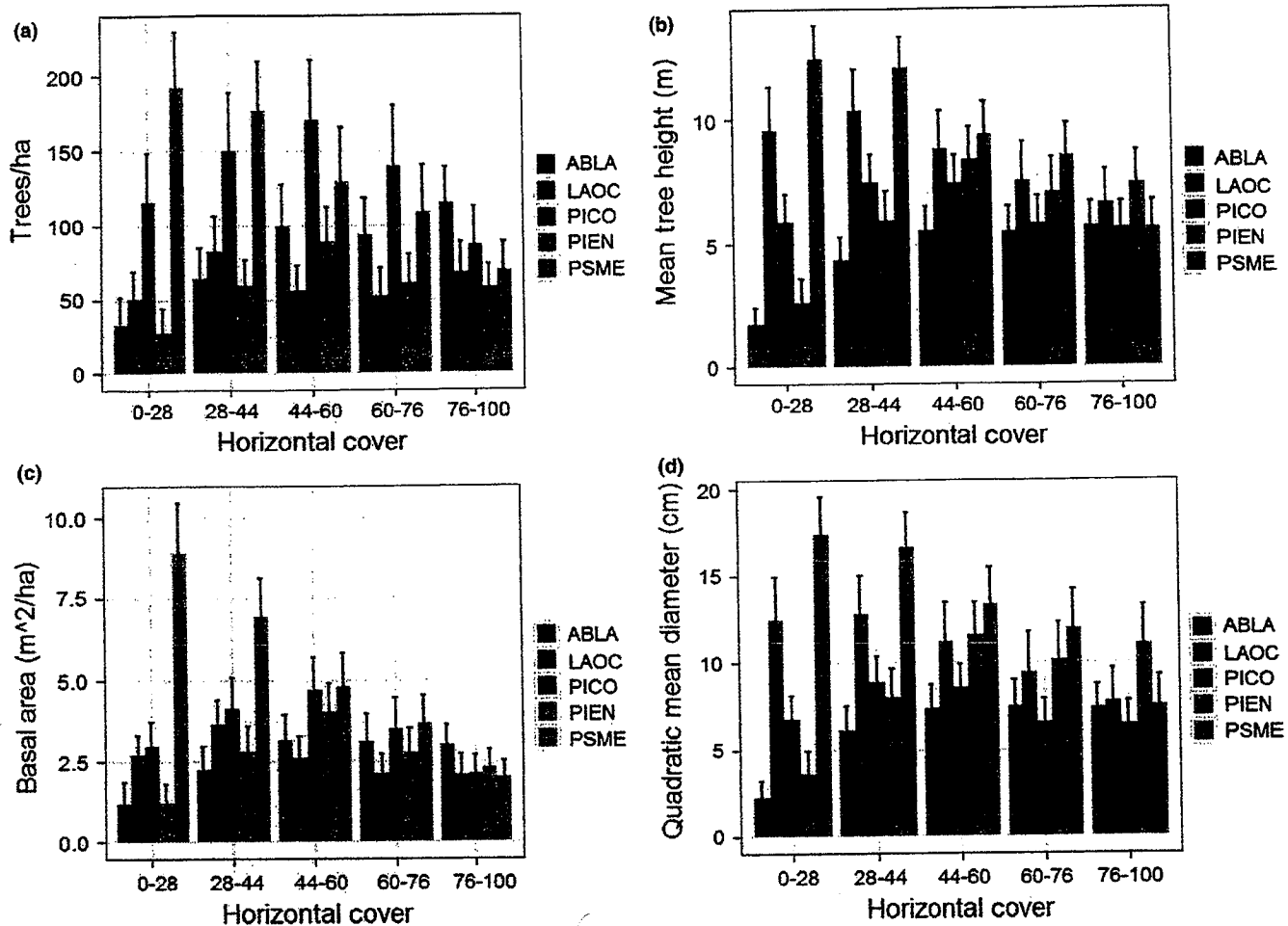


FIGURE 8 Mean ($\pm 95\%$ CI) of trees/ha (a), tree height (b), basal area (c), and quadratic mean diameter (d) across the distribution of horizontal cover. Codes ABLA, LAOC, PICO, PIEN, and PSME indicate subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and Douglas-fir (*Pseudotsuga menziesii*), respectively. All metrics were calculated using the Forest Vegetation Simulator (Crookston & Dixon, 2005) from data collected using a 10 basal area factor prism, and only included trees ≥ 12.7 cm (i.e., 5 inches) in DBH

understory) would likely have a negative effect on snowshoe hares in the short term (e.g., Abele, Wirsing, & Murray, 2013; Griffin & Mills, 2007), but may benefit them in the future (e.g., 20–50 years; Hodson et al., 2011; Allard-Duchêne et al., 2014).

4.2 | Landscape-scale patterns

At the landscape level, our study is the first to spatially map horizontal cover for modeling snowshoe hare habitat, as well as to model and map both occupancy and intensity of use of snowshoe hares (although see recent maps of occupancy in Sultaire, Pauli, Martin, Meyer, & Zuckerberg, 2016; Sultaire, Pauli, Martin, Meyer, Notaro, et al., 2016). Analyses of our maps indicated that protected areas (i.e., wilderness and Glacier National Park) captured less area of predicted occupancy of snowshoe hares than expected and that the predicted pellet density was also lower in protected areas relative to multiple-use lands. This pattern is consistent with national parks disproportionately protecting alpine habitats (e.g., Bunn, 2009) and emphasizes the importance of multiple-use lands (e.g., national forests, state and private lands)

for the conservation of snowshoe hares and their predators within the Northern Rockies. In addition, our maps indicated that occupancy and intensity of use by snowshoe hares were patchily distributed at a course scale, which generally contrasts with previously developed maps in the north-central continental USA (see occupancy maps in Sultaire, Pauli, Martin, Meyer, & Zuckerberg, 2016; Sultaire, Pauli, Martin, Meyer, Notaro, et al., 2016). The spatial products we provide in this study advance the landscape-level understanding of snowshoe hares in the Northern Rockies, and also provide a basis of comparison for future modeling efforts assessing changes in the distribution and density of snowshoe hares. However, it is important to mention that subsequent analyses of our snowshoe hare maps should be at course resolutions (e.g., ≥ 100 m²), and we suggest caution when analyzing predicted values of snowshoe hare use because unmodeled temporal processes (e.g., predation, source-sink dynamics, cyclicity) could induce substantial variation. Our map of predicted occupancy, however, should be comparatively more stable because it approximates the realized Grinnellian niche (Grinnell, 1917; Hirzel & Le Lay, 2008). Developing these spatial products specifically within the Northern Rockies was important

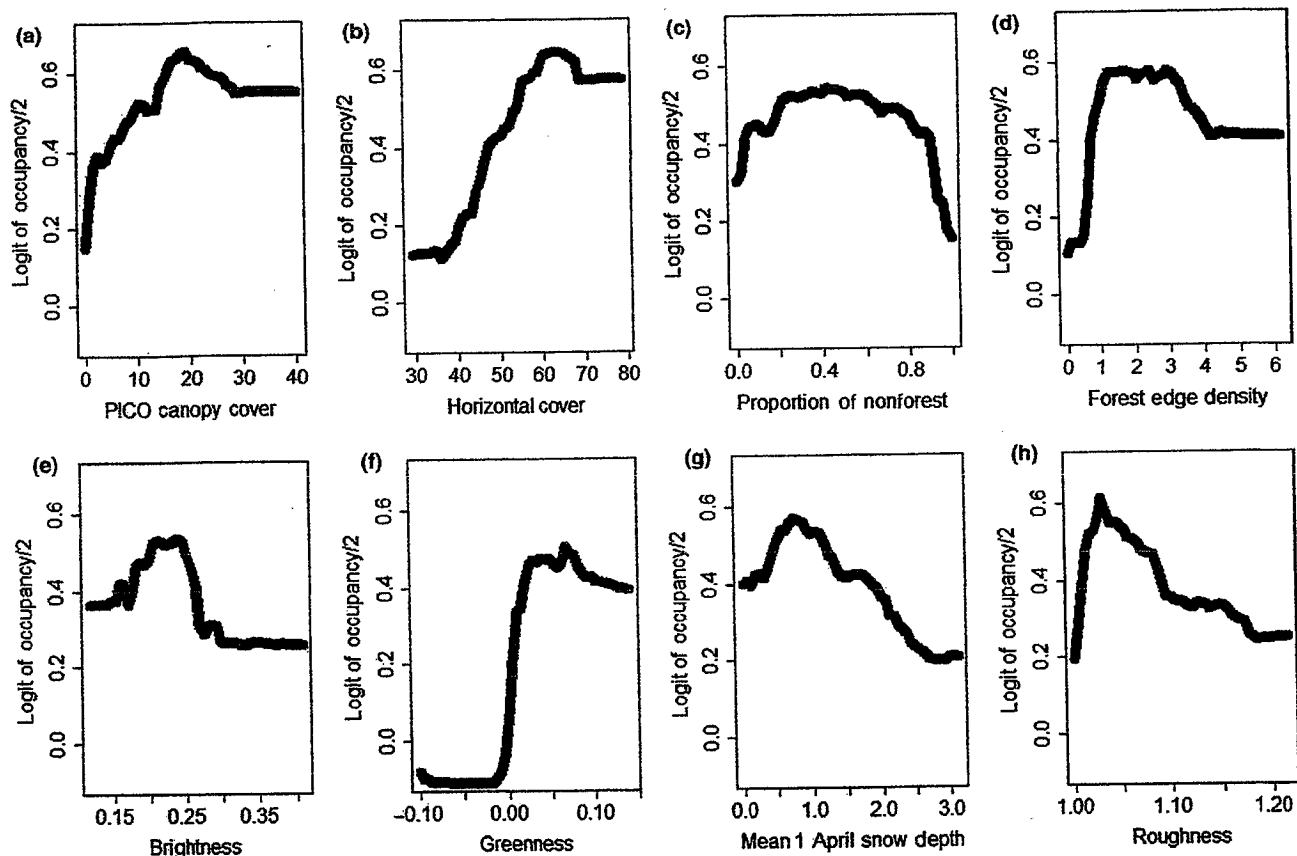


FIGURE 9 Partial dependence plots displaying the relationship between occupancy probability of snowshoe hares (*Lepus americanus*) and the covariates (a–h) that exhibited a consistent trend from our top Random Forest model. See Table 1 for covariate descriptions

because this landscape is projected to experience substantial changes via reduction in snow (e.g., Klos et al., 2014; McKelvey et al., 2011) and increased wildfire (Liu et al., 2013; Stavros et al., 2014).

Of the few studies on snowshoe hares that have been conducted at a landscape level, results indicated that occupancy is positively associated with vegetation cover, snow cover, and surrounding population density (Saultaire, Pauli, Martin, Meyer, & Zuckerberg, 2016; Saultaire, Pauli, Martin, Meyer, Notaro, et al., 2016; Thornton et al., 2013). Furthermore, Lewis et al. (2011) highlighted that vegetation cover at the local and neighborhood level was important for density of snowshoe hares. Our occupancy results support the notion that vegetation cover and perhaps moisture content are important for snowshoe hares in that we observed a positive relationship between occupancy and canopy cover of lodgepole pine, horizontal cover, and tasseled cap greenness and wetness. Snow depth, however, was the most important variable characterizing occupancy of snowshoe hares, which supports the recent findings of Saultaire, Pauli, Martin, Meyer, & Zuckerberg (2016) and Saultaire, Pauli, Martin, Meyer, Notaro, et al. (2016) indicating that snow cover is more important than forest cover for characterizing snowshoe hare occupancy. In addition, we discovered that occupancy of snowshoe hares was associated with relatively flat topography, and perhaps some level of disturbance at a coarse resolution. Although canopy and horizontal cover are clearly important, our results suggest that some open areas (e.g., edges) within a matrix of high-quality cover provide resources for increased use by

snowshoe hares. Finally, similar to occupancy, the intensity of use by snowshoe hares exhibited a positive relationship with canopy cover (both lodgepole and western larch) and horizontal cover. We attributed the positive effect of lodgepole pine to similar nutritional mechanisms aforementioned (e.g., Ellsworth et al., 2013). However, the positive effect of western larch appeared to be related to a broad-scale productivity gradient in that western larch tended to occur only in multiple-use lands (vs. wilderness and national parks), and was most abundant in the northwestern portion of our study area (i.e., considered most productive). We observed a negative effect of Douglas-fir on intensity of use by snowshoe hares, which was expected given the low level of horizontal cover associated with stands dominated by Douglas-fir (Figures 6 and 8). The positive effect of tasseled cap brightness and a negative effect of greenness are consistent with the hypothesis that a few open areas (e.g., edges) within a matrix of high-quality cover could provide additional foraging opportunities for snowshoe hares. This hypothesis is supported by previous work indicating that foraging behavior by snowshoe hares was largely associated with food supply (e.g., Ellsworth et al., 2013; Hodges & Sinclair, 2005), and not simply driven by predation risk.

4.3 | Foreseeable conservation challenges

Our work also highlighted the foreseeable challenges facing decision makers that are related to climate-induced reductions in snow depth

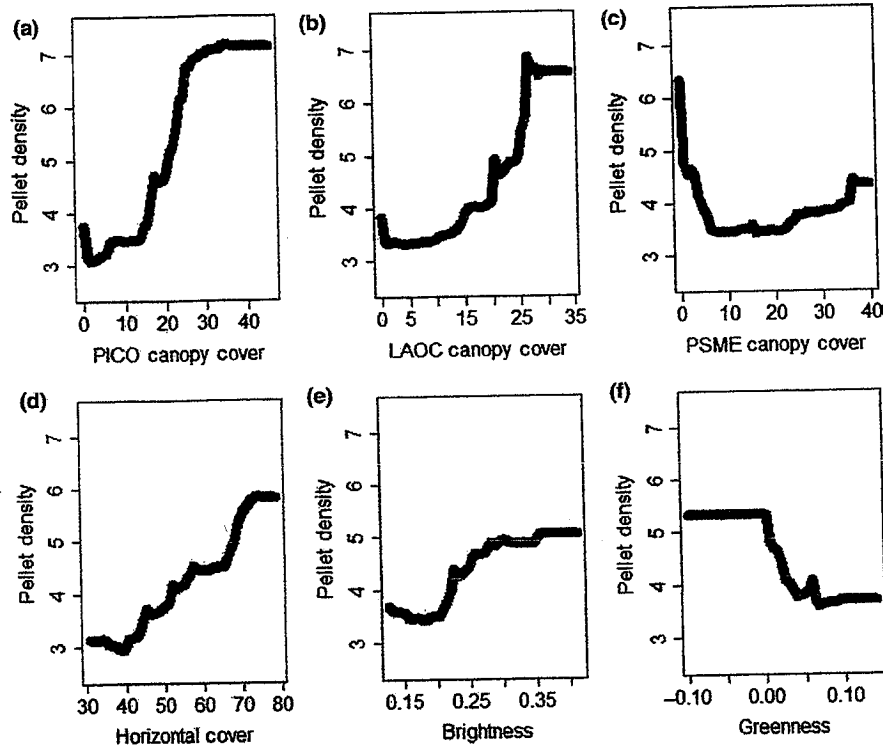


FIGURE 10 Partial dependence plots displaying the relationship between intensity of use by snowshoe hares (*Lepus americanus*) and the covariates (a–f) that exhibited a consistent trend from our top Random Forest model. See Table 1 for covariate descriptions

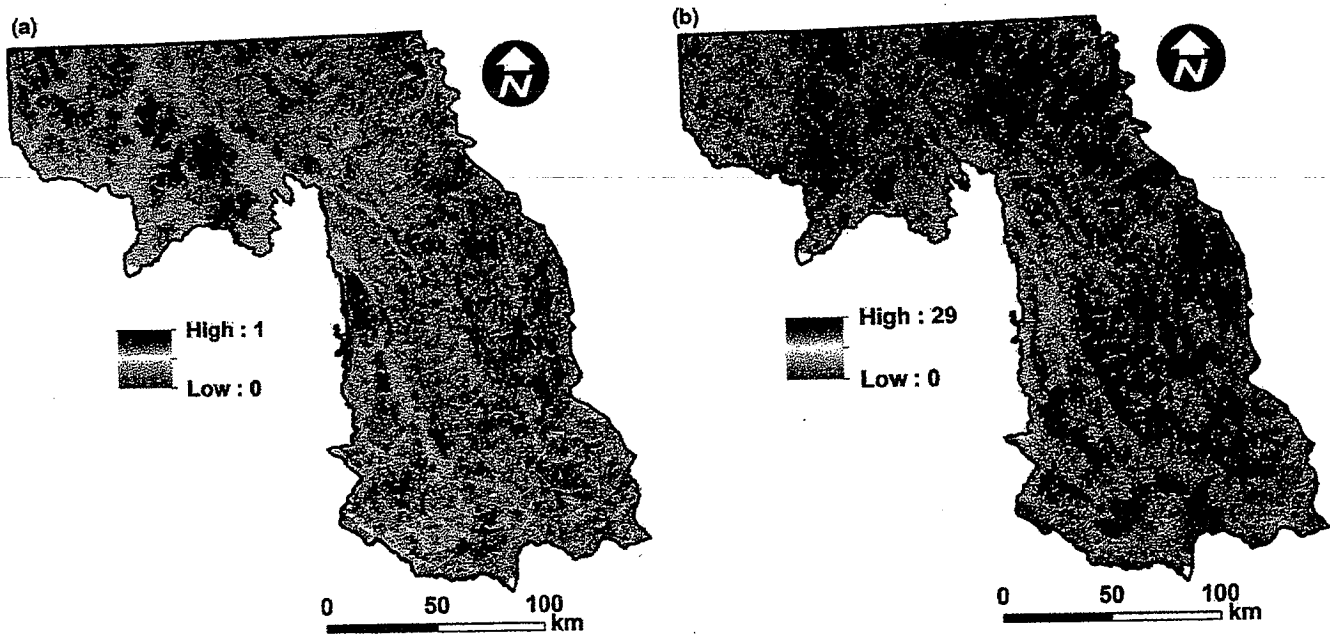


FIGURE 11 Predicted probability of occupancy (a) and intensity of use (b; indexed by the mean number of pellets/5.1 × 305 cm subplot) of snowshoe hares (*Lepus americanus*) throughout western Montana, USA. To account for absence, we multiplied our occupancy mask by the predicted intensity of use to produce our map of snowshoe hare intensity of use (b)

and increases in wildfire. Evidence suggests that changes in snow extent and depth will continue to have direct effects on snowshoe hare distribution and abundance because of mismatches in coat color leading to increased mortality (e.g., Mills et al., 2013; Zimova et al., 2016). Similarly, the observed and projected increase in wildfire within the Northern Rockies could impact forest structure, composition, and

landscape arrangement, all of which could certainly influence occupancy and abundance of snowshoe hares. For instance, Picotte, Peterson, Meier, and Howard (2016) demonstrated that subalpine habitats in the Rocky Mountains have exhibited temporal increases in both fire size and severity during 1984–2010, which together could act as a large-scale homogenization process in terms of forest

structure (e.g., more stand initiation and regeneration) and species composition (e.g., increase in fire-adapted species such as lodgepole pine). Previous work has indicated a positive response of snowshoe hares to fire (e.g., Cheng et al., 2015; Hodson et al., 2011), but there is a temporal delay, suggesting that the unburned matrix surrounding fires might be critically important in the short term (e.g., Abele et al., 2013; Ausband & Baty, 2005; Lewis et al., 2011). These broad-scale changes suggest that forest management for snowshoe hare habitat will likely be a nuanced and landscape-level endeavor.

Additionally, perhaps of equal concern are the indirect effects associated with changes induced by snow reduction and increased wildfire. For example, predation is the main process driving population dynamics of snowshoe hares (Feierabend & Kielland, 2015; Krebs, 2011; Wirsing et al., 2002), and changes in snow, or vegetation structure due to fire, could introduce or remove predators. These indirect effects might be of more concern in the southern range of snowshoe hares because densities tend to be lower than the northern range and the landscapes are generally more fragmented (Hodges et al., 2009; Thornton et al., 2013; Wirsing et al., 2002), perhaps making the persistence of southern populations more vulnerable to changes. Understanding the consequences of landscape-scale changes such as climate and wildfire on the distribution, density, and demography of snowshoe hares and their predators will continue to be important for wildlife conservation in northern North America.

5 | CONCLUSIONS

Our gradient-based (vs. type-based) and multiscale approach embraced the current paradigm in ecology (e.g., Cushman et al., 2010; McGill, 2010) and advanced the understanding and management of snowshoe hare habitat. First, our analyses produced consistent patterns across scales and emphasized the importance of horizontal cover, spruce-fir, and lodgepole pine as indicators of hare habitat within the mixed conifer context of the Northern Rockies. Second, we predicted snowshoe hare habitat and demonstrated that it is patchily distributed at a coarse scale within the Northern Rockies and that multiple-use lands (e.g., national forests, state-managed lands) are essential for the conservation of snowshoe hare habitat. Simply focusing on wilderness areas or national parks for conservation of snowshoe hares will likely result in ineffective strategies. Third, we provided explicit structural information concerning snowshoe hare habitat within the mixed conifer forests of the Northern Rockies that can be directly implemented by forest managers. The structure of forests with high use by snowshoe hares was characterized as dense (particularly in the understory), relatively closed, and multistoried, which we described using metrics such as quadratic mean diameter, trees/ha, canopy cover, and basal area (for additional metrics, see Table 2 and Table A1 in Appendix A). These stand characteristics can arise in nearly all successional stages and are presumably realized following disturbance agents (e.g., wildfire, insect damage, root disease, or cutting) of intermediate severity that allow patches of light to reach the forest floor. Overall, forest managers can apply this collective understanding to

inform decision making relevant to habitat management of snowshoe hares and their associated predators within the Northern Rockies.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

None declared.

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Sciurid Habitat Relationships in Forests Managed Under Selection and Shelterwood Silviculture in Ontario

GILLIAN L. HOLLOWAY,¹ Faculty of Forestry, University of Toronto, Earth Sciences Centre, Toronto, ON M5S 3B3, Canada
JAY R. MALCOLM, Faculty of Forestry, University of Toronto, Earth Sciences Centre, Toronto, ON M5S 3B3, Canada

Abstract

Although partial forest harvesting is practiced over large areas, managers know little about its impacts on sciurid rodents, particularly on northern (*Glaucomys sabrinus*) and southern flying squirrels (*G. volans*) in the northeastern United States and Canada. We examined habitat relationships of sciurid rodents (northern flying squirrels, southern flying squirrels, red squirrels [*Tamiasciurus hudsonicus*], and eastern chipmunks [*Tamias striatus*]) at 2 spatial scales in managed and unmanaged coniferous and hardwood forests of Algonquin Provincial Park, Ontario, Canada. We live-trapped rodents in 26 northern hardwood stands and in 16 white pine (*Pinus strobus*) stands from 2002 to 2004. Northern flying squirrel and red squirrel densities were significantly lower in recently harvested (3–10 yr since harvest) shelterwood stands than in unmanaged stands. In contrast, southern flying squirrel densities were higher in selection-harvested stands than in old-forest areas. The densities of northern flying squirrels and red squirrels had a strong relationship with the density of large spruce (*Picea* sp.) and hardwood trees and snags in conifer sites. Southern flying squirrel numbers had a positive association with the density of mast trees at the landscape level but not at the stand level in hardwood forests. Eastern chipmunk density had a positive correlation with the volume of old downed woody debris and the stems per hectare of declining trees. We recommend forest managers retain more large spruce and hardwood trees to mitigate the impacts of shelterwood harvesting on northern flying squirrels and red squirrels, and that they maintain high mast availability at the landscape level to ensure the persistence of southern flying squirrels. (JOURNAL OF WILDLIFE MANAGEMENT 70(6):1735–1745; 2006)

Key words

eastern chipmunk, *Glaucomys sabrinus*, *Glaucomys volans*, habitat use, northern flying squirrel, Ontario, partial harvesting, red squirrel, southern flying squirrel, stepwise regression, *Tamias striatus*, *Tamiasciurus hudsonicus*

Many jurisdictions in North America, including Ontario, Canada, have selected flying squirrels (*Glaucomys* spp.) as indicators of sustainable forest management practices. This designation has resulted in a relatively large body of research on these and other tree squirrels in landscapes managed under clearcut logging (Rosenberg and Anthony 1992, Witt 1992, Carey 1995, 2000, Martin and Anthony 1999, Cote and Ferron 2001). However, partial harvesting techniques, such as selection and shelterwood logging, have received less attention. These are common silvicultural techniques employed in temperate mixedwood forests in northeastern Northern America. In these systems, forest operators remove a portion of the overstory at relatively shorter intervals (approx. 20 yr), creating a more frequent, but less intensive disturbance regime, than under clearcut logging. The effects of partial harvesting on canopy-dwelling organisms are likely to differ from those resulting from clearcutting because partial harvesting maintains a relatively closed-canopy mature forest throughout the harvest cycle. Unfortunately, only 2 studies have examined the effects of partial harvesting (shelterwood harvesting) on flying squirrels (Waters and Zabel 1995, Taulman et al. 1998). These studies found that relatively high harvest intensities (<10 m²/ha residual basal area) negatively affected flying squirrel populations. Researchers have not examined the effects of

selection harvesting systems in hardwood forests, which typically leave greater residual basal areas than shelterwood logging.

Although partial harvesting systems retain canopy cover on sites, impacts on tree squirrel populations may manifest through other logging-induced changes in forest structure. Partial harvesting typically involves a reduction in the abundance of diseased and dead trees (McComb and Lindenmayer 1999, McGee et al. 1999, Costello et al. 2000) and often results in more homogenous forest structure, with reduced tree density and size (Costello et al. 2000). These changes may be important for arboreal mammals (Gerrow 1996, Carey 2000) and could result in negative effects for cavity nesters (Imbeau et al. 2001).

Most past studies on sciurids have only considered local (site-level) effects; however, organisms may demonstrate different responses to the same factor at different scales (Wiens 1989). Studies in fragmented landscapes suggest that flying squirrels may be sensitive to area effects (Nupp and Swihart 2000) and indicate that large clearcuts may act as barriers to dispersal and movement (Bendel and Gates 1987). Taulman (1999) found that flying squirrels nested in adjacent unharvested forest following partial harvesting, suggesting that the amount and configuration of unharvested stands might modulate flying squirrel responses to forest harvesting. In concert, these studies raise the possibility that local responses to forest harvesting might,

¹ E-mail: gillian.holloway@utoronto.ca

Table 3. Mean (\pm SE) values for site-level habitat variables that differed among logged and old hardwood and pine forest sites in Algonquin Provincial Park, Ontario, Canada, 2002–2004. Variable units are the number of stems per hectare unless otherwise stated.

Habitat variable ^c	Recent cut $n = 8$, 7 ^a		Old cut $n = 8$ ^b		Old forest $n = 10$, 9 ^a		P
	Mean	SE	Mean	SE	Mean	SE	
Hardwood							
BA (m ² /ha)	19.0	1.2	20.7	0.8	31.0	1.4	<0.001
Conifer	13.1	7.7	11.5	5.9	39.9	8.4	0.020
Con ≥ 25	8.1	5.4	5.0	2.5	23.6	5.8	0.028
Hwd ≥ 25	54.5	3.8	62.4	5.0	70.4	4.0	0.044
Spruce ≥ 25	0.5	0.4	0.5	0.3	3.5	1.1	0.014
Snags	10.8	3.7	13.3	3.5	28.8	4.6	0.008
Snags ≥ 25	3.0	0.7	6.0	1.4	10.1	1.1	<0.001
Pine							
BA (m ² /ha)	20.0	1.8	NA	NA	30.7	1.3	<0.001
CanClos (%)	76.2	3.2	NA	NA	89.4	1.6	0.001
Conifer	153.8	21.5	NA	NA	229.3	25.4	0.047
Hwd ≥ 25	12.4	3.9	NA	NA	27.4	3.9	0.018
Spruce ≥ 25	3.2	1.0	NA	NA	8.1	2.1	0.080
Snags ≥ 25	4.7	1.1	NA	NA	11.1	2.0	0.022

^a Sample sizes for hardwood and pine forests, respectively.

^b We sampled old cut stands only in hardwood forests.

^c See text for definition of habitat variables.

logging histories evenly between years, and hence allow equal application of any biases among comparisons.

Habitat variable reduction and variance partitioning.—The various sciurid species tended to be more or less abundant in one forest type (hardwood or conifer), but uncommon in the other; hence, we undertook community analyses separately for hardwood and white pine sites. Because squirrel densities differed between trap years (see Table 1), we first partialled it out of the models. To examine species–habitat relationships, we performed partial redundancy analysis (RDA), which served to reduce the number of site-level habitat variables (some of which were highly correlated with each other). Initially, we entered the 17 site habitat variables into the RDA (see Habitat Measurements, above). We computed the statistical significance of each variable using Monte Carlo simulations and a forward selection routine (9,999 permutations). We sequentially removed variables that contributed little (highest non-significant P -value) until the inflation factor was <10 (ter Braak and Smilauer 1998). We retained 11 variables in the hardwood model and 9 in the white pine model.

We investigated the relative importance of site and landscape variables using variance partitioning (Borcard et al. 1992, Cushman and McGarigal 2004). This analysis measures the variation in a community matrix, explained independently and jointly by different sets of explanatory variables. We calculated the unique variation at each level (site and landscape) by partialling out (as a covariate) variation due to the other level. We performed all multivariate analyses with CANOCO 4.5 for Windows (ter Braak and Smilauer 1998).

Individual species responses.—We plotted the density of each squirrel species against all habitat variables to ensure that assumptions of normality and homogeneity were satisfied and to check for the possibility of curvilinear relationships. We ln-transformed southern flying squirrel

densities in hardwood sites and red squirrel densities in pine sites to normalize the variance. We performed analysis of variance (ANOVA) with Bonferroni-corrected post hoc tests for each species to compare densities among years. Where a significant year effect existed ($P \leq 0.050$), we included it in all the following regression and ANOVA analyses. We analyzed the influence of logging history on squirrel density and habitat variables with ANOVA.

We used linear regression to develop sciurid habitat relationship, except in 2 instances (northern flying squirrels and red squirrels in hardwood sites) where densities were low and we therefore used logistic regression (on presence/absence). For all species, if a year effect was significant, we included it in all models. To develop site-level habitat models, we used 2 methods, stepwise regression and a priori selection of candidate variables followed by use of Akaike's Information Criterion (AIC; Burnham and Anderson 1998) to compare among models created from these candidate variables. In the former method, we used the site-level habitat variables remaining after the RDA forward selection routine. In the latter method, we picked 5–6 variables for each species that we reasoned to be most important based on relationships observed or hypothesized in the literature (listed in Table 1). From these candidate variables, we constructed all possible models of up to 3 terms and used AIC_c to compare among them. Specifically, we calculated the difference between the i th model and the minimum AIC_c (i.e., ΔAIC_c) and the Akaike weight (w_i) for each model.

To incorporate landscape-level variables into these analyses, we first forced the best site-level model into the analysis and then evaluated the value of the landscape variables in explaining additional variation in squirrel densities. We followed this hierarchical procedure for 2 reasons: 1) site-level variables proved to be more important than landscape-level variables in explaining squirrel captures

$$\frac{4.7}{11.1} = 42\% \text{ loss}$$

$$= 58\%$$

(see Results, below; see also Cushman and McGarigal 2004), and 2) in a forested landscape, we reasoned that a first-order model would incorporate local site features, whereas any landscape-level effects would be additive to these local effects. As before, we undertook both stepwise and AIC-based approaches. If results of the site-level AIC evaluation were equivocal—that is, ≥ 2 models were of approximately equal explanatory value—then we evaluated all combinations of these site models and landscape variables. For example, if 2 site-level models were equivalent, then in combination with 3 landscape variables, we evaluated 8 models (the 2 best site-level models plus 6 combinations of 1 site model plus 1 landscape variable). We performed all analyses with SPSS 11.0 (SPSS Inc., Chicago, Illinois).

Results

Over 3 summers we captured 274 individual southern flying squirrels, 83 northern flying squirrels, 1,709 eastern chipmunks, and 110 red squirrels during 28,548 trap-nights (21,091 grid-station nights). In general, small mammal populations were intermediate in abundance in 2002, high in 2003, and low in 2004. In hardwood sites, southern flying squirrel density was significantly lower in 2002 compared with 2003 (ANOVA $P=0.044$; mean MNKA/ha [\pm SE] = 0.35 [0.15]), and 1.12 [0.20] for 2002 and 2003, respectively). We only analyzed grids sampled in 2002 and 2003 for southern flying squirrels because, remarkably, we did not capture a single individual in 2004. This dramatic crash in numbers appeared to be a widespread phenomenon across the far northern range of the species (Bowman et al. 2005). Similarly, eastern chipmunk density was significantly higher in 2003 than in 2002 or 2004 ($P < 0.001$; mean MNKA/ha [\pm SE] = 2.98 [0.55], 7.16 [0.63], and 0.90 [0.28] for 2002, 2003, and 2004, respectively). In pine stands, eastern chipmunk densities in 2004 were significantly lower than in 2002 and 2003 ($P = 0.048$; mean MNKA/ha [\pm SE] = 4.20 [1.51], 5.20 [0.88], and 1.16 [0.51] for 2002, 2003, and 2004, respectively). In contrast, red squirrel densities were significantly high in 2004, compared with densities in 2002 or 2003 ($P = 0.025$; mean MNKA/ha [\pm SE] = 0.33 [0.12], 0.17 [0.05], and 1.08 [0.46] for 2002, 2003, and 2004, respectively).

Partial harvesting appeared to have little effect on densities of southern flying squirrels or eastern chipmunks. Densities of both species were slightly higher in cut sites of both ages than in old-forest stands, although not significantly so for either the hardwood or the white pine stands ($P > 0.120$; Table 2). In pine sites, both northern flying squirrels and red squirrels had significantly higher densities in old-forest sites than in recent cuts (Table 2). However, there was a significant interaction between trap year and logging history ($P < 0.001$) for red squirrels because of especially high abundances in old-forest stands in 2004 compared with 2002 and 2003. We did not perform any analyses for northern flying squirrels or red squirrels in hardwood stands because of low captures.

In both hardwood and pine sites, logging history changed the habitat structure present (Table 3). In hardwood sites, 6 habitat variables were significantly higher in old-forest sites than in either age of cut sites: basal area, spruce stems/ha ≥ 25 cm dbh, total conifer stems per hectare, conifer stems/ha ≥ 25 cm dbh, total snag stems per hectare, and snag stems/ha ≥ 25 cm dbh. Stems per hectare of hardwood trees ≥ 25 cm dbh were significantly higher in old-forest stands than in recent cuts. In pine sites, 5 habitat variables were significantly higher in old-forest sites than in recently harvested sites: basal area, canopy closure, total conifer, hardwood stems/ha ≥ 25 cm dbh, and snags/ha ≥ 25 cm dbh. Although not significant, stems per hectare of spruce ≥ 25 cm dbh were greater in old-forest sites than in cut sites.

Habitat Associations

Habitat variable reduction.—Eleven habitat variables remained in the site-level hardwood data set after collinearity was reduced to acceptable levels: basal area, canopy closure, conifer density, hardwood density ≥ 25 cm dbh, spruce density ≥ 25 cm dbh, mast density ≥ 25 cm dbh, declining tree density ≥ 25 cm dbh, snag density, understory stem density ≤ 10 cm dbh, volume of DWD ≥ 25 cm dbh, and volume of old decay class DWD. The 9 habitat variables remaining in the pine habitat data set were canopy closure, conifer density, hardwood density, hardwood density ≥ 25 cm dbh, spruce density ≥ 25 cm dbh, mast density ≥ 25 cm dbh, snag density ≥ 25 cm dbh, hardwood understory density ≤ 10 cm dbh, and the volume of recent decay class DWD.

Variance partitioning: site and landscape habitat associations.—In the variance partitioning analysis, site-level factors were more important than landscape-level factors, accounting for nearly twice as much explained variance. The unique site-level variance accounted for 46.4% and 43.7% of the explained variance in the squirrel community (in hardwood and pine sites, respectively), whereas the landscape-level variance accounted for only 22.0% and 22.5%, respectively. The remaining variance (31.6% and 33.8%, respectively) represented joint and unexplained variance.

Species-specific habitat models.—The stepwise regression models compared favorably with those chosen through the AIC_c procedure (Tables 4, 5). We ranked them as the best or second best model in all pine sites; when they were second best, the Δ AIC_c value was ≤ 0.64 . In hardwood sites, in 6 of 7 instances the stepwise model was one of the best 3 models, with Δ AIC_c values of < 1.29 . The only discrepancy was the model for red squirrels in hardwood sites, with the best AIC_c model adding an additional term (snag stems/ha) in comparison to the stepwise model. As a result, below we describe in more detail the results of the stepwise regression analyses, except for red squirrels in hardwood sites, for which we describe the top-ranked AIC_c model instead.

In hardwood forest, southern flying squirrel densities had a negative correlation with several habitat variables, including basal area (Fig. 1b) and conifer stems per hectare ($r = -0.52$,

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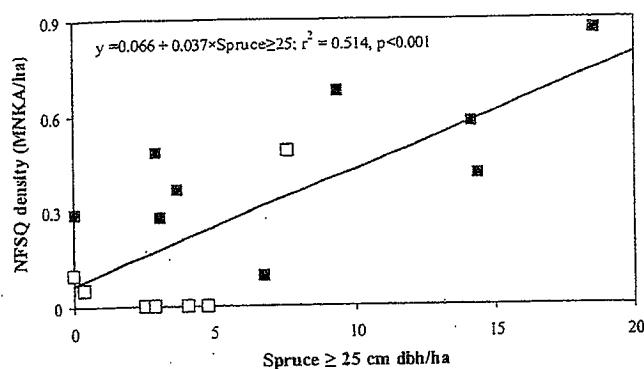


Figure 2. Northern flying squirrel (NFSQ) density in white pine sites in Algonquin Provincial Park, Ontario, Canada, plotted against stems/ha of spruce ≥ 25 cm diameter at breast height (dbh) from summers 2002–2004. Black squares = old-forest sites, empty squares = recent cuts, and the solid line represents the linear regression line.

density and basal area. However, our study measured density, not reproductive success or survival. Taulman et al. (1998) found that predation on radiocollared animals was more frequent in disturbed habitats; similarly, in a concurrent radiotelemetry study, we found that the loss of radiocollared animals was 2.5 times greater in selection cuts than in old-forest stands (Holloway 2006). Open stand structure may lead to easier movement, not only by flying squirrels, but also by their owl predators.

The relationship we observed for southern flying squirrels and snags in hardwood forest was the reverse of our initial predictions. The negative relationship this species showed with snags suggests southern flying squirrels are adaptable in regards to den use. In fact, cavities in live declining trees were the most common den substrate used by southern flying squirrels in our study area (Holloway 2006), and the density of declining trees did not differ between old-forest and cut sites. Mast density is a key habitat feature for southern flying squirrels (Sonenshine and Levy 1981, Bendel and Gates 1987, Taulman et al. 1998), but the availability of this resource appears to influence the spatial scale at which mast is most critical. In suboptimal habitat (mixed conifer–hardwood), mast density was important directly at the local site level. In more suitable hardwood stands, similar to those in Fridell and Litvaitis (1991), we observed a positive relationship between southern flying squirrel density and mast availability on the landscape. Flying squirrels are mobile animals, and presumably move into mast stands during the fall, but a supply of mast must exist either within an animal's home range or in the surrounding vicinity for overwinter survival. Low mast abundance the preceding fall, coupled with cold winter conditions, most parsimoniously explains the crash of the southern flying squirrel population at our study site in 2004 (Bowman et al. 2005).

Chipmunks were ubiquitous across our study sites and partial harvesting had little discernable effect on their populations. Declining trees, dense understory cover, and downed woody debris are important habitat features for eastern chipmunks (Bennett et al. 1994, Mahan and Yahner

1996, Zollner and Crane 2003, this study). Chipmunks use fallen logs and branches as travel runways, while high shrub density provides both protective cover and abundant food. These features in our study area were most abundant in sites with intermediate levels of canopy closure (particularly declining trees). Intermediate canopy closure shows a link to sites with intermediate gap sizes created by less intensive (or older) logging activity, or the mortality of overstory trees, which results in mosaic of gaps in old-forest stands.

This study affirmed the link between high densities of northern flying squirrels and red squirrels and older, undisturbed forests (Carey et al. 1999). Characteristics associated with old-forest areas (high snag density and basal area) were important predictors for these 2 species. Shelterwood harvesting resulted in significantly lower densities of standing trees, spruce, hardwoods, snags, and canopy closure, leading to an overall reduction in structural complexity. The loss of these features under shelterwood harvesting may be problematic for both northern flying squirrels and red squirrels because high structural diversity and overstory cover are associated with decreased predation risk (Vahle and Patton 1983, Carey 2000). Moreover, these changes will affect the availability of nesting habitat because northern flying squirrels and red squirrels commonly use hardwood trees and snags as nests in central Ontario (Obbard 1987, Holloway 2006). Finally, the removal of trees increases the habitat suitability for understory species such as eastern chipmunks at the expense of the arboreal sciurids.

The abundance and availability of foraging resources also may be a critical consideration for these species (Kemp and Keith 1970, Ransome and Sullivan 1997, Carey et al. 1999). Hypogeous fungi are major dietary items for northern flying squirrels and red squirrels, and both species act as primary dispersers of fungal spores (Maser et al. 1986, Vernes et al. 2004). Spruce density was a key habitat predictor for both species, supporting previous research both in the boreal forest and in the southern Appalachians (Fancy 1980, Payne et al. 1989, Cotton and Parker 2000, Ford et al. 2004). Spruce is important directly as a seed source (a major diet item for red squirrels; Kemp and Keith 1970) and indirectly because of its mycorrhizal associations with fungi. In the Appalachians, the presence of truffles was associated with red spruce (*Picea rubra*) abundances (Loeb et al. 2000), and the frequency of ectomycorrhizal fungi occurrence in red spruce stands was double that found in adjacent hardwood stands (Bills et al. 1986). In particular, the most common fungal genus, *Elaphomyces*, found in the Appalachians (Loeb et al. 2000) and in northern flying squirrel feces in this study (Holloway 2006), was associated with spruce (*Picea* sp.) and fir (*Abies* sp.) trees.

In addition to a reduction in spruce and snag densities, shelterwood harvesting may also decrease the microclimatic suitability in stands for fungi. Hypogeous fungal productivity is associated with old-growth features (such as a well-developed organic soil layer, abundant coarse woody debris, and the presence of large, old trees; North et al. 1997). The

abundance of flying squirrels and hypogeous fungi was significantly lower in shelterwood stands than in uncut old-growth stands in California (Waters and Zabel 1995). Beyond the local site-level effects of harvesting, we observed additive effects of logging on the surrounding landscape. This suggests that the interspersed of large harvested and unharvested blocks on the landscape may be important to ensure the persistence of red squirrels and northern flying squirrels.

We developed habitat models using both stepwise regression and models developed a priori. Stepwise regression has fallen into disfavor recently because of misuse of the technique (excessive data dredging), its reliance on arbitrary cutoffs (e.g., $\alpha = 0.05$), and model over-fitting (Burnham and Anderson 1998, Stephens et al. 2005). However, models developed a priori may be equally prone to problems when considering a large number of potential variables (i.e., model dredging; Stephens et al. 2005). Thoughtful model development is critical in both stepwise techniques and a priori model building. If researchers take care in developing models, we believe stepwise regression is a powerful tool and should continue to be used in habitat studies. Habitat studies often lead to the development of large sets of potential variables, and the inclusion of novel variables can lead to new insights.

Management Implications

Shelterwood harvesting decreased the density of large spruces and hardwoods below critical thresholds for north-

ern flying squirrels and red squirrels. In order to mitigate the structural changes resulting from logging, we recommend managers retain at least 4.5 spruce trees/ha ≥ 25 cm dbh and 15 hardwood trees/ha ≥ 25 cm dbh in white pine stands (levels predicted to maintain northern flying squirrel densities in shelterwood stands at 50% of their mean level in old-forest areas). The abundance of mast trees on the landscape appears to limit southern flying squirrel density. In hardwood stands, we recommend foresters maintain a minimum of 17% of the landscape area (to maintain 80% of their mean level in hardwood forests) with high mast tree abundance (i.e., where $\geq 20\%$ of the stand composition is a mast tree).

Acknowledgments

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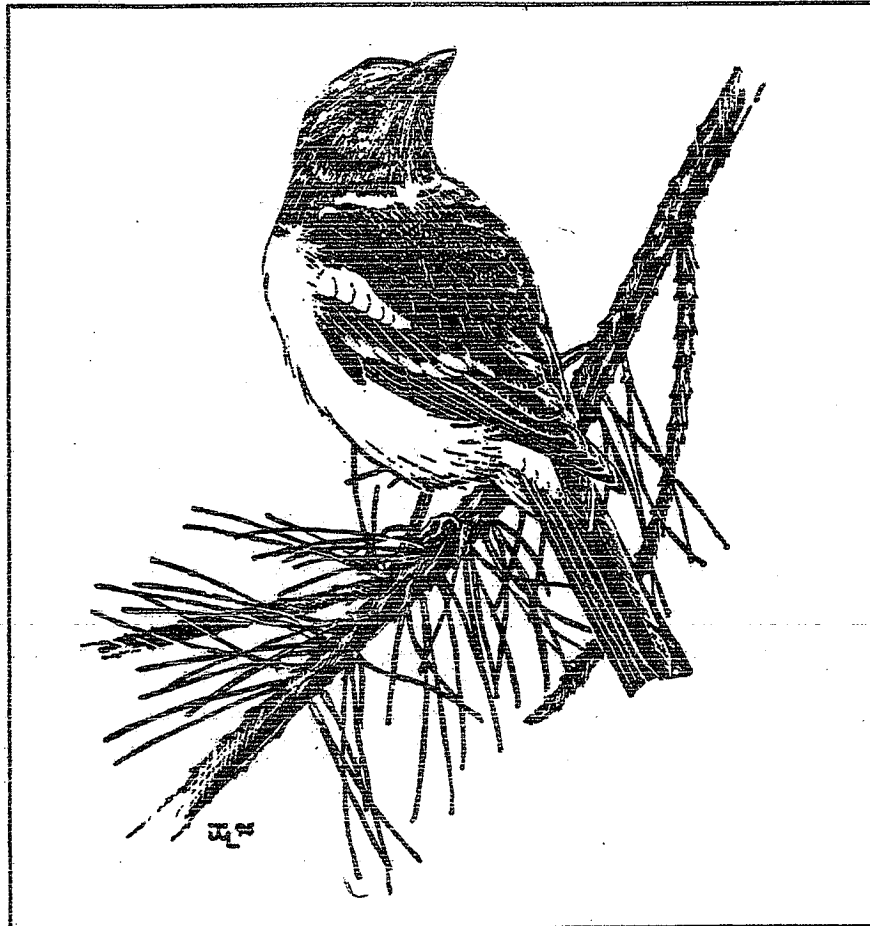
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**USFS Northern Region
Songbird Monitoring Program**

**Distribution and
Habitat Relationships**



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USFS contract #R1-95-05, Second Report

6 November 1995

Richard L. Hutto
Division of Biological Sciences
University of Montana
Missoula, MT 59812
(406) 243-4292
e-mail: hutto@selway.umt.edu

Which species are included in the modeling effort? Several published studies suggest that a species should be detected on about 50 point counts before initiating a model-building effort, and 98 species met that criterion. I have appended models for each of those species plus 10 additional species that did not meet the sample size criterion, but that illustrate potential management issues nonetheless.

Summary of principal results.

1. Based on a single year's field effort across all 13 forests, the monitoring program has produced a wealth of knowledge about the geographic and habitat distribution of an amazing number of bird species. We detected a total of 186 bird species, 137 of which were species that the point count method was designed to detect--songbirds (loosely defined as doves through sparrows). We also detected 14 waterfowl species, 19 raptor species, 8 shorebird species, and 8 game bird species (Table 1). Geographic and habitat distribution patterns for most (108) of the 137 songbird species are included in this report.
2. The detail and region-specific nature of this information can be matched by no other database in existence. Yes, some patterns of habitat use were already common knowledge (e.g., Grasshopper Sparrow is restricted to grasslands, or Brewer's Sparrow is restricted to sagebrush), but other patterns of restricted distribution were not as evident prior to this work (e.g., Black-backed Woodpecker to burned forests, or Brown Creeper to relatively uncut cedar-hemlock forests). More importantly, prior to this survey, we had no knowledge of the relative abundance of the more widespread species across cover types, especially harvested forest types. It is now evident that Orange-crowned Warbler and Solitary Vireo, for example, occur not only broadly across forest types, but most commonly in harvested forest types, and that Williamson's Sapsucker is even relatively restricted to such types! This kind of information is available nowhere else.
3. Results from this report can already provide clear guidance for land-use decisions that involve input from wildlife biologists. For example, a number of bird species are relatively restricted in their habitat distribution to each of the following (species that best illustrate a given distribution pattern are highlighted in **bold** lettering): (a) post-fire, standing-dead forests, (e.g., **Black-backed Woodpecker**, Cassin's Finch, Clark's Nutcracker, Hairy Woodpecker, House Wren, Lincoln's Sparrow, Mountain Bluebird, Olive-sided Flycatcher, Pine Siskin, Ruby-crowned Kinglet, Tree Swallow, Three-toed Woodpecker, Western Wood-Pewee); (b) relatively uncut, older forests (e.g., **Brown Creeper**, Chestnut-backed Chickadee, Golden-crowned Kinglet, Gray Jay, Hammond's Flycatcher, Hermit Thrush, Mountain Chickadee, Pine Grosbeak, Pileated Woodpecker, Red-breasted Nuthatch, Townsend's Warbler, Varied Thrush, Winter Wren); (c) marshes (e.g., Common Snipe, **Common Yellowthroat**, [Marsh Wren], Red-winged Blackbird, [Yellow-headed Blackbird]); (d) riparian bottomlands (e.g., American Goldfinch, American Redstart, Belted Kingfisher, Black-capped Chickadee, [Bank Swallow], Cedar Waxwing, Gray Catbird, Lazuli Bunting, **Least Flycatcher**, Northern Waterthrush, Ovenbird, Red-eyed Vireo,

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Song Sparrow, Tree Swallow, Veery, Western Wood-Pewee, Willow Flycatcher, Yellow-breasted Chat, Yellow Warbler); (e) upland riparian stream environments (e.g., **American Dipper**, Lincoln's Sparrow, Wilson's Warbler); (f) grassland and/or sagebrush (e.g., Baird's Sparrow, Brewer's Sparrow, Chestnut-collared Longspur, Clay-colored Sparrow, Common Nighthawk, Field Sparrow, Grasshopper Sparrow, Horned Lark, Lark Sparrow, **Sprague's Pipit**, Vesper Sparrow, Western Meadowlark); and (g) agricultural fields (e.g., **Bobolink**, Savannah Sparrow, Vesper Sparrow, Western Meadowlark). Obviously, the loss any one of these cover types will mean the loss of those bird species that are relatively restricted to it. Thus, it's clear that we need to maintain each of those elements on the broader landscape, although it's unclear how much of each needs to be retained to maintain viable populations.

4. Even if we are not about to lose a given cover type from the broader landscape, land use practices within and around that type may have important implications, especially for species restricted to that cover type. For example,

a) **Bird species relatively restricted to early post-fire situations.**--salvage logging will have a negative impact on species that are either restricted to, or relatively restricted to, early post-fire conditions. Such distribution patterns result from the fact that those wildlife species depend to a great extent on standing dead trees in burned forests for feeding and/or nesting purposes. The presence of such narrowly distributed habitat specialists leaves little doubt that post-fire salvage cutting activities are in direct conflict with the needs of these bird species.

b) **Bird species restricted to relatively uncut, older forests.**--Based on observed distribution patterns, the cutting (even light thinning) of dense, older forests (especially the cedar-hemlock type) will have negative effects on several species that are restricted to those conditions. To assure the maintenance of their populations, we probably need to maintain relatively large patches of older forest types on the landscape.

c) **Bird species restricted to marshlands.**--The draining and conversion of wetlands will have negative effects on species restricted to those conditions. Because our methods were not well designed to survey birds that occupy this cover type, we did not detect additional species that are known to fall into this category.

d) **Bird species restricted to riparian bottomlands.**--Numerous songbird species are relatively restricted to riparian bottomlands. This fact takes on special meaning when we consider that bottomland riparian cover types make up less than 0.5% of all land area, and that they incur a disproportionate amount of human activity (i.e., home building, recreation, and livestock grazing) and cowbird activity. Much of this land base is private, making publicly-owned land of this type much more important as refuges for wildlife that might be sensitive to the human activities outlined above. We currently lack, but desperately need, information on cowbird parasitism rates in relation to the presence of livestock in riparian bottomlands, and we need information on the effects of vegetation

Michael Stellanor

alteration and livestock presence on nesting success of our riparian bottomland birds.

e) **Bird species restricted to upland riparian stream environments.**--These species may be especially sensitive to so-called "best management practices", which have never been evaluated in terms of their effects on a wide variety of riparian-dependent terrestrial wildlife species.

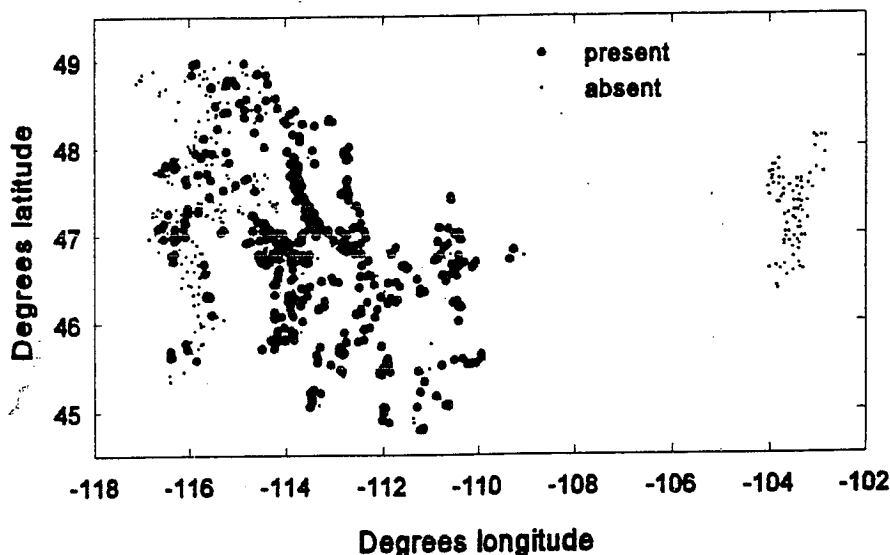
f) **Birds restricted to grassland and sagebrush environments.**--If we couple the fact that many species are restricted to grassland, sagebrush, or a combination of both, with the fact that many of the same species are declining on a nation-wide scale, the management of those lands becomes an issue. We cannot comment on the effects of grazing until the 1995 data have been incorporated into the database, but this is a common land-use activity on grassland and shrubsteppe environments that may be incompatible with the needs of some of these bird species.

g) **Birds that occur commonly in agricultural fields.**--Several species occur commonly in (and in some cases are nearly restricted to) agricultural fields during the breeding season. The main issue here is one of whether mechanical disturbance from farm machinery interferes with the reproductive biology of these species. If so, these environments may be acting as "ecological traps" that attract the species, but don't allow them to be successful there.

5. Most conifer-forest birds are distributed broadly across forest types, and many occur relatively commonly in variously cut forests (e.g., American Kestrel, Black-headed Grosbeak, Chipping Sparrow, Dusky Flycatcher, Hairy Woodpecker, House Wren, MacGillivray's Warbler, Mountain Bluebird, Northern Flicker, Orange-crowned Warbler, Rufous Hummingbird, Steller's Jay, Swainson's Thrush, Townsend's Solitaire, Warbling Vireo, Western Tanager, **Williamson's Sapsucker**, Yellow-rumped Warbler). This probably means that, except for those species restricted to older, relatively uncut forests, we can modify forest lands to an extent and still retain conditions necessary for most forest birds. The potential management issue that still looms is related to the fact that harvested forests are "unnatural" in the sense that their structure consists of combinations of elements (widely, or evenly-spaced live trees) that simply do not exist in natural successional seres. The problem is that these unnatural cover types may elicit settling responses by species that are "programmed" to respond to superficially similar, but fundamentally different, early successional forest types. Thus, it becomes imperative that we determine whether these unnatural forest types are acting as "ecological traps", where species are being attracted to areas where suitability (in terms of reproductive success and or adult survival) is poor because food resources, predation, or parasitism rates are unnaturally high there. Because no forest bird species is **restricted** to harvested conditions, there will always be a "backup" of lightly harvested or unharvested forest as a refuge from such a potential problem, should it exist. Although we need data on nest success to be sure, I suspect that most bird species do well in harvested forests. Moreover, if our abundance data reflect suitability of cover types, we have improved conditions for most forest bird species through timber harvesting activities.

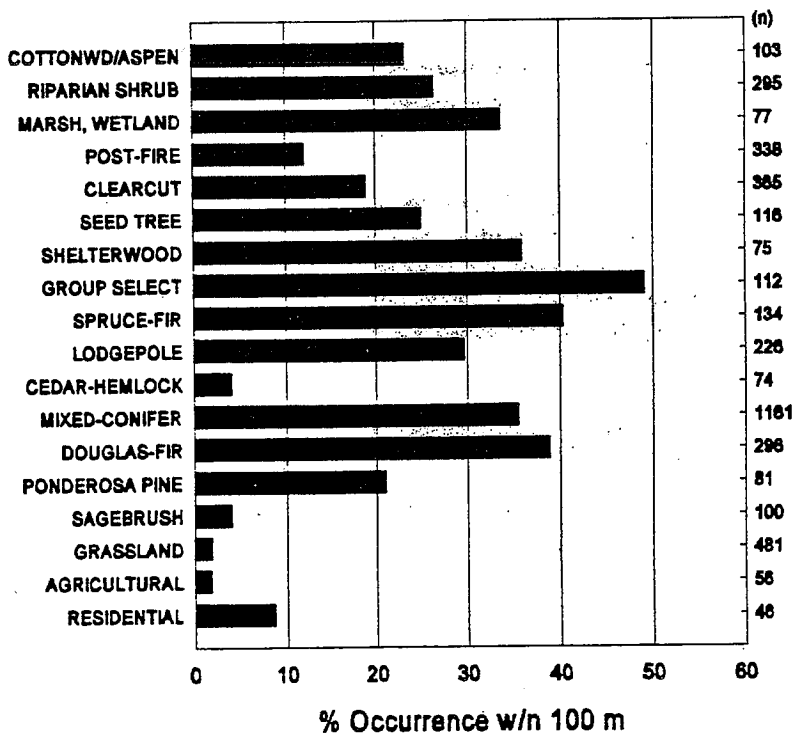
Ruby-crowned Kinglet

Distribution and habitat use. Ruby-crowned Kinglets are widely distributed throughout the middle portion of the region (see map at right). The species is restricted to conifer forest cover types (see histogram below). The fact that this kinglet is less likely to occur on points with riparian cover near (20.3% occurrence) than on points without such cover near (24.1%) suggests that its apparent abundance in the riparian cover types is an artifact of the bird being detected in nearby forest types, and not that the bird is common in riparian cover types, per se.



Management considerations.

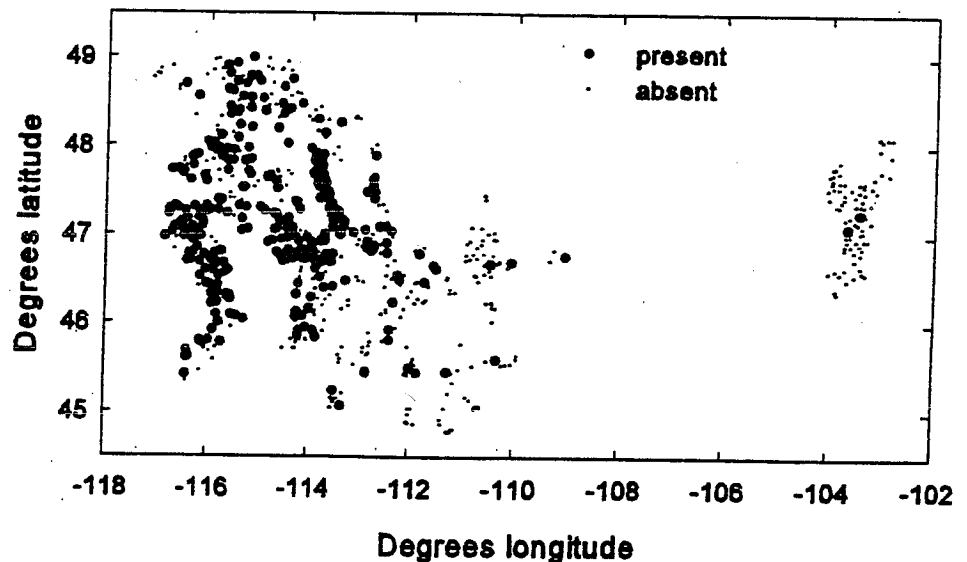
Despite its widespread occurrence across most conifer forest types, including the harvested types, it is noteworthy that this species shows a continuous decrease in abundance with increasing amounts of timber removed (see histogram). Thus, it is a species that is sensitive to timber harvesting in the same way that the Red-breasted Nuthatch is. For whatever reason, this species probably needs an abundance of trees to attain normal population levels.



Solitary Vireo

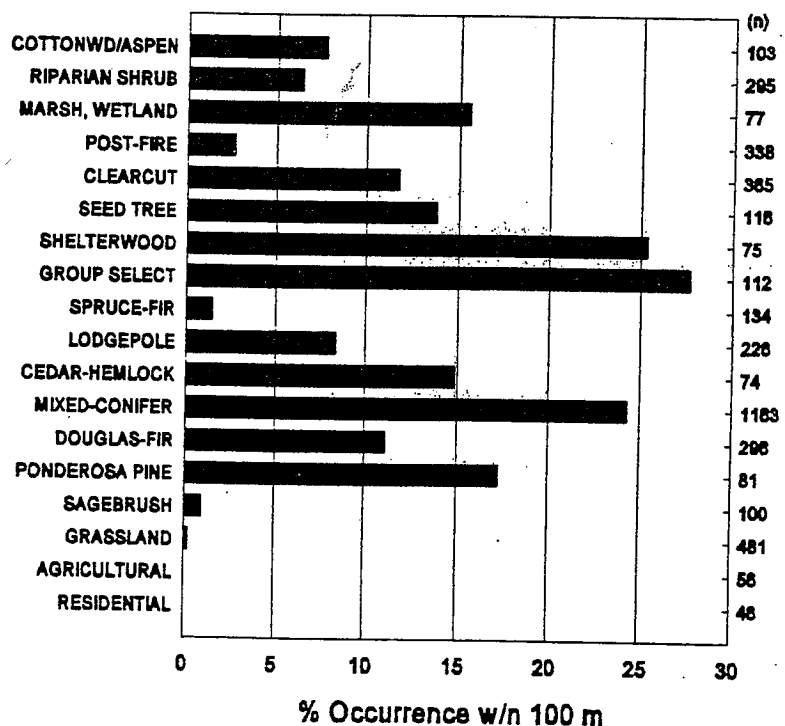
Distribution and habitat use. The Solitary Vireo is widespread throughout the westernmost portions of the region (see map). The species is restricted to coniferous forest cover types (see histogram), and is not uncommon in the harvested forest types.

Most occurrences in the riparian cover types are probably because the birds were detected in adjacent forest, as suggested by the fact that they are less likely to occur on points with (8.5% occurrence) than on points without (12.3% occurrence) riparian cover nearby.



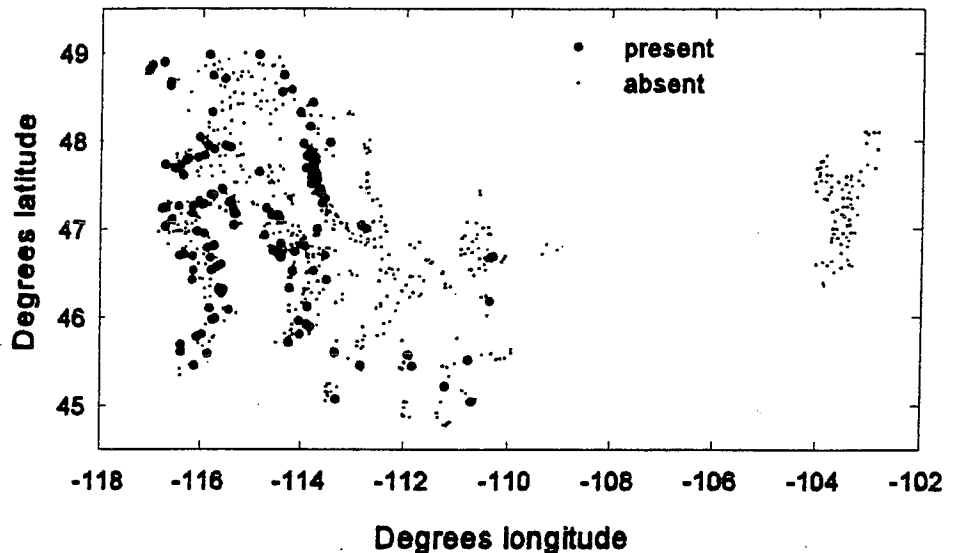
Management considerations.

Although the Solitary Vireo is common in the moderately cut forest types (group selection and shelterwood cuts), its occurrence drops off continuously with increasing levels of tree removal. This is the same pattern exhibited by several other forest bird species, including Ruby-crowned Kinglet, Red-breasted Nuthatch, and Townsend's Warbler, and it implies a certain degree of dependence on the retention of some older, relatively uncut conifer forests.



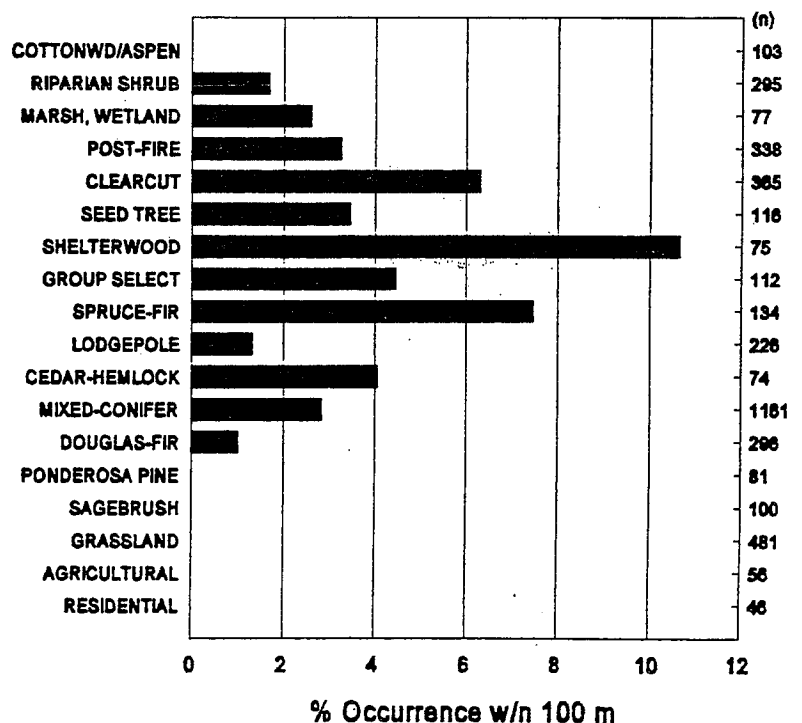
Steller's Jay

Distribution and habitat use. Steller's Jay is a bird of the westernmost portion of the region (see map at right). It occurs primarily in higher elevation spruce-fir forests (see histogram below), where it is six times more likely to occur on points with dead/down than on points without such. It is common in a variety of harvested forest type as well.



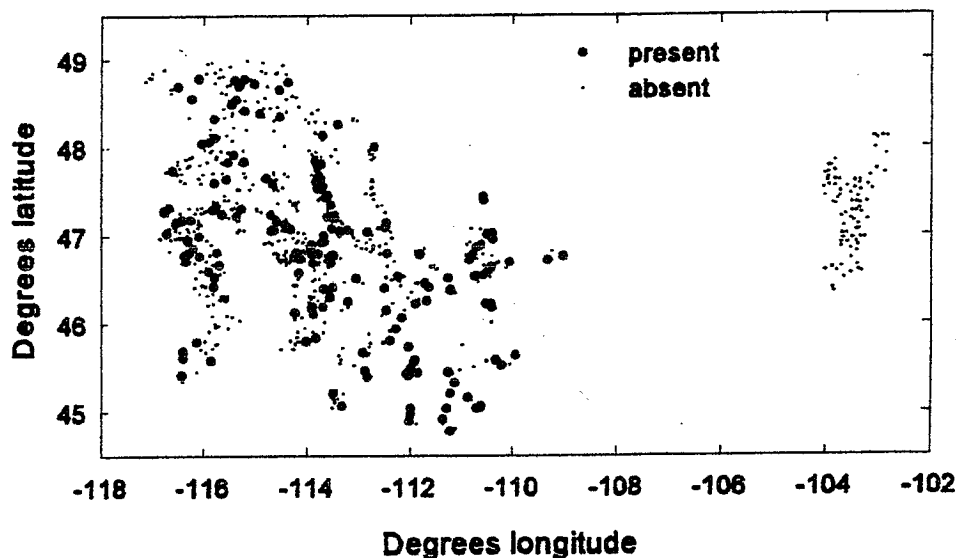
Management Considerations.

Although this species appears to be reasonably abundant in harvested forests, I suspect that nesting activity is limited there. Instead, I suspect that this wide-ranging species frequents such areas for other reasons (nest egg predation?) and that its primary nesting habitat is in the less disturbed forest. This species may be a big reason why nest success of other songbirds might not be as great as implied by census data alone, and underscores the need for nest success studies in cut forests.



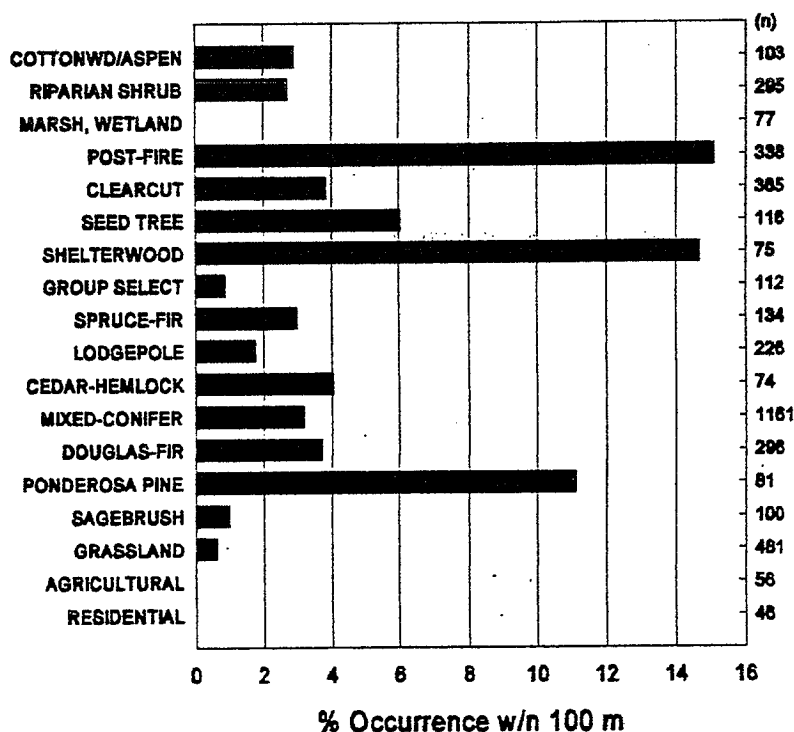
Cassin's Finch

Distribution and habitat use. Cassin's Finch occurs throughout the western portion of the region (see map at right). They occur across most of the conifer forest types, but are detected most frequently in early post-fire situations, shelterwood cuts, and ponderosa pine forests (see histogram below) where they apparently hone in on conifer seed production.



Management Considerations.

The seed resources that become available shortly after a stand-replacement fire may be important to this species. Thus, post-fire salvage cutting may be in direct conflict with its needs. Shelterwood cuts look quite suitable, but they may act as "ecological traps" by creating stands that take on a post-fire-like, open appearance but fail to provide needs otherwise. In this instance, however, I believe the other needs of this species are likely to be provided as well because the cone (seed) production in the remaining trees often increases after harvesting.



Subject: Great Gray owls in Tetons logging impacts them.
From: George Wuerthner (gwuerthner@gmail.com)
To: stonefly@olympen.com;
Bcc: sjjohnsonkoa@yahoo.com;
Date: Wednesday, July 31, 2013 10:19 PM

Jackson Hole News & Guide

Environmental

Biologists track owls to save homes from logging
Great grays fitted with GPS backpacks to learn about habits, numbers.

*By Mike Koshmrl, Jackson Hole, Wyo.
July 31, 2013*

Perched partway up a twisted pine, a great gray owl stared at a white mouse that had nowhere to run.

The mouse, tethered to the ground by an alligator clip, was planted by Craighead Beringia South biologists hoping to catch the female *Strix nebulosa*, which sat nearby panting. It was an easy meal, and the great gray had a clear line of sight on the critter, but she seemed not to give a hoot.

"Right when we arrived, she fed the fledgling a vole," said Beth Mendelsohn, who'd been tracking the owl since sunup. "This bird seems a little more spooky than most."

Mendelsohn, along with Katherine Gura and Bryan Bedrosian, had hoped to net and then fix a GPS-equipped backpack to the great gray. The team had managed to fix backpacks to five great grays this summer.

These are some of the first electronically tracked owls in the world, Bedrosian said. GPS trackers are usually solar-powered, and that's an issue because owls are most active at night.

The owl-catching crew came up empty-handed. The female, which was caring for a lone offspring, saw through the biologists' ploy.

"Some birds are like, 'yeah, nice try,'" Bedrosian, Beringia South's avian program director, said after giving up.

Beringia South, based in Kelly, is in the middle of the first great gray owl research project in Jackson

<http://us-mg4.mail.yahoo.com/neo/launch?.rand=akhhc7k7lql14>

[print page](#) | [email editor](#)



*Craighead Beringia South biologist Bryan Bedrosian lets a captured gray owl spread its wings to allow a newly-attached tracking device to work into its feathers near Red Top Meadows. Bedrosian has been putting transmitters and ID bands on several owls in order to study the birds' home range.
BRADLY J. BONER / NEWS&GUIDE*

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Hole in two decades. Biologists Susan Patla, with the Wyoming Game and Fish Department, and Kerry Murphy, with the Bridger-Teton National Forest, are collaborators. Funds have come from a state of Wyoming wildlife grant, the Community Foundation of Jackson Hole, Four Seasons Hotel and Resorts and Ecotour Adventures.

Locally, little is known about the species. Numbers, home ranges — it's all unknown territory, Bedrosian said.

What is known is that there aren't many great grays.

"We found very few owls," Bedrosian said, recalling a winter of combing the mountains from Grand Teton National Park to the Snake River. "There just isn't that many nests."

Meanwhile, the Teton to Snake Fuels Management Project, a wildfire reduction plan that will thin critical old-growth habitat, looms. Cuts, thinning and limbing is proposed in some of the birds' prime range in the Bridger-Teton National Forest.

The plan is designed to protect private property and to allow natural fires to burn in the nearby Palisades Wilderness Study Area.

The Forest Service has pledged to put a buffer around the home ranges of great grays and other owl species, Bedrosian said. As a result his team of biologists has been going "gangbusters" trying to find nest sites.

At 6 a.m. four days later, the biologists were back wandering the woods near Red Top Meadows.

Bedrosian hooted.

"My call must not be that bad — it screwing up both the girls," he said.

On the second take, the biologists opted to switch capture techniques.

A gerbil enclosed in a mesh cage lined with looped monofilament fishing line took the place of the tethered mouse. It's name was Peppermint.

Just shy of two hours into the search the group once again found the mother great gray.

Shortly thereafter, they caught her.

"Got it," Bedrosian shouted.

"Thankfully I didn't have to tackle her this time," he said. "Last time I had to do a flying leap as it got off the trap."

It was routine work for the Beringia South team, but they all seemed energized.



"Peppermint worked," Gura said.

The great gray, whose beady yellow eyes were covered with a ball cap, was a healthy two-pound female.

The bird looked much larger, but that's because she was all fluff.

"There's just so many feathers," Bedrosian said. "They appear larger in size than a great horned owl, but a great horned owl is quite a bit bigger actually."

The plumage is for a reason.

Great grays are a boreal forest species and don't venture much farther south than Jackson Hole in the Northern Rockies. Warming climates figure to shift their ranges north and uphill, Bedrosian said.

"They are an extremely heat-intolerant species," he said.

After measurements and blood samples were taken, the captive owl was fixed with two ID bands. Somewhere in the process a razor-sharp talon punctured the webbing between two of Bedrosian's fingers, and blood trickled.

The team then began to fit the great gray with the GPS backpack.

The transmitter weighs just 30 grams, equivalent to less than 3 percent of her weight.

"We're right at the edge of what technology can do for owls," Bedrosian said.

After she was released, the great gray, now No. A8, settled onto a perch 30 feet up and 100 or so feet away.

She started picking at the foreign straps that secured the transmitter, pausing mostly to peer down at the biologists.

Little does she know that the data the team will glean from her annoying new outfit will help save her soon-to-be mapped home range.

The area around her nest site, Bedrosian said, had been slated for treatment under the Bridger-Teton's wildfire plan.

2004

HABITAT ASSOCIATIONS OF SYMPATRIC RED-TAILED HAWKS AND NORTHERN GOSHAWKS ON THE KAIBAB PLATEAU

FRANK A. LA SORTE,^{1,2} School of Renewable Natural Resources, 325 Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

R. WILLIAM MANNAN, School of Renewable Natural Resources, 325 Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

RICHARD T. REYNOLDS, Rocky Mountain Research Station, 2150 Centre Avenue, Building A, Suite 354, Fort Collins, CO 80526, USA

TERYL G. GRUBB, Rocky Mountain Research Station, 2500 South Pine Knoll Drive, Flagstaff, AZ 86001, USA

Abstract: We investigated habitat association of sympatric red-tailed hawks (*Buteo jamaicensis*) and northern goshawks (*Accipiter gentilis*) at 2 spatial scales centered on nest sites: (1) fine-scale patterns of forest structure and topography within 16-m radius circles (0.08 ha), and (2) midscale patterns of forested and nonforested areas, forest fragmentation, and topography within 2,085-m-radius circles (1,367 ha). Nonforested areas were defined as any area lacking >20% canopy closure within a 30 × 30-m cell. At both scales, red-tailed hawk associations were more variable and goshawk associations less variable. At the fine scale, goshawks were consistently associated with open understories, tall trees, and gentle slopes (\bar{x} = 9.6°, SD = 6.9) while red-tailed hawks were associated, on average, with steep, north-facing slopes (\bar{x} = 17.4°, SD = 8.1) and dense understories. At the midscale, goshawks were consistently associated with patches of continuous forest and level terrain within 645 m of nest sites. Red-tailed hawks were associated with nonforested areas located within 105–645 m of nest sites and steep slopes within 105 m of nest sites. Forest fragmentation was greater around red-tailed hawk nest sites, and forested regions were more aggregated around goshawk nest sites when compared with the other species. These patterns indicate that on the Kaibab Plateau, red-tailed hawks will gain habitat at the mid-scale and goshawks will lose habitat at both scales if forests are fragmented and mature forest structure is lost.

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Key words: *Accipiter gentilis*, Arizona, *Buteo jamaicensis*, forest fragmentation, GIS, habitat association, Landsat, landscape pattern, northern goshawk, patch analysis, red-tailed hawk, remote sensing.

Northern goshawks (hereafter referred to as goshawk) in North America breed in a variety of forest types with nest sites typically found in association with mature to old-growth forest structure; foraging and winter habitat are poorly studied but appear to be more diverse and not as strongly dependent on mature forest structure (Squires and Reynolds 1997). The U.S. Forest Service designated goshawks as a "sensitive species" throughout the species' western range based on concerns related to the impact of forest management practices on goshawk breeding habitat. The status of goshawk populations in the western United States remains the subject of concern and debate (Kennedy 1997, DeStefano 1998, Smallwood 1998). In North America, red-tailed hawks are abundant, ubiquitous, and typically associated with nonforested areas in various environments including coniferous and deciduous forests (Preston and Beane 1993). Several investigators have suggested that red-tailed hawks may be replacing goshawks as

forests are cleared and fragmented (Crocker-Bedford 1990, Kenward 1996, Erdman et al. 1998). The relationship and habitat associations for sympatric *Accipiter* species (Reynolds et al. 1982, Reynolds and Meslow 1984, Bosakowski et al. 1992), sympatric *Buteo* species (Schmutz et al. 1980, Janes 1994, Bosakowski et al. 1996), and sympatric *Buteo* and *Accipiter* species (Titus and Mosher 1981, Selås 1997, Sánchez-Zapata and Calvo 1999) have been the subject of numerous investigations; yet the relationship and habitat associations of sympatric red-tailed hawks and goshawks has not been studied.

Our objective was to provide descriptive information on the habitat associations of sympatric red-tailed hawks and goshawks during the breeding season. We focused our investigation on forest structure at nest sites and forest fragmentation and the presence of nonforested areas around nest sites to clarify how these species will be impacted by forest alterations in the western United States.

STUDY AREA

Red-tailed hawks and goshawks occur sympatrically on the Kaibab Plateau in northern Arizona, USA. Vegetation within our study area on the plateau consisted of ponderosa pine (*Pinus pon-*

¹ Present address: Department of Biology, New Mexico State University, P.O. Box 30001 MSC 3AF, Las Cruces, NM 88003-8001, USA.

² E-mail: flasorte@nmsu.edu

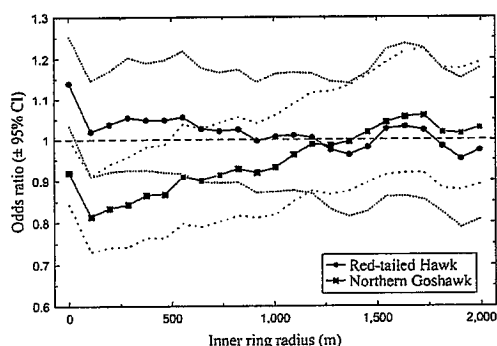


Fig. 4. Estimated change in odds and 95% confidence intervals associated with a 1° increase in slope within 23 concentric ring plots (midscale) at 90-m intervals centered on red-tailed hawk ($n = 41$) and goshawk ($n = 62$) nests and random sites ($n = 62$) on the Kaibab Plateau, Arizona, USA, in 2000.

age goshawk nest site contained a forested area centered at the nest site with small nonforested areas dispersed around the perimeter of the plot (Fig. B).

DISCUSSION

The associations at the fine scale can be interpreted based on behaviors unique to the species. Typically, red-tailed hawks enter nests from above the canopy and goshawks enter nests from below the canopy. Researchers have argued that open and unobstructed access to nests from above the canopy is an important factor in red-tailed hawk nest-site habitat selection (Orians and Kuhlman, Titus and Mosher, Bednarz and Dinsmore). Therefore, forest structure below red-tailed hawk nests is secondary, and features related to the nest tree and topography are primary. Nests located high in tall trees on steep, north-facing slopes would presumably allow easy access to nests, a favorable microclimate within the nest with reduced solar radiation, and a clear view of the surrounding area. In contrast, goshawk nest sites were associated with characteristics of mature forest structure. This result is consistent with numerous investigations documenting high canopy closure, mature trees, and open understories at goshawk nest sites (Reynolds et al., Speiser and Bosakowski, Hayward and Escano, Squires and Ruggiero). These features presumably would allow easier access to nests, unhindered movement through the surrounding forest, a clear view of the forest floor, and a suitable microclimate within the nest.

At the midscale, red-tailed hawks displayed more variation overall and were associated with nonforested areas between 100 and 200 m of the nest site and steeper slopes within 100 m of the nest site. At the midscale, patterns documented within 100 m of the nest site mirrored patterns documented at the fine scale, thus supporting the conclusion that steep slopes are an important factor and forest structure is secondary at, and immediately surrounding, the nest site. Studies examining red-tailed hawk habitat associations have documented both a strong association (Mindell and Samuel, Speiser and Bosakowski, Moorman and Chapman) and no apparent association with nonforested areas (Titus and Mosher). These discrepancies likely result from differences in forest structure and landscape pattern among study areas. Our results support the conclusion that red-tailed hawks nesting in forested environments are capable of tolerating a broad array of forest structures and that fragmented forest structure and nonforested areas appear to play a central role in these associations.

Goshawks were consistently associated at the midscale with regions of continuous forest centered at the nest site. The negative association with nonforested areas extended to 100 m and was strongest within 100 m of the nest site. This forested area corresponds to the post-fledging family area (PFA; Reynolds et al.) estimated at 0.5 ha or a circle with a radius of 125 m (Kennedy et al.). The PFA, characterized by mature forest structure, is the area where adults forage during the breeding season and young develop their hunting skills. In addition, our results indicate an association with gentle slopes that extend to 100 m from goshawk nest sites. This pattern is consistent across the fine scale and midscale but is not consistent with findings of other investigations (Squires and Reynolds).

The predominance of gentle terrain on the Kaibab Plateau and the presence of mature forest structure with open understories in regions with gentle slopes might explain this pattern. In summary, the patterns of goshawk and red-tailed hawk habitat associations were distinctly different at both the fine and midscale. Goshawks were considerably more specialized at both scales and presented consistent patterns of continuous forest structure on level terrain at both scales. Red-tailed hawks presented greater variation at both scales, with differing central tendencies from goshawks. The pattern at the fine scale suggested that habitat selection for red-tailed hawks

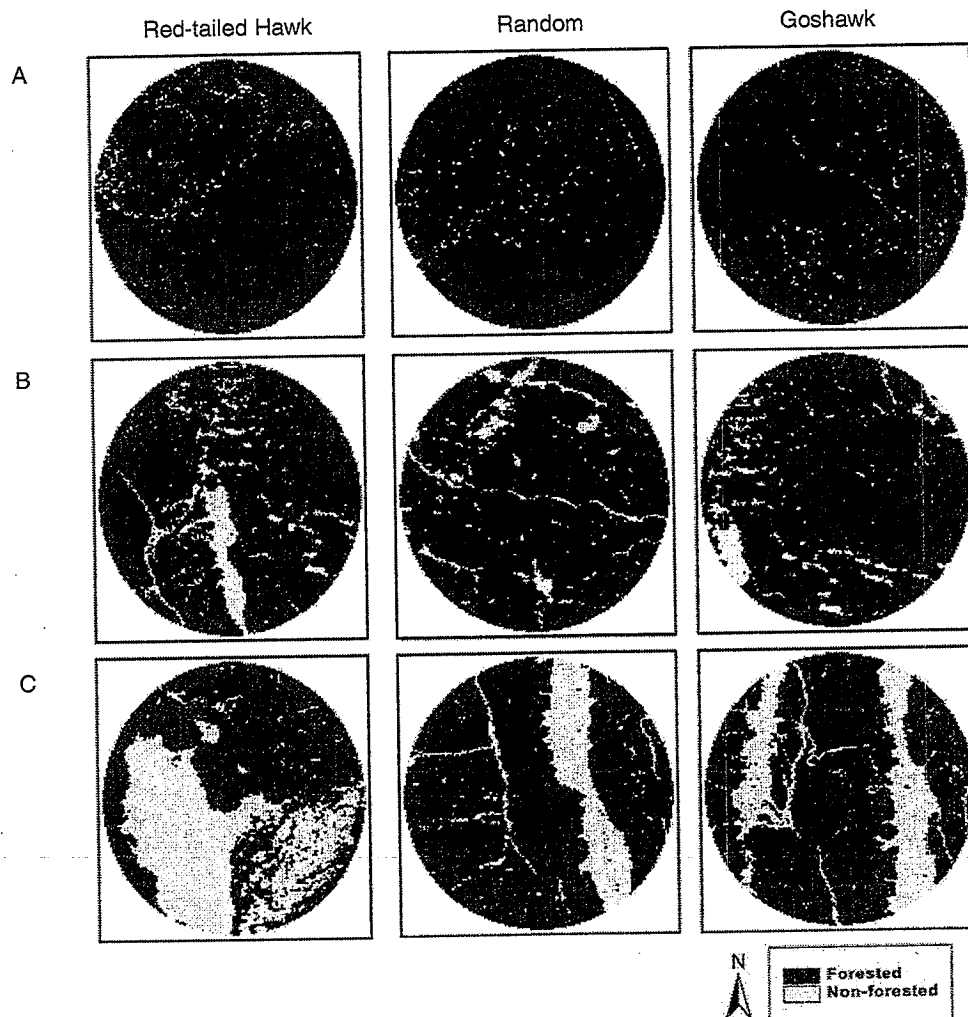


Fig. 5. Classified Landsat images (10 Oct 1999; 30 × 30-m cells) of sites that represented the (A) minimum, (B) that most closely approximated the mean, and (C) represented the maximum for 6 landscape indices measured in 2,085-m radius circles (mid-scale) centered on red-tailed hawk ($n = 41$) and goshawk ($n = 62$) nests and random sites ($n = 62$) on the Kaibab Plateau, Arizona, USA, in 2000.

was not based on consistent patterns of forest structure, as was found at goshawk nest sites, but with features related to nest position and access. Thus, selection was occurring primarily for the nest tree and its relationship to the surrounding topography for red-tailed hawks and for features within and below the canopy for goshawks. Patterns at the midscale suggested that habitat selection for red-tailed hawks was based on the presence of nonforested areas and fragmented forest structure around the nest site and steep slopes at the nest site. For goshawks, patterns at the mid-

scale suggested that selection was occurring exclusively for regions of continuous forest on level terrain centered at the nest site.

MANAGEMENT IMPLICATIONS

Our study reaffirms that the habitat associations of goshawks during the breeding season are regionally consistent within a particular environment. This allows resource managers to identify areas containing goshawk breeding habitat and develop management guidelines to protect them (e.g., Reynolds et al.). However, successfully

managing for a species' unique habitat requirements is becoming more difficult in the western United States due to a variety of economic, political, ecological, and social pressures placed on forests and forest managers. An ecological factor that we examined is the presence of a very successful generalist, the red-tailed hawk, which introduces a variety of concerns for goshawk management. One is the possibility of competition for habitat or prey between the species. Another is the encroachment of red-tailed hawks into goshawk territories. If goshawk habitat is altered beyond the range of association documented in our study, it could transition into red-tailed hawk habitat. Both factors could reduce the number of goshawk breeding territories within a region and potentially negatively impact the goshawk population. Our study did not attempt to examine the consequences of competition or habitat alteration; nevertheless, when sympatric, these species coexist in a relationship defined in large part by available habitat. Red-tailed hawks, or any other bird-of-prey, are not likely to represent a serious competitive threat to goshawk populations because of the goshawk's unique habitat associations and highly aggressive behavior. The real issue is one of habitat; if the habitat requirements of a species are not available, that species will have difficulty fulfilling its ecological role. In this case, the threats to goshawk breeding habitat are more severe because of the goshawk's specialization on features that have economic value and features that are threatened by catastrophic wildfires. Thus, to increase the likelihood that goshawk populations persist in the western United States, an important management goal should be to retain goshawk breeding habitat within the goshawk's range of association. This study and many others have attempted to document these associations for particular regions and environments. In addition, an understanding of the forces that are acting to alter forests in the western United States and the potential long-term outcomes of these processes to forest ecosystems need to be incorporated into management strategies.

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USING FIRE HISTORY MODELS TO ESTIMATE PROPORTIONS OF OLD GROWTH FOREST IN NORTHWEST MONTANA, USA

Peter Lesica

Conservation Biology Research, 929 Locust, Missoula, Montana 59802, USA and Division of Biological Sciences, University of Montana, Missoula, Montana 59812, USA

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Abstract

Mature and post-mature stands may be under-represented in many modern forest landscapes as a result of preferential harvest of these age classes. It is important for land managers concerned with protecting biological diversity to know the approximate proportion of old growth in forest landscapes prior to European interference. Negative exponential models, based on mean stand-replacing fire intervals taken from fire history studies, were used to estimate presettlement stand-age distributions for three areas in northwest Montana. Results were compared with empirical distributions calculated from stand maps prepared in 1937–38, prior to significant timber harvest and effective fire suppression. The models predicted the observed proportion of 1937–38 old growth (≥ 200 years) within 10% but were poor at predicting proportions in 20-year age classes. These results suggest that negative exponential models based on empirically determined estimates of fire interval can be used to obtain approximate estimates of presettlement old growth if local fire history studies have been done. Results of this study and numerous fire-history studies suggest that old growth occupied 20–50% of many presettlement forest ecosystems in the Northern Rockies. Copyright © 1996 Elsevier Science Ltd

Keywords: Montana, old growth, fire history models, forest conservation.

INTRODUCTION

One goal of modern forestry is to use ecological principles to manage forest lands for both commodity production and the conservation of species diversity (Norse *et al.*, 1986; Hansen *et al.*, 1991). In order to attain this goal it is necessary to have forests with all successional stages in quantities and spatial arrays like those to which resident organisms are adapted (Harris, 1984; Bunnell, 1995). During the past decade attention in western North America has been focused on mature

and especially post-mature (i.e. old growth) forests (Morrison, 1988; Norse, 1990). Conservation advocates believe that the extent of old growth forests has been reduced by harvest activities to the point where many species are jeopardized. However, land management agencies and private timber interests often argue that the present inventory of old growth is similar to presettlement levels, and conservation is unnecessary (USDA Forest Service, 1992).

Unfortunately, knowledge of forest age structure prior to European disturbance is often difficult to obtain. In some cases this information can be obtained from historical documentation. However, quantifiable historical information is not available for many areas of western North America. In these cases a method for estimating the proportion of old forests on the presettlement landscape would be useful to those managing land for biological diversity.

Historically, fire has been an integral part of forest ecosystems in the Northern Rocky Mountains and was certainly the most important disturbance structuring these systems prior to European settlement (Wellner, 1970; Arno, 1980; Habeck & Mutch, 1983). Fire regime was the principal factor determining the mosaic of different stand ages across the landscape. At low elevations, drier habitats experienced frequent non-lethal fires, while moist sites were more likely to have had infrequent stand-replacing fires. At higher elevations, cool slopes experienced infrequent lethal fires, while warmer slopes experienced a mixture of more frequent stand-replacing and non-lethal fires (Barrett & Arno, 1991). Forest habitats with infrequent stand-replacing fires would have supported greater proportions of mature and old-growth forests.

There have been several attempts to model the relationship between fire interval and age-class distribution mathematically. Van Wagner (1978) proposed the negative exponential distribution as an approximation to this relationship. The Weibull model takes changing flammability with stand age into account and has been considered by some to be more ecologically realistic (Johnson, 1979; Yarie, 1981). These models have been shown to fit fire frequency data collected in coniferous

Correspondence to: P. Lesica, Tel.: 406-728-8740; Fax: 406-243-4184.

forests from a variety of landscapes throughout boreal and cordilleran western North America. Although Johnson (1979) found that the Weibull model better described fire behavior in northwest Canada, he also showed that the Weibull model was nearly equivalent to the negative exponential model when terrain was broken, suggesting that the negative exponential model is appropriate for the Northern Rocky Mountains.

Rowe *et al.* (1975) found that the Weibull model fit their data from northwest Canada better than the negative exponential model. However, McCune (1983) and Johnson and Larsen (1991), working in the more mountainous terrain of western Montana and west-central Alberta respectively, determined that the negative exponential model fit their data well, and Yarie (1981) found that the two models fit most of his data from Alaska equally well. The majority of studies from similar landscapes suggest the negative exponential model provides a good approximation for fire behavior in mesic forests of the Northern Rocky Mountains. Maximum likelihood estimates for negative exponential and Weibull distributions for my data were very similar.

Even though they make many simplifying assumptions, Van Wagner (1978) proposed that negative exponential models can be used to estimate presettlement stand-age distribution as well as the expected proportion of forest in particular age classes given mean stand-replacing fire interval and that certain assumptions are met. Thus, a simple equation relates the proportion of old forests to the mean stand-replacing fire interval. However, Baker (1989) argued that estimates of mean fire frequency cannot be used to this end because fire intervals are too variable.

The purpose of this study is to use empirical estimates of stand-replacing fire intervals to test predictions of proportions of old growth (defined solely on the basis of age) derived from simple fire history models. This comparison can be made in northwest Montana because both historical data and estimates of pre-interference fire frequency are available. The US Forest Service conducted timber inventories of forested lands in western Montana from 1937 to 1943. These inventories can be used to determine the distribution of stand ages at a time before significant timber harvest and effective fire suppression. Fire history studies have been conducted in western Montana, and estimates of mean stand-replacing fire intervals are available for some areas (Arno, 1980).

MATERIALS AND METHODS

Study areas

Each study area consisted of six townships (56,000 ha) and was adjacent to or included the site of a previous study that provided an estimate of mean stand-replacing fire interval (Fig. 1). Forests with similar site potential, successional patterns and fire disturbance regimes are called 'fire groups' (Fischer & Clayton, 1983;

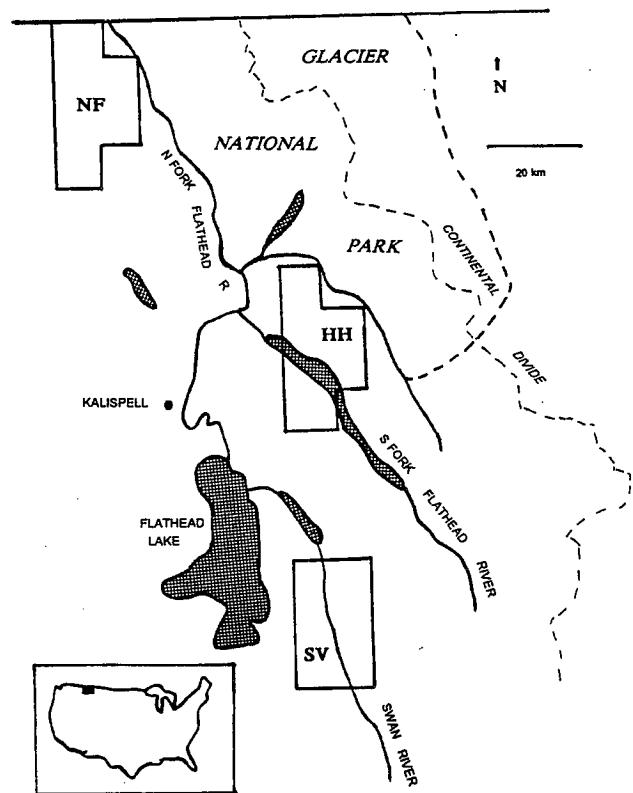


Fig. 1. Location of study sites in northwest Montana: (HH) Hungry Horse, (NF) North Fork, (SV) Swan Valley.

Fischer & Bradley, 1987) and were assigned according to Fischer and Bradley (1987). Only stands classified to the dominant fire group for that study area were included in the analyses.

Hungry Horse

The moist lower subalpine fire group is dominant with *Abies lasiocarpa* as the climax species in most stands, and *Larix occidentalis*, *Pinus contorta* and *Pseudotsuga menziesii* as the most common seral species. The analysis area was 18,515 ha, and 1065–1890 m elevation. Mean stand-replacing fire interval before 1910 at the north end of the study area was 121 years below 1650 m (Davis, 1980).

North Fork

Dominant fire group and species composition are similar to those at Hungry Horse. Analysis area was 28,090 ha and 1220–1890 m in elevation. Barrett *et al.* (1991) conducted a fire history study along the North Fork of the Flathead River in Glacier National Park 1 km east of this area and estimated mean stand-replacing fire interval to be 186 years prior to 1935.

Swan Valley

The moist grand fir/western redcedar fire group dominates the valley floor at 975–1400 m with *Abies grandis* and *Thuja plicata* as the climax species, and *Larix occidentalis*,

Pinus monticola and *Pseudotsuga menziesii* the most common seral species. The analysis area was 19,750 ha. A study of this fire group in the Middle Fork of the Flathead River drainage in Glacier National Park 90 km to the north estimated the mean stand-replacing fire interval prior to 1935 to be 261 years for this fire group (Barrett *et al.*, 1991).

Fire history models

In the negative exponential model the proportion of stands reaching a particular age is the random variable, and the reciprocal of mean fire interval (probability of fire in a stand) is the only parameter. A lucid discussion of the model's derivation is presented by Van Wagner (1978). The cumulative proportion of all stands less than or equal to age t is given by

$$F(t) = 1 - \exp(-pt) = 1 - \exp(-t/b) \quad (1)$$

where p is the annual probability of fire in any one stand and $b = 1/p$ is the mean fire interval (Van Wagner, 1978). For example, the % of stands 101–120 years old is

$$\text{Stands}_{101-120} = [\exp(-101/b) - \exp(-120/b)] \times 100 \quad (2)$$

This model assumes that stand flammability is constant with age. If fire hazard increases with stand age, then the model will overestimate the proportion of very old stands (Van Wagner, 1978).

In order to use mean fire interval models to estimate average presettlement stand-age distribution, the following assumptions must be met:

- (1) Mean fire interval is determined on a point or stand basis (Hawkes, 1980; Arno & Petersen, 1983).
- (2) Estimates of mean fire interval apply only to areas with similar fire regimes, topography and histories of human-caused fires (Hawkes, 1980; Johnson & Van Wagner, 1985).
- (3) Mean fire interval must be determined from the time predating effective fire suppression.
- (4) The size of the study area must be large compared to the extent of the largest fire (Johnson & Van Wagner, 1985; Baker, 1989). Johnson and Gutsell (1994) propose the general rule that study areas in which $\geq 33\%$ of the area has been burned by a single fire are too small. Fire history models provide an estimate of proportion of stands in each age class. In order to compare the predictions of the models with the observed areal data and to estimate the proportion of forested landscape in old-growth condition, it is necessary to assume that the proportions of stands and area are equivalent (W. Baker, pers. comm.), i.e. the size distributions within the different age classes must be similar. This assumption becomes more reasonable as the number of stands in each class becomes larger. Thus, larger study areas and/or broader age classes will yield more robust results.

With one exception, my study met the assumptions of the fire history models. Fire interval was determined

by examining fire scars and cohort regeneration on a stand basis and preparing master fire chronologies (Davis, 1980; Barrett *et al.*, 1991). Only stands with similar fire regimes (i.e. in the same fire group) were used in the analysis. Estimates of mean stand-replacing fire interval were made before fire suppression became effective (Arno & Sneck, 1977; Pyne, 1982). Fires, or perhaps a single fire, occurring in the 1920s initiated 31% of the stands in the Hungry Horse study area (Fig. 2), suggesting that the study area may have been too small (Johnson & Gutsell, 1994). Otherwise no single 20-year interval accounted for initiation of more than 16% of the stands in any study area (Fig. 2). Every township in the study had stands of numerous different ages. Thus, it is reasonable to assume that the size of the study areas was sufficiently large.

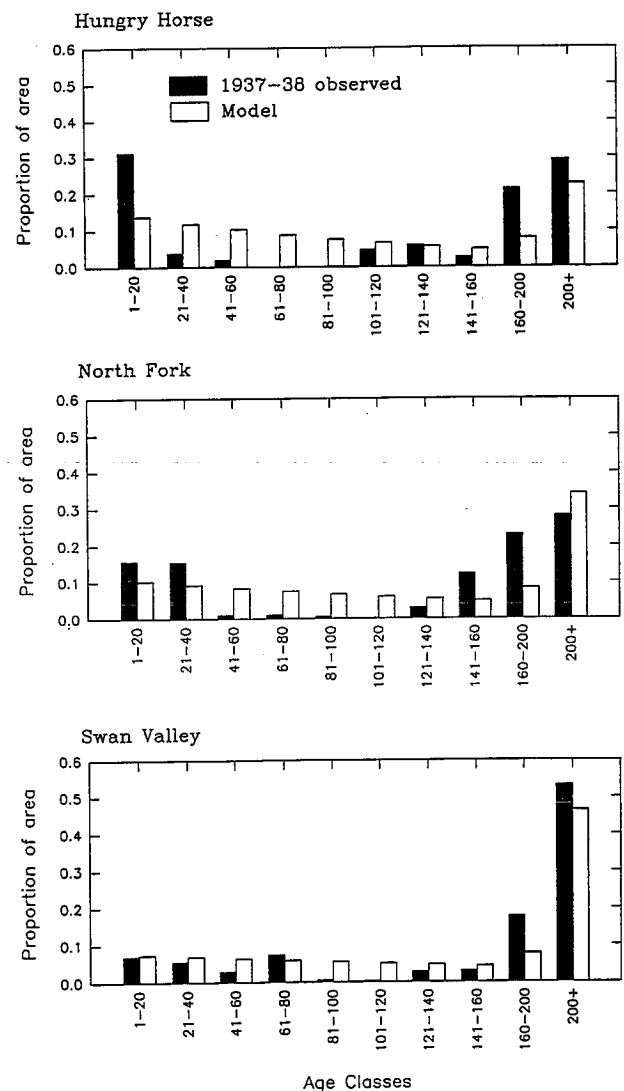


Fig. 2. Age class distribution of forest stands for three study areas in northwest Montana determined from (1) 1937–38 stand exam maps (filled bars) and (2) mean fire frequency models (open bars). Distributions appear bimodal or skewed to the left rather than skewed to the right because the two oldest age classes encompass more than 20 years.

Historical data

I compared results derived from negative exponential models with empirical data from stand maps prepared in 1937–38. Age of the cohort having the greatest basal area was determined from increment cores taken by surveyors. Stand boundaries were delineated on the ground, with the aid of aerial photography (Hart & Lesica, 1994). Stands were placed in 20-year age classes up to 160 years and then 160–200 years and 200+ years. Forests above 2130 m were generally considered non-commercial and were not examined. Stands were delineated on 1:31,700 maps (USFS, 1937–43).

Hart and Lesica (1994) assessed the degree of congruency between these early age estimates and those from stand exams made during the last decade. They found that 52% of the early estimates were within 20 years of the modern estimates, and less than 27% showed discrepancies of greater than 60 years. There was no bias toward either older or younger estimates, and the distribution of discrepancies was symmetric about zero. Thus, when a large number of stands are considered, the distribution of age classes should be reasonably accurate. Discrepancies may be the result of errors in either the early or modern exams or differences in how stand age was determined for the two data sets. Although far from perfect, these early maps provide the best one-point-in-time estimates of stand age distribution previous to timber harvest and fire suppression available for western Montana.

For each study area the dominant fire group was used to obtain the estimate of mean stand-replacing fire interval. All stands in that fire group were located using 1:24,000 stand maps based on surveys conducted by the US Forest Service, Montana Department of State Lands and Plum Creek. Thus, the fire regime of the lands I mapped was similar to that on which the fire frequency estimate was based. Areas were calculated for each age class using 1:2.4 ha dot grids.

RESULTS

Stand-age distributions, using 20-year classes derived from mean fire interval models, were significantly different than from distributions derived from 1937–38 data (Fig. 2; Kolmogorov-Smirnov test, $p < 0.01$). The models underestimated proportions in the two oldest age classes in five of six cases (Fig. 2).

Although the mean fire interval models predicted individual 20-year age classes poorly for the 1937–38 data, predictions for the 200+ class were relatively accurate (Fig. 2); model predictions of old growth proportions were all within 6–10% of observed proportions.

DISCUSSION

Model performance

There are a number of possible reasons for the models' failure to predict observed distributions. The poor fit is

most likely due to the large variance in the size and frequency of fires compared to the size of the age classes. Fire hazard in the Northern Rocky Mountains is not constant over short periods but can vary on the scale of decades due to prolonged periods of drought or cool, wet weather. As a result, some 20-year age classes are large due to extreme fire years, while others are small as a result of long fire-free periods. A model based on a single mean fire interval derived from 300–500 years of fires will not be robust at predicting point-in-time distributions when small age classes are used (Baker, 1989). Estimates of mean stand-replacing fire intervals were taken from study areas close to my study areas, but the lack of exact geographical correspondence could introduce errors into estimates obtained from the fire history models. Estimates of mean fire interval obtained without random sampling of fire-scarred trees may be biased (Johnson & Gutsell, 1994); however, there is no reason to suspect any systematic bias in the data collection (S. Barrett, pers. comm.). In some areas fire cycles have changed in the 200–400 years preceding fire suppression (reviewed in Johnson, 1992). If the change in fire frequency was large, models based on mean fire interval for the whole period could not accurately predict age-class distribution for a single point in time.

The 200+ class encompasses c. 200 years, an order of magnitude larger than the other classes. This is undoubtedly the reason for the increased accuracy of area predictions for this class. Using large age-classes reduces the effect of the variance associated with fire size and frequency. Larger study areas would likely have increased the accuracy of the estimates, especially in the Hungry Horse area.

One explanation for the consistent underestimates in old classes is that the negative exponential model assumes a constant hazard of fire, but old stands are less prone to stand-replacing fire than young and moderate-age stands (Van Wagner, 1977). The underestimates may also result from some stand-replacing fires failing to kill all of the trees in the stand, especially fire-resistant species such as western larch (Barrett *et al.*, 1991). If enough larch survived, 1937–38 timber surveyors may occasionally have recorded the survivors as the dominant cohort.

Implications for conservation

Negative exponential fire history models can be useful for estimating approximate proportions of old growth in presettlement forest landscapes where fire is the dominant force controlling stand replacement. In the Northern Rocky Mountains, mean stand-replacing fire frequency is variable even within the same fire group (Table 1; Arno, 1980). Thus, it is important to use localized fire history data to estimate the mean stand-replacing fire interval. Such studies can provide managers with information useful for setting guidelines for the conservation of old growth in many forest landscapes.

Table 1. Mean stand-replacing fire intervals and estimated % of presettlement old growth (>200 years old) forest (OG) in different fire groups (Fischer & Bradley, 1987) in the Northern Rocky Mountains of northern Idaho (ID) and western Montana (MT) % old growth was derived using negative exponential models computed from mean fire interval (eqn 2).

Fire group	Location	Elevation (m)	Source	Mean fire interval	OG %
Warm dry Douglas fir	ID	550–1615	Barrett & Arno (1991)	>200	>37
Moist Douglas fir	MT	1100–1575	Barrett <i>et al.</i> (1991)	186	34
Dry lower subalpine	MT	1800–1910	Davis (1980)	>146	>25
Cool lodgepole pine	ID	1615–2285	Barrett & Arno (1991)	117	18
Moist lower subalpine	MT	1000–1140	Davis (1980)	>117	>18
Moist lower subalpine	MT	1200–1650	Davis (1980)	121	19
Moist lower subalpine	MT	1575–1800	Davis (1980)	146	25
Moist lower subalpine	ID	1430–130	Arno & Davis (1980)	>150	>26
Moist lower subalpine	ID	1525–1980	Barrett & Arno (1991)	174	32
Moist lower subalpine	MT	1200–1575	Barrett <i>et al.</i> (1991)	186	34
Moist lower subalpine	MT	1220–1830	Barrett <i>et al.</i> (1991)	202	37
Moist lower subalpine	MT	1260–1400	McCune (1983)	63	4
Grand fir/cedar-hemlock	ID	760–1525	Arno & Davis (1980)	100	14
Grand fir/cedar-hemlock	ID	1280–1830	Barrett & Arno (1991)	119	19
Grand fir/cedar-hemlock	ID	550–1280	Barrett & Arno (1991)	197	36
Grand fir/cedar-hemlock	ID	760–1065	Arno & Davis (1980)	>200	>37
Grand fir/cedar-hemlock	MT	975–1525	Barrett <i>et al.</i> (1991)	261	46

There is evidence that native vertebrate faunas are adapted to particular fire regimes and stand age distributions (Bunnell, 1995). Furthermore, many species of plants and animals require or find optimum habitat in old-growth forests of the Northern Rocky Mountains (McClelland, 1979; Hejl & Wood, 1991; Lesica *et al.*, 1991). Although old growth is often defined by structural as well as age characteristics (Old Growth Definition Task Force, 1986), stand age is strongly correlated with structural characters as well as the occurrence of many animal species (Franklin *et al.*, 1981; Norse, 1990). Theory and empirical studies predict that many species will have difficulty maintaining genetically and demographically viable populations in a greatly reduced habitat base (Harris, 1984; Gilpin & Soulé, 1986; Wilcove, 1987; Gilpin, 1988; Doak, 1989).

Results of this study and model estimates based on fire history studies throughout the Northern Rocky Mountains (Table 1) suggest that old growth occupied 20–50% of the presettlement forest landscape in low- and many mid-elevation habitats. Yet most national forests in the Northern Rocky Mountains plan to maintain at most 10% of their total forest inventory in old growth (Yanishevsky, 1987). Low-elevation landscapes have suffered the greatest losses because much of this land is owned by private companies who have harvested all or nearly all of their ancient forests. A reduction from 20–50% to less 10% in old growth in low- to mid-elevation forests may well cause extirpation of many old-growth dependent species.

Fire suppression and management for timber production have greatly altered the age-class distribution of stands on forested landscapes (Arno, 1976; Habeck, 1983; Harris, 1984; McCune, 1983). By reducing the occurrence of low intensity burns, fire suppression has

increased the chance of stand-replacing fires in many remaining old-growth stands. Furthermore, low-elevation habitats undoubtedly support a much smaller proportion of old growth than before European settlement. All seral stages provide critical habitat to some plants and animals (Hansen *et al.*, 1991). Perhaps the best prescription for maintaining biological diversity and sustainable ecosystems is to imitate as closely as possible the natural stand age distribution (Bunnell, 1995). Although the method presented here cannot be used to estimate accurately presettlement stand age distribution, it can help guide managers in protecting adequate amounts of old growth.

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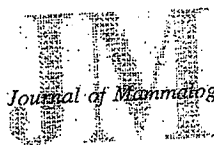
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Influence of stand and landscape features on snowshoe hare abundance in fragmented forests

C. W. LEWIS,* K. E. HODGES, G. M. KOEHLER, AND L. S. MILLS

Wildlife Biology Program, Department of Ecosystem and Conservation Sciences, University of Montana, Missoula, MT 59812, USA (CWL, KEH, LSM)

Centre for Species at Risk and Habitat Studies, University of British Columbia Okanagan, 3333 University Way, Kelowna, British Columbia V1V 1V7, Canada (KEH)

Washington Department of Fish and Wildlife, 2218 Stephanie Brooke, Wenatchee, WA 98801, USA (GMK)

* Correspondent: cwlewis@fs.fed.us

Habitat fragmentation often separates and reduces populations of vertebrates, but the relative effects of habitat attributes within remnant patches versus the matrix surrounding the patches are less clear. For snowshoe hares (*Lepus americanus*) lower densities and disrupted cycles in their southern range have been ascribed to habitat fragmentation, although relevant scales of landscape influence remain unknown. In a fragmented forest in north-central Washington we counted fecal pellets of snowshoe hares to examine the extent to which relative snowshoe hare densities within stands of suitable habitat changed with the composition of surrounding habitats. Pellet densities were associated primarily with density of large shrubs and saplings and medium trees within a stand. Pellet densities also were correlated positively with the amount of moist forest (dominated by Engelmann spruce [*Picea engelmannii*] and subalpine fir [*Abies lasiocarpa*]) and correlated negatively with the amount of open-structured habitat within 300 m of the stand perimeter. These results suggest that forest managers will have positive impacts on hare densities by managing both focal stands and the surrounding stands for the higher densities of large shrubs and saplings and medium trees that hares select.

Key words: fecal pellets, forest fragmentation, landscape, *Lepus americanus*, relative abundance, snowshoe hare, Washington

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740% = harel

Habitat loss and fragmentation are dominant threats to biodiversity (Ewers and Didham 2006; Fahrig 2003). In forested ecosystems fire and management activities create mosaic landscapes of different stand ages and stem densities. Often these activities are additive to natural fragmentation arising from topography and other factors that influence forest habitat types. Although research has addressed the effects of patch size and isolation on the persistence of wildlife species, these metrics alone do not describe adequately or predict population persistence or extinction (Doak and Mills 1994; Prugh et al. 2008). The habitats in the matrix surrounding the remnant patches can be hostile, neutral, or beneficial to a population, and the attributes and spatial patterning of habitats within the matrix can affect population dynamics within habitat patches (Lindenmayer et al. 2008).

The composition of the matrix and movements of animals among habitat patches are presumed to drive population dynamics of snowshoe hares (*Lepus americanus*) in fragmented forests in southern parts of their range (Dolbeer and Clark

1975; Sievert and Keith 1985; Wolff 1980). Snowshoe hare densities, survival, and population growth are highest in densely forested stands where understory structure provides forage and protection from predators (Griffin and Mills 2009; Orr and Dodds 1982; Parker et al. 1983; Thompson et al. 1989; Wolff 1980). In the southern parts of snowshoe hare range patches of dense forest often are fragmented by natural and anthropogenic causes, resulting in a heterogeneous mix of habitat types that range from poor to high quality for hares. Hare densities vary widely in patches of dense forest with similar stand-scale attributes in fragmented forests in Montana and Wyoming (Griffin and Mills 2007; Hodges et al. 2009; Mills et al. 2005), suggesting that matrix habitats influence hare densities.



Understanding the processes that drive snowshoe hare dynamics is important for management of forests at southern latitudes, because hares are an important food source for many forest carnivores, including the federally threatened Canada lynx (*Lynx canadensis*). In the United States forest management strategies include guidelines for considering habitat for hares in areas where lynx occur (Ruediger et al. 2000). The effectiveness of these strategies could depend on the importance of matrix habitats for hare dynamics in fragmented forests at southern latitudes.

Most studies on densities of snowshoe hares have focused on relationships with stand attributes (Griffin and Mills 2007; Hodges 2000a, 2000b; Homyack et al. 2007). Open-structured stands, such as recent clear-cuts, natural meadows, and recently burned forests, support low densities of snowshoe hares (Ferron et al. 1998; Hik 1995; O'Donoghue 1983; Sievert and Keith 1985). Moderately dense stands can support moderate hare densities (Koehler 1990; Thompson et al. 1989). However, little is known about how densities of hares vary with the spatial structure of landscapes, where preferred habitat can be either abundant or scarce and set among a matrix of either poor- or intermediate-quality habitat types (but see Griffin and Mills 2009; St-Laurent et al. 2007, 2008).

The primary objective of this study was to determine whether snowshoe hare abundance within patches of good-quality habitat is influenced by single- and multiscale habitat factors. Because no previous work has identified landscape scales particularly relevant to snowshoe hares, we examined 3 landscape scales and stand-level attributes tied to different aspects of hare biology. Based on previous research on habitat relationships for hares (Hodges 2000a, 2000b), we expected a strong influence of stand-level understory structure on hare densities, but no existing literature suggests the magnitude or scale of any landscape-level impacts.

MATERIALS AND METHODS

Study area and vegetation classification.—The field research was conducted during May–August of 2003 and 2004 in a 211-km² study area on the Okanogan National Forest in north-central Washington (48°N, 120°W) concurrent with research on lynx habitat in the same area (Koehler et al. 2008; Maletzke et al. 2008). Elevations ranged from 643 m to 2,134 m, and average snow depth was 315 cm at 655 m (Western Regional Climate Center; www.wrcc.dri.edu).

The study area contained a mosaic of habitats due to the varied topography and microclimates, natural and prescribed fires, and forest management activities such as roads, timber harvests, and timber thinning. The median stand size was 10 ha, and the mean was 21 ha ($SE = 1.5$ ha); large patches of homogenous vegetation were rare, which reflects conditions typical of most lynx habitat in the state of Washington and throughout the mountainous western United States (Ruggiero et al. 2000).

We used geographic information system coverages developed by Maletzke (2004) to select sample sites and for spatial

analyses. Stand data included vegetation type, canopy cover, and understory cover. Stands were classified into 4 categories based on their dominant vegetation: moist forest, dry forest, recent burns, and natural openings. Moist forest stands were dominated by subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), with subdominant Douglas fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), whitebark pine (*Pinus albicaulis*), or a combination of these. Shrub species that contributed substantially to understory cover included alder (*Alnus* spp.) and willow (*Salix* spp.). Moist forest stands covered 55% of the study area, mostly on north-facing slopes and steeper drainage bottoms. Dry forest stands were characterized by ponderosa pine (*Pinus ponderosa*) and Douglas fir, covered 37% of the area, and dominated lower elevations (<1,066 m), south-facing slopes at higher elevations, and broad drainage bottoms. Recent burns covered 6% of the study area, resulted from wildfires within the previous 10 years, and had sparse sapling regeneration (<10% understory cover from 0.5 to 2.0 m above ground). Natural openings, which included meadows and rocky slopes, covered 2% of the study area.

Site selection.—From the geographic information system layers we identified all stands ($n = 356$) within the study area in which canopy cover was >40% or understory cover was >40%; that is, conditions that likely provided snowshoe hare habitat (Hodges 2000a, 2000b). From these 356 stands we randomly sampled 76 stands. Because we wanted to sample both stands that were surrounded by poorer-quality patch types and stands that had matrix habitats of similar quality to the focal stand, we selected 20 ha as our maximum stand size, even if the actual forest stand was larger. We chose 20 ha for this upper limit on our stand sampling because at least some hares could have their entire home range within the stand (hare home ranges typically do not exceed 10 ha—de Bellefeuille et al. 2001; Griffin 2003; Hodges 1999). For stands 3.4–20 ha we sampled the entire stand ($n = 36$). For forest stands > 20 ha ($n = 40$, ranging from 21 to 190 ha) we delineated an arbitrary 20-ha stand boundary at the stand center within which we counted hare fecal pellets and recorded stand features. We used this boundary to calculate landscape metrics.

Snowshoe hare relative abundance.—Within each stand we counted fecal pellets in 50 randomly placed plots (3.05 m × 5.08 cm—Krebs et al. 2001), because this sample size has reasonable power for evaluating differences in relative abundances of snowshoe hares (Hodges and Mills 2008). The plots were not cleared previously and therefore integrate across an unknown time period, but uncleared plots are highly correlated with estimates from annually cleared plots (Hodges and Mills 2008). Although the density of snowshoe hares in any given forest stand is estimated best with mark-recapture approaches, Mills et al. (2005) and Murray et al. (2002) compared estimated hare densities to pellet counts in Montana and Idaho, respectively, and concluded that counts of pellets on uncleared plots are adequate for ranking relative hare abundance in many stands across large spatial scales. For

TABLE 1.—Spearman rank correlations (r_s) between densities of snowshoe hare (*Lepus americanus*) pellets and vegetation variables measured in 76 forest stands in northern Washington during 2003–2004. Variables measured for each focal stand included length of the stand perimeter (m), stand area (ha), edge-to-area ratio (m:ha), slope (%), aspect ($^\circ$), canopy cover (%), understory cover (%), and density (trees/ha) of saplings (<10.2 cm diameter at breast height [DBH]), medium-sized trees (10.3–27.9 cm DBH), and large-sized trees (>27.9 cm DBH).

	Perimeter	Area	Edge:area	Slope	Aspect	Canopy cover	Understory cover	Saplings	Medium trees	Large trees
Pellets	-0.15	-0.03	-0.12	-0.01	-0.09	0.15	0.34*	0.55*	0.54*	-0.09
Perimeter		0.72*	0.23	0.01	0.16	0.11	0.01	-0.01	-0.03	0.04
Area			-0.37*	0.07	0.14	0.09	-0.07	0.06	0.00	0.10
Edge:area				-0.07	-0.02	-0.04	0.05	-0.04	-0.11	-0.04
Slope					-0.09	-0.04	-0.20	-0.20	-0.08	0.15
Aspect						0.07	-0.13	0.02	-0.10	0.07
Canopy cover							0.29	0.14	0.33*	0.46*
Understory cover								0.39*	0.28	-0.03
Saplings									0.54*	-0.06
Medium trees										0.08

* $P < 0.05$ (with Bonferroni correction—Rice 1989).

Modeling forest management scenarios.—To explore the potential magnitude of effects on hare densities of making changes to either stand or landscape features within hare habitat, we used the best-fitting model to run a simple projection. We projected changes in pellet densities for 2 hypothetical stands with 4,000 saplings/ha and 500 medium trees/ha (similar to stands surveyed in the study area), but located in 2 different landscapes: within a high-quality matrix in which moist forest stands comprised 80% of the habitat within a 300-m buffer, or within a matrix of poor quality in which only 20% was moist forest stands and 80% was dry forest stands. In both projections we defined 20% of the surrounding matrix as open-structured habitat.

We examined 1 scenario in which the surrounding landscape was converted to 80% open-structured habitat (e.g., via timber harvest or fire); for a 20-ha stand this change would mean harvesting timber on about 48 ha within the 300-m buffer with a seed tree or similar prescription that would decrease the canopy and understory to <10%. We also examined the effect of thinning within the stand from 4,000 to 1,000 saplings/ha while leaving medium trees at 500 trees/ha. These alterations reflect strategies used by forest managers in harvesting timber and in thinning for fuels reduction or precommercial purposes. This analysis was designed as a heuristic example that simply illustrated the kind of possible effect rather than making specific inferences about these sample cases.

RESULTS

The mean pellet density across 76 surveyed stands was 1.93 pellets plot⁻¹ stand⁻¹ ($SE = 0.19$ pellets plot⁻¹ stand⁻¹), with a range of 0.04–6.28 pellets plot⁻¹ stand⁻¹. Converting mean pellets to hare density (Krebs et al. 2001) resulted in a range of 0.03–2.38 hares/ha, with a mean of 0.82 hares/ha ($SE = 0.07$ hares/ha) and a median of 0.67 hares/ha.

Of the suite of stand-scale variables considered, only 4 were highly correlated with pellet density (Table 1): vegetation type, understory cover, sapling density, and medium tree

density. Most variables were correlated with one another. To avoid overfitting by using autocorrelated variables we used only sapling and medium tree density as predictive stand-scale variables in the model, because they created understory cover, were more highly correlated with pellet density, and are the variables most directly targeted in forest management.

Multiscale model evaluation.—Models including only stand-scale variables better fit the data than models that included only landscape-scale variables. However, the model that best fit the data included stand- and landscape-scale (300-m) variables (Table 2), with an Akaike weight of 0.69 and >2.36 AIC_c values separating it from the 2nd-best (global) model. The model showed positive relationships between pellet density and sapling and medium tree densities at the stand scale and moist forest at the 300-m scale and a negative correlation with open-structured habitat at 300 m:

$$\begin{aligned} \ln(\text{pellets}) = & -1.405 + 0.0003 (\text{saplings}) \\ & + 0.0007 (\text{medium trees}) \\ & + 0.0113 (\text{moist forest 300 m}) - 0.0021 \\ & (\text{open-structured habitat 300 m}). \end{aligned}$$

Projections based on field data indicated that matrix quality had a meaningful impact on hare densities. Patches of habitat with equal stand-scale attributes set within the moist forest matrix had approximately twice as many hares as did stands in the dry forest matrix—1.15 hares/ha versus 0.63 hares/ha, using the Krebs equation (Krebs et al. 2001) to convert pellet numbers to hare densities. In both types of landscape increasing the amount of open-structured habitat within 300 m of the focal stand decreased relative hare densities by approximately 11%. Reducing sapling density reduced hare density by approximately 55% in each landscape.

DISCUSSION

Our study demonstrated that snowshoe hares are influenced by habitat at both stand and landscape scales. Pellet densities of snowshoe hares were explained best by stem density of

TABLE 2.—Models describing densities of snowshoe hare (*Lepus americanus*) pellets from 76 forest stands in northern Washington during 2003–2004. Values reported represent number of model parameters (K), Akaike information criterion corrected for small sample size (AIC_c) scores and differences (Δ_i), and Akaike weights (w_i) for the 8 models. Stand-scale variables included the density of saplings (<10.2 cm diameter at breast height [DBH]) and medium trees (10.3–27.9 cm DBH) per hectare in the focal patch. Landscape variables were the amount of moist forest (dominated by Engelmann spruce and subalpine fir) and open-structured habitat (<10% understory and canopy cover) along the perimeter and within 300-m and 600-m buffers around the focal stand.

Model name	Model structure	K	AIC_c	Δ_i	w_i	R^2
Stand + 300 m	Saplings + Medium Trees + Moist (300 m) + Open (300 m)	6	-5.25	0	0.69	0.40
Global	Saplings + Medium Trees + Moist (perim) + Moist (300 m) + Moist (600 m) + Open (perim) + Open (300 m) + Open (600 m)	10	-2.89	2.36	0.21	0.48
Stand	Saplings + Medium Trees	4	-0.76	4.49	0.07	0.32
Stand + 600 m	Saplings + Medium Trees + Moist (600 m) + Open (600 m)	6	1.14	6.39	0.03	0.35
Stand + Perimeter	Saplings + Medium Trees + Moist (perim) + Open (perim)	6	5.81	11.06	<0.01	0.32
300 m	Moist (300 m) + Open (300 m)	4	13.16	18.41	<0.01	0.19
600 m	Moist (600 m) + Open (600 m)	4	22.97	28.22	<0.01	0.09
Perimeter	Moist (perim) + Open (perim)	4	29.39	34.64	<0.01	0.01

trees within the stand and at the landscape scale within 300 m of the stand. Pellet densities were associated positively with the amount of moist forest and associated negatively with the amount of open-structured habitat within 300 m of a focal patch.

Our results suggest that landscapes in which hare habitat is more contiguous, or where good patches of hare habitat are surrounded by other patches of similar habitat quality, support more hares than landscapes that are more fragmented or include matrix habitats that are poorer quality. The importance of matrix quality for snowshoe hares is supported by Walker's (2005) observation of significantly higher averages and lower variation in pellet densities across stands in a nearby area where similarly dense forest was less fragmented—2.8 pellets/plot in the "Meadows" area described by Koehler et al. (2008) compared to the 1.9 pellets/plot described here.

Although our results demonstrated that matrix composition influenced pellet densities, the models reiterated the importance of vegetative density within forest patches, because all of the top models contained stand-scale variables. The model containing only stand-scale variables explained 32% of the variation in pellet densities; including variables at the 300-m landscape scale explained another 8% of the variation. Similarly, our projection scenarios showed that decreasing sapling density in a stand might decrease hare densities by >50%, a finding supported by experimental studies of forest thinning (Ausband and Baty 2004; Bull et al. 2005; Griffin and Mills 2007; Homyack et al. 2007). Although this level of effect emphasizes the importance of managing stand-scale characteristics, activities that increase the amount of open-structured habitat in the matrix can reduce hare densities by $\geq 10\%$.

Our conclusions are based on using pellet counts from uncleared plots as an index of snowshoe hare density. Although this index is adequate for evaluating coarse patterns in hare density or relative use of different habitats (Hodges and Mills 2008; Krebs et al. 2001; McCann et al. 2008; Mills et al. 2005; Murray et al. 2002), pellet counts are not as reliable as mark-recapture models for estimating hare density in the individual focal stands. Although this choice of index

could have reduced our overall model fit (our best-fit model explained only 40% of the variation and the global model 48%), we suspect that unexplained variance also arose from factors that we did not model explicitly, including stand and landscape factors such as availability of specific food plants and locations of predators.

The relative influence of landscape characteristics on hares might reflect the degree to which the matrix is used. Although the majority of a hare's activities take place at the stand-level scale (Ferron and Ouellet 1992; Griffin 2003; Hodges 1999; Walker 2005), dispersal and mate-seeking behaviors occur at larger scales (up to thousands of meters—Gillis and Krebs 1999) and necessitate that hares also use matrix habitats. Low-quality matrix habitat could decrease survival for hares, because predators might have higher hunting success or be more numerous in the matrix habitats (Griffin and Mills 2009). Conversely, a high-quality matrix could provide alternative or supplemental resources (Dunning et al. 1992; Norton et al. 2000), thus supporting higher densities of hares in the focal stand. Further exploration of hare densities in relation to larger landscape scales could add insight as to whether hare densities are further influenced by wide-ranging predators or rare long-distance dispersal of hares.

When managing for snowshoe hares, managers should consider the potential effects of changing the landscape matrix and also within-stand alterations. Specifically, good stands for hares in poor matrix landscapes could benefit from changes made in the matrix, whereas if the best stands in a landscape are only mediocre for hares, the best strategy might involve focusing 1st on improving stand-level attributes. Although our results showed that stand-level vegetative structure had roughly 5 times the influence that landscape-level vegetation did on hare density, we do not know how robust this result is across different landscapes. Because vegetation, soil, and weather conditions vary throughout the range of snowshoe hares, research is needed on the influences of landscape-scale characteristics on snowshoe hare numbers in different regions. Information on movements, diets, and behavior of hares in fragmented landscapes would help determine the mechanisms by which stand and landscape habitats affect hare densities.

example, relative abundances of snowshoe hares from uncleared pellet plots have been used in Yellowstone National Park (Hodges et al. 2009) and in forestry-intensive landscapes in Labrador, Canada (Newbury and Simon 2005).

Throughout our analyses we used the mean number of pellets per plot per stand as the dependent variable. We also converted pellet counts into hare densities using the equation from Krebs et al. (2001) solely for easy comparison of hare densities in our study area to those in other studies, although our estimates are likely to be slightly high because we used uncleared plots, which do result in larger pellet counts than cleared plots (Hodges and Mills 2008). The Krebs equation, which was developed for another region, is a robust equation for other locations in the western United States (Mills et al. 2005).

Stand-scale variables.—Studies of snowshoe hare habitat conducted throughout their range have reported a variety of characteristics to explain hare densities or habitat use. The majority of these studies quantify characteristics of forest stands, such as vegetation density (stem counts or visual measures of cover), vegetation types, and patch characteristics such as size or aspect (Hodges 2000a, 2000b). Because no work had been done in our particular study area to determine which variables best explained hare densities within stands, we measured a suite of variables in an effort to discern which of the stand variables would be most appropriate for including in our *a priori* models.

We used geographic information system data to quantify stand size, perimeter length, and edge-to-area ratio of stands. To measure vegetation structure we randomly placed 10 circular plots with a 5-m radius in each stand. At each plot center we used a spherical convex densiometer to estimate canopy cover (Lemon 1957). To estimate understory cover we used a 0.5 × 2-m cover board viewed at 5 m from plot center and estimated the percentage of the board from 0 to 2 m that was obstructed by vegetation, recording the average horizontal cover at true north, 120°, and 240° to account for the high variation in understory cover. We counted the number of stems from all trees and shrubs > 1 m tall and > 2.5 cm diameter at breast height (DBH) within the circular plots and converted the counts to trees/ha. Tree size classes were: saplings (2.5–10.2 cm DBH), medium (10.3–27.9 cm DBH), or large (>27.9 cm DBH). Coniferous trees constituted approximately 90% of the sapling class of vegetation and 100% of the 2 larger classes; hereafter, we refer to the smallest class as saplings even though some shrubs were present in this class. We used the average of measures for canopy and understory cover readings, tree densities, slope, and aspect across the 10 plots to characterize each variable per stand.

Landscape-scale variables.—Because the appropriate landscape scale at which hares relate to their environment is unknown, we explored multiple scales (Fuhlendorff et al. 2002; Martin and McComb 2003; Naugle et al. 1999). We selected 3 hierarchical landscape scales likely to relate to snowshoe hare behavior and movement: perimeter, and distances of 300 m and 600 m from the perimeter. The perimeter scale examined the stands that directly border the

selected stand; for stands > 20 ha, in which we delineated an internal 20-ha patch to sample, some or even all of the perimeter would consist of the same stand type. Measures at the perimeter scale reflect the habitats immediately available to a hare should it decide to leave the focal patch. The 300-m and 600-m scales consider all stands within those distances of the focal stands, regardless of whether they directly touch the perimeter. The 300-m scale represented habitats available to hares on a daily basis, because it approximates the diameter of a hare's home range (de Bellefeuille et al. 2001; Griffin 2003; Hodges 1999) and is close to the maximum distance hares moved in an hour in this region (Walker 2005). The 600-m scale represented habitats available to a dispersing hare (Gillis and Krebs 1999; Griffin 2003).

We investigated 2 landscape-scale variables of high relevance to snowshoe hares and to forest management, the amount of moist forest and the amount of open-structured habitat. Open-structured habitat consisted of natural openings, recent burns, or timber harvest units where the canopy and understory were both ≤10%. These areas likely present barriers to interpatch movement by snowshoe hares (Griffin and Mills 2007, 2009; Hodges et al. 2009; Wirsing et al. 2002), because they provide little food or shelter, especially during winter. We calculated the percentage of the area adjacent to the stand perimeter or within a 300-m or 600-m buffer of the focal stand that was moist forest or open-structured habitat.

Model selection and data analysis.—We chose to use an information-theoretic approach to assess whether stand-scale variables, landscape-scale variables, or a combination of stand- and landscape-scale variables would best explain variations in pellet densities, and to assess which, if any, landscape scale was most appropriate. Because the snowshoe hare literature reports a variety of stand-scale variables as being the best predictors of hare density in different study areas, and the best predictor variables for hare habitat had not been explored in our study area, we 1st used Spearman rank correlations (r_s) between pellet densities and each of the stand-scale variables to screen variables for inclusion in the models (SPSS, Inc., Somers, New York). We developed a suite of *a priori* linear regression models that examined pellet densities in relation to stand-scale variables only, landscape-scale variables only (at each of three different scales: perimeter, 300 m buffer, and 600 m buffer), and combinations of stand- and landscape-scale variables (Table 2). To avoid spatial autocorrelation of landscape variables we considered only 1 landscape scale at a time, except in the global model. We populated the models with the best stand-scale variables and with the landscape-scale variables described above, and used the log-transformed mean number of pellets per stand as the dependent variable (Krebs et al. 2001; Mills et al. 2005). For each candidate model we calculated the residual sum of squares using SPSS and used residual sum of squares to calculate Akaike information criterion corrected for small sample size (AIC_c) values and Akaike weights (Burnham and Anderson 2002).



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Ecology and Conservation of Lynx in the United States

Leonard F. Ruggiero
Keith B. Aubry
Steven W. Buskirk
Gary M. Koehler
Charles J. Krebs
Kevin S. McKelvey
John R. Squires

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Lynx Conservation in an Ecosystem Management Context

Kevin S. McKelvey, USDA Forest Service, Rocky Mountain Research Station,
800 E. Beckwith, Missoula, MT 59801

Keith B. Aubry, USDA Forest Service, Pacific Northwest Research Station,
3625 93rd Ave. SW, Olympia, WA 98512

James K. Agee, College of Forest Resources, University of Washington,
Box 352100, Seattle, WA 98195

Steven W. Buskirk, Department of Zoology and Physiology, University of
Wyoming, P.O. Box 3166, Laramie, WY 82071

Leonard F. Ruggiero, USDA Forest Service, Rocky Mountain Research
Station, 800 E. Beckwith, Missoula, MT 59801

Gary M. Koehler, Washington Department of Fish and Wildlife,
600 Capitol Way N., Olympia, WA 98501

Abstract—In an ecosystem management context, management for lynx must occur in the context of the needs of other species, watershed health, and a variety of products, outputs, and uses. This chapter presents a management model based on the restoration of historical patterns and processes. We argue that this model is sustainable in a formal sense, practical, and likely to provide for the needs of a variety of species, including lynx. Because our knowledge of lynx biology and disturbance ecology is limited, implementation of this model will be experimental and must be accompanied by a well-planned monitoring program.

disturbance stochasticity; one drainage may burn frequently, whereas an adjacent drainage may avoid fire for centuries. For example, within a burned drainage variation in wind patterns may leave unburned patches, and diurnal variation in moisture and temperature during a fire may result in some areas having high tree survival, whereas others do not. This stochastic process leads to a landscape with a mosaic of conditions at various spatial scales. A very large, stand-replacing fire has little mosaic within its boundaries (Eberhart and Woodard 1987), but viewed at the spatial scale of the region and the temporal scale of 100 years, it represents a patch in a fire mosaic on the landscape. Such an event produces a large, contiguous area of young forest but, in the larger context, there will be areas of very old forest as well.

Johnson et al. (1995) and Agee (Chapter 3) argue that naturally occurring age distributions in forested landscapes, especially landscapes composed of boreal and subalpine forests (Johnson et al. 1995), often fit negative exponential functions, indicating a constant-probability stochastic process. While this model may not always produce the best fit (Chapter 3), all stochastic processes produce a characteristic signature in the resulting age distribution, including asymptotic "tails" in the older age classes (Fig. 15.1a; Van Wagner 1978; McKelvey and Lamberson 1994). In contrast, cyclic processes, such as even-aged rotation forestry, truncate the age distribution (Fig. 15.1c). In a cyclic system, there is no formal mechanism to generate stands or elements older than rotation age. However, in a forested landscape with a negative exponential stand-age distribution, about 36% of the landscape will be older than the average stand age, about 13% older than twice the average stand age, and about 5% older than three times the average stand age (Table 15.1). Although there is no maximum stand age in this system (Finney 1994), old stands that have not burned will be subject to other sources of mortality, such as insects and disease.

Table 15.1—Equilibrium time since disturbance for forests with a negative exponential stand age distribution. Where time since disturbance exceeds the longevity of individual trees, the stand ages will be younger than are indicated in this table, and the forests will be characterized by "gap" processes due to overstory mortality.

Fire return interval (average stand age)	Percent of area (by age class)				
	<50	50-100	100-200	200-300	>300
100 years	40	24	23	9	4
150 years	29	20	25	13	13
200 years	23	17	24	14	22
300 years	16	13	20	15	36

= 36% 7100 yr
= 51%
= 60%
= 71%

The retention of older stands essentially mimics the process of ecological "escape" in systems characterized by large-scale disturbances. In a catastrophic fire, variation in fire intensities and the vagaries of weather allow forest elements at many scales to survive, including individual trees, small groups of trees, stands, or entire watersheds. As multiple fires overlap over many years, there will be small areas embedded in larger areas of younger forest that have, by chance or location, survived multiple fires. This escape of older elements is not effectively mimicked by embedding fixed reserves in a landscape of cyclic management. In a stochastic system, with each new disturbance event, older forests may be destroyed or altered, or they may be left intact; thus, late-successional stands are not spatially assigned and maintained, but emerge dynamically within the disturbance process. A variety of other differences, some of them dramatic, also distinguish fixed-rotation from stochastic systems. For example, if a natural fire-return interval is 100 years, and a 100-year clearcut rotation is implemented to mimic natural rates of disturbance, the average stand age in the managed forest will be 50 years. In a stochastic system with a negative exponential stand-age distribution, however, the same landscape would have an average stand age equal to the fire-return interval, or 100 years.

Assuming that the scale of disturbance corresponds with the movement capabilities of individual lynx, landscapes generated through these stochastic processes would provide an amenable environment for lynx by producing areas of young, dense forest without removing the older elements. If the natural fire regime can be estimated for an area that is to be managed for lynx, then it is logical to use this rate to design management strategies. The overall rate of disturbance would be an aggregate of the cumulative effects of timber harvest, fire, and other natural disturbances (catastrophic windthrow or insect epidemics) on age structure. Therefore, in areas subjected to large wildland fires, or where inholdings are managed for short-rotation timber yield using even-aged management, timber harvest (including salvage) may be inappropriate for decades. In some regions, significant amounts of wilderness or National Park land will be part of the planning area, and management of natural fires must be incorporated into planning. We assume here that fire and timber harvest are similar processes in their capacity to initiate secondary succession. In addition, we would argue for a planned rate of disturbance somewhat less than the historically derived estimate. It is easy to increase the disturbance rate if desirable, but much harder to recover old-growth forests removed through overly aggressive management.

Old-Growth Descriptions for the Major Forest Cover Types in the Rocky Mountain Region¹

Mel S. Mehl²

Abstract.—Old-growth descriptions have been developed for each of the major forest cover types in the Rocky Mountain Region of the Forest Service. Included with each description is a minimum list of tree and stand variables that characterize old growth. Additional attributes are listed that affect the quality of old growth. These descriptions will be used to locate, map, and inventory old-growth forests for forest planning.

INTRODUCTION

This document describes the old-growth forest conditions for the major forest cover types in the Rocky Mountain Region (Region 2) of the Forest Service. Region 2 covers the states of Colorado, Wyoming, South Dakota, Kansas and Nebraska.

These old-growth descriptions are not precise definitions. There is a certain amount of subjectivity in defining old growth. Old growth is conceptual and difficult to define precisely. For that reason the term "description" was chosen instead of "definition." They describe the ecologically important structural features of old-growth forest ecosystems. They include a list of attributes measurable from stand-level inventories that characterize old-growth ecosystems. There are intangible elements, various functions and interactions occurring in old-growth ecosystems and the composition of the understory vegetation that are not part of these descriptions.

The following descriptions are the first attempt to describe old growth structurally by major forest cover type for Region 2. They form the collective knowledge of what is thought to describe old growth. These descriptions will be dynamic and will be modified as we learn more about the dynamics of old-growth ecosystems and its need and influence on the landscape.

Descriptions have been developed for the Engelmann spruce/subalpine fir, Douglas-fir, lodgepole pine, ponderosa pine, aspen and pin-yon-juniper forest cover types. Ponderosa pine grows in 3 distinct topographical areas in Region 2: the Black Hills, front range of the Rocky Mountains, and southwest Colorado, each with different stand characteristics. Separate old-growth descriptions have been developed for each area.

The forest cover types are defined in the Society of American Foresters (SAF) handbook *Forest Cover Types of the United State and Canada*, 1980. These cover types are those by which most inventory and management is done. Descriptions for the minor forest types such as limber pine or white pine will be added in the future.

These descriptions and associated attributes will be used to map and inventory old growth in the Region for Forest planning. They are general. For project level work detailed site specific analyses may be needed.

The descriptions follow a format developed by the National Old-Growth Task Group.

Description

Old-growth forests are unique ecosystems that are an important component of biological diversity. Old growth occurs at some point in the later stages of the development of a stand (fig. 1).

A stand that has reached an old-growth condition has developed a diversity of functions and interactions that did not exist in earlier stages. The later stages of development also differ from earlier stages by structure such as tree size, standing and down dead trees, number of canopy levels, age and the composition of the understory species.

The age at which old growth develops and the structural attributes that characterize old growth will vary by forest cover type, climate, site conditions and past disturbances. However, old growth is typically distinguished from younger growth by several of the following stand attributes:

- large trees for species and site.
- variation in tree sizes and spacing.
- standing and down dead trees.
- decadence in the form of broken or deformed tops or bole and root decay.
- multiple canopy layers.
- gaps in the tree canopy and understory patchiness.

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²Regional Old-Growth Coordinator, USDA-Forest Service, Rocky Mountain Region, P.O. Box 25127, Lakewood, CO., 80225

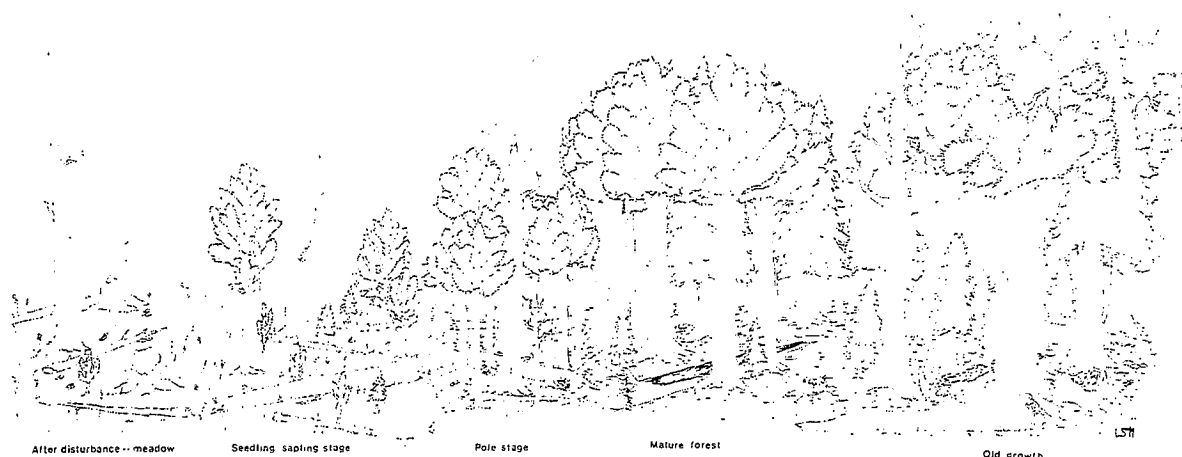


Figure 1. Developmental stages of a stand to an old-growth condition.

A stand may contain some trees that meet the criteria for old growth but the stand as a whole could lack the functions and interactions of an old-growth ecosystem and would not be considered old growth.

Old growth encompasses both older forests dominated by fire-dependent species and forests dominated by shade tolerant species. Different stages or qualities of old growth will be recognizable in many forest cover types. Sporadic, low to moderate, severity disturbances are an integral part of the internal dynamics of many old-growth ecosystems. Canopy openings resulting from the death of overstory trees often give rise to patches of small trees, shrubs, and herbs in the under-story. Frequent, low intensity fires are important for some species to maintain their dominance on a site.

Old growth is not necessarily "virgin" or "pristine". It could develop following human disturbances. It could also develop from man's indirect influence on the landscape by the control of fire.

Attributes

There are many attributes that could be used to characterize old growth, but these descriptions are attributes that are tree and stand-level characteristics such as diameter, canopy layers or openness. While there may be some attributes that seem applicable to all cover types, there is not one universal set of attributes that can adequately describe old growth for all cover types.

Each Region, as directed by the National Old-Growth Task Group, was to use a basic set of attributes to describe old growth. These are referred to as the "standard" attributes. Where necessary each Region had the option to add "supplemental" attributes to more fully describe old growth. In implementing they grew to the minimum requirements for determining if a stand is old growth.

that further enhance the value of an old-growth stand once it has been determined to be old growth based on the above minimums. They are not required for old growth, but provide higher quality old growth if present. These criteria would be useful for deciding which old-growth stands are the most important for retention.

These attributes are tree and stand characteristics that are normally used in stand inventories. Table 1 summarizes the attributes by forest cover type. The glossary at the end of this paper defines each attribute. They are readily identifiable and measurable in a consistent manner. In addition the standard attributes are generally obtainable from remote sensing sources such as aerial photography. The additional and quality attributes may require some field work to collect.

The minimum stand size required for a stand to be old growth was not considered in these descriptions. Managers will decide the appropriate size as configuration, location and position in the landscape are also important in determining the value of a stand as old growth.

Old growth may have evidence of past treatment including stumps, slash, down logs, roads, fences and other improvements. However, this may affect the quality of old growth.

Development of Descriptions

During the summer of 1990, workshops were held in various locations throughout the Region (fig 2).

The purpose was to visit old-growth sites and discuss the tree and stand related attributes that could describe these old-growth sites. Attendees at the workshops included District, Forest and Regional staff and scientists from the Rocky Mountain Research Station. Each workshop was focused on a specific forest cover type. From the workshops a list of tree and stand attributes by each forest cover type was developed descriptive old growth. The description and list of attributes.



Figure 2. Workshop on the Arapaho/Roosevelt NF looking at lodgepole pine old growth.

The descriptions and lists were then sent out for review and comments to additional Regional and Rocky Mountain Station staff and interested publics.

SPRUCE-FIR - SAF COVER TYPE 206

Narrative

Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) comprise the spruce/fir forest cover type in the subalpine zone in the Rocky Mountain Region. Spruce-fir occupies the highest and coldest forest area in the Region and is generally found from 9,000 to 11,000 feet but may grow as low as 8,000 feet and as high as 12,000 feet or timberline.

Engelmann spruce and subalpine fir are extremely shade tolerant compared to the other major forest species. By being shade tolerant they can reproduce under themselves and barring any major disturbance, perpetuate the stand. Subalpine fir is more shade tolerant than Engelmann spruce and may reproduce vegetatively by layering. In younger stands subalpine fir may be the major component of the forest type. However, it is shorter lived than Engelmann spruce. Consequently, most of the overstory in a spruce-fir old growth stand is Engelmann spruce. The under-

Table 1.—The minimum criteria for the structural attributes used to determine old growth and those that add a quality attachment. Attributes with an "X" or a numerical value are considered "must" criteria. Those with a "Q" are quality criteria. The quality attributes are not required for old growth, but provide for higher quality old growth if present. Any of the "must" criteria in excess of the minimums could also indicate a higher quality of old growth.

Forest Cover Type, Name	Spruce/ Fir	Douglas- Fir	Lodgepole Pine	Ponderosa Pine			Aspen	Pinyon Juniper
				Front Rng	Blk Hills	So. West		
Forest Cover Type, SAF Code	206	210	218	237	237	237	217	217
STANDARD ATTRIBUTES								
LIVE TREES:								
Upper Canopy								
DBH/DRC	16	18	10	16	16	18	14	
TREES/ACRE	10	10	10	10	10	10	20	
AGE	200	200	150	200	160	160	100	
VARIATION IN DIAMETER	X	X		X	Q	X	Q	
DECADENCE	X	X	X	X	X	X	X	
MULTIPLE CANOPY LAYERS	X	Q	Q				Q	
DEAD TREES:								
Standing								
DBH/DRC	10	10	8	10	10	10	10	
TREES/ACRE	2	2	2	2	2	2	Q	
Down								
PIECES/ACRE	X	X	X	Q	Q	Q	Q	
ADDITIONAL/QUALITY ATTRIBUTES								
SLOW GROWING (MAIN CANOPY)	X	X	X	X	X	X	X	
CANOPY CLOSURE 50% PLUS							X	
CANOPY CLOSURE 35% PLUS								
WIDE RANGE OF VIGOR	Q	X		X		Q		
NET GROWTH NEAR ZERO	X		Q					
PATCHINESS	X	Q	Q					
MANY STAGES OF DECOMPOSITION	X		Q			X		
MULTIPLE TREE SPECIES			Q				Q	
DISTINCTIVE BARK	Q			Q	Q	Q		
DISTINCTIVE CROWNS			Q	Q	Q	Q		

may still have an abundance subalpine fir due to its high tolerance to shade and vegetative layering. Engelmann spruce life span averages 350 to 400 years with 500-year-old or more trees not uncommon. Trees over 250 years are not uncommon for subalpine fir but most are 150 to 200 years old. It is quite susceptible to heart rot and generally dies at an earlier age than Engelmann spruce.

Spruce-fir is climax in the range that it occupies. No other tree species will replace it. The only time the stand would be replaced by another species is when a major disturbance like fire would occur, opening up the stand to sunlight. Less shade tolerant species then could occupy the site. Over time, up to 300 years or so, the more shade tolerant Engelmann spruce and subalpine fir would re-dominate the site.

After a stand replacing event such as fire or clear felling, lodgepole pine or aspen will be the replacing species at the lower elevational range of spruce-fir. If there is a sufficient seed source, spruce-fir will begin to develop in the understory and the lodgepole will begin to break apart with the stand reverting back to spruce-fir. Where there is not a sufficient spruce-fir seed source the stand will remain in lodgepole pine or aspen.

When at climax the stands are usually quite stable and will remain on the site indefinitely until replaced because of fire, logging, insect, disease, windstorm or other major disturbance.

Description

Spruce-fir old-growth stands are at climax and generally have a high number of large, old trees with an understory of shrubs and small subalpine firs. The percentage of canopy closure can vary. There is usually a considerable amount of stand-



Figure 3. Down trees in an old-growth spruce-fir stand on the Arapaho/Roosevelt NF.

ing dead and down trees making it quite difficult at times to walk through the stand (fig. 3).

There can be lichens hanging from the tree branches and on the stems of the trees. It usually contains a mixture of different tree sizes providing a variety of structure within the stand. The upper canopy would consist of a cohort of older trees that are slow growing. These older trees can be characterized as having dead or broken tops, having flattened and open crowns, containing rot and possibly having bark that is reddish in color. Other tree species could be present such as lodgepole pine or aspen but generally would be scattered within the stand and at the lower elevations.

Attributes

Table 2 lists the tree attributes that are being used to describe spruce-fir old growth.

Table 2—Summary of Old-Growth Attributes for Spruce Fir – SAF Cover Type Code 206

STANDARD ATTRIBUTES

LIVE TREES:

Upper Canopy - Older Component	
Minimum DBH (inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	Yes

DEAD TREES:

Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	Some

ADDITIONAL ATTRIBUTES:

Trees in Upper Canopy Are Slow Growing	Yes
Net Growth Near Zero	Yes
Patchiness	Yes
Many Stages of Decomposition	Yes

QUALITY ATTRIBUTES:

Above Attributes in Excess of	
Minimums	Yes
Wide Range of Tree Vigor	Yes
Distinctive Bark	Yes

INTERIOR DOUGLAS-FIR - SAF COVER TYPE 210

Narrative

The interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) cover type occurs throughout the

2 from 6,000 to 10,000 feet in elevation. It occurs as pure stands or in association with other species such as Engelmann spruce and subalpine fir at higher elevations to lodgepole pine and aspen at its mid-elevational range and to ponderosa pine in its lower elevational range. In southwest Colorado, it grows with white fir and ponderosa pine where it is also referred to as mixed conifer.

Interior Douglas-fir is much different than the coastal variety of the Pacific Northwest. It grows in a drier climate and does not attain the growth, size or age of the Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) of the Pacific coast.

Douglas-fir is more shade tolerant than pine and aspen but less tolerant than Engelmann spruce or subalpine fir. When growing in association with spruce-fir it will be seral giving way eventually to the more shade tolerant spruce-fir. When growing in association with ponderosa pine, lodgepole pine or aspen it often dominates these species becoming the climax species if succession is not interrupted by a major disturbance such as fire.

Since Douglas-fir is shade tolerant, it can reproduce under its own canopy. This results in old stands of pure Douglas-fir that tend to be uneven-aged rather than single-aged. These pure stands most likely originated from fire. They remain over time because of Douglas-fir's ability to survive successive fires due to rapid growth, thick corky bark, ability to form adventitious roots and the longer fire interval on cool and moist north facing slopes. These stands generally reach a maximum age of 400 years old although some have reached an age of 700 years.

Where Douglas-fir grows in pure stands, it is usually on cooler and damper north facing slopes. Along the front range of Colorado, these stands have been heavily damaged by a spruce budworm infestation that began in the mid 1980's.

Insects often modify the structure of older Douglas-fir stands, creating large gaps or patches and groups of dead trees. This produces a patchy stand of large trees with Douglas-fir seedlings and saplings growing in the gaps giving the stand more vertical structure and an uneven aged composition.

At its lower elevational range, it has been easily accessible and influenced by post settlement activities. It has been heavily utilized for mining timbers and lumber and for recreation. Consequently few stands of old-growth Douglas-fir exist at lower elevations. However, its area is increasing in the lower elevations as it is replacing ponderosa pine especially on the cooler more moist north facing slopes. The frequent low intensity fires that kept Douglas-fir from becoming established in the ponderosa pine type have been reduced, allowing Douglas-fir to become established under the ponderosa pine.

Description

An old-growth Douglas-fir stand would consist of an overstory of trees that are predominately or entirely Douglas-fir. On the cooler, more moist, north facing slopes it may be growing in association with spruce-fir or white fir. On drier sites old-growth Douglas-fir could be associated with ponderosa pine, lodgepole pine and aspen. Where the site is dry, the stand would be more open-grown compared to a cooler, more moist site such as a north facing slope or drainage bottom. Some dead standing trees and down dead trees would be present. Some of the overstory trees would have large and open branched, flattened or dead tops and contain some rot.

Attributes

The following table lists the tree attributes that are being used to describe Douglas-fir old-growth.

Table 3—Summary of Old-Growth Attributes
Interior Douglas-Fir – SAF Cover Type 210

STANDARD ATTRIBUTES

LIVE TREES:

Upper Canopy - Older Component

Minimum DBH (inches) 18

Minimum Number of Trees Per Acre 10

Minimum Age 200

Variation in Tree Diameter Yes

Decadence - dead, broken or deformed

tops and/or bole or root rot Yes

Multiple Tree Canopy Layers No

DEAD TREES:

Standing

Minimum DBH (inches) 10

Minimum Number of Trees Per Acre 2

Down

Minimum Pieces Per Acre Some

ADDITIONAL ATTRIBUTES:

Trees in Upper Canopy Are Slow

Growing Yes

Wide Range of Tree Vigor Yes

QUALITY ATTRIBUTES:

Above Attributes in Excess of

Minimums Yes

Multiple Tree Canopy Layers Yes

Patchiness Yes

LODGEPOLE PINE - SAF COVER TYPE 218

Narrative

The lodgepole pine (*Pinus contorta* var. *latifolia*) cover type in Region 2 consists of extensive stands of pure lodgepole pine or, to a lesser extent, stands in association with other species such as Engelmann spruce, subalpine fir, or aspen. It occurs between 7,500 feet and 11,500

feet elevation but reaches maximum development in the upper montane and lower subalpine zones on south and west facing slopes between 9,000 and 10,000 feet elevation.

In contrast to the shade tolerant Engelmann spruce and subalpine fir, lodgepole pine is shade intolerant and is an aggressive pioneer developing on sites recently opened up due to fire, insects and disease, windstorms, clearcutting or other major stand removing disturbance. Lodgepole pine stands that are 350 to 400 years old exist but they are uncommon. The average life span of lodgepole pine is probably closer to 250 years or less because of the frequency of stand replacing disturbances such as fire. Fires are more frequent in lodgepole pine than spruce-fir as they occur in a warmer and dryer environment.

Lodgepole pine is generally considered a seral species. That is, it will be replaced by the more shade tolerant Engelmann spruce and subalpine fir. Most lodgepole pine stands become established after stand replacing events such as fire. As the lodgepole pine matures Engelmann spruce and subalpine fir will appear as the understory eventually replacing the overstory lodgepole pine. The stand will remain as spruce-fir until another stand replacing event occurs.

There are instances when lodgepole pine can be considered climax. In areas where a seed source of more shade tolerant trees species does not exist or the site is marginal for other tree species, the lodgepole pine stand will not be replaced. If there is a stand replacing occurrence like fire the stand will re-seed with lodgepole pine. If not disturbed the stand will begin to develop gaps in the tree canopy as trees die. These gaps will allow sunlight to reach seedlings, renewing the stand but a stand with a more varied structure. Over successive generations the stand would develop a structure more consistent of old growth in shade tolerant species. When fire was more prevalent few stands would have had the opportunity to reach this structure.

When the overstory trees in a lodgepole pine stand begin to die and fall, the overstory probably will not persist for more than 50 years or so.

Description

Many people do not believe that lodgepole pine old growth really exists. Using a definition of old-growth where a stand must be climax would eliminate much of the Region's lodgepole pine as old growth. However, the seral lodgepole pine condition can exhibit old-growth characteristics albeit they may not last long in one place, but overall in a landscape this old-growth condition can exist for quite some time. Lodgepole pine is more dynamic in its landscape behavior than the more shade tolerant species such as Engelmann spruce or subalpine fir.

In a seral condition lodgepole pine old growth would be described as having an overstory of large old trees without lower limbs, with dead or dying tops and with crowns that are sparse, open branched and somewhat flattened (fig 4).

The stand would probably have mistletoe, rust or stem rot present contributing to the decadence of the overstory. The understory would consist of Engelmann spruce and subalpine fir. Depending on the age of the understory there could be a fair amount of structure and variation in tree diameters within the stand. Some down material would be present, increasing as the overstory continued to degenerate. It is important to note that when the older lodgepole pine is replaced by the understory, the stand is no longer old growth. The stand would be a young spruce-fir stand.

Where lodgepole pine is considered climax, old growth will again include large old trees lacking lower limbs and with dead or dying tops and crowns with sparse foliage, open branched, misshapened and somewhat flattened. It would probably have mistletoe, rust and/or stem rot present contributing to the decadence of the overstory. However, it will not have the spruce-fir understory. It will most likely have one canopy layer and thus not much structure. There probably would be very little variation in tree diameter. There may be a lot or little down dead material depending on how advanced the decline is of the overstory. In stands that are very old perhaps 300 or more years old, there may be a fair amount of stand structure developed due to trees developing in openings created by trees in the original overstory that had fallen.



Figure 4. Seral old-growth lodgepole pine stand.

Attributes

The following table lists the tree attributes that are being used to describe lodgepole pine old growth.

Table 4—Summary of Old-Growth Attributes
Lodgepole Pine – SAF Cover Type 218

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches).....	10
Minimum Number of Trees Per Acre	10
Minimum Age	150
Variation in Tree Diameter	No
Decadence - dead, broken or deformed	
tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches).....	8
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	Some
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow	
Growing.....	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of	
Minimums	Yes
Net Growth Near Zero	Yes
Multiple Tree Canopy Layers	Yes
Multiple Tree Species	Yes
Patchiness	Yes
Many Stages of Decomposition	Yes
Distinctive Crowns in the Upper Canopy ..	Yes

INTERIOR PONDEROSA PINE - SAF COVER TYPE 237 (Front Range)

Narrative

Front Range ponderosa pine (*Pinus ponderosa* var. *scopulorum*) forests extend along the east slope of the Rocky Mountains from south of Pueblo on the Pike/San Isabel National Forest north to the Laramie Peak area on the Medicine Bow National Forest. It occurs at elevations between 6,000 and 8,000 feet, lower than the other Rocky Mountain conifers except for pinyon juniper and is well adapted to the warm dry sites

at these lower elevations. Although there are stands of pure ponderosa pine, it frequently occurs with Douglas-fir and is often referred to as mixed conifer.

Ponderosa pine is shade intolerant. It occurs in stands that are open-grown, often lower in stocking than other conifers and interspersed with meadows and parks. Fire has played a very important role in shaping ponderosa pine stands. In the past cool, light ground fires would burn through ponderosa pine stands every 8-15 years, removing competing understory vegetation, down dead material and young trees. This resulted in developing irregular shaped stands with even-aged groups of trees varying in size. Patchy distribution of clumps of trees varying in size, age and density are characteristic of naturally occurring ponderosa pine forests.

Where ponderosa pine is the sole species or fire is still part of the ecology, it can be considered the climax species. These stands develop into and remain as open-grown, irregular and uneven-aged stands. Some stands with trees over 450 years do exist but 300 to 350 year old trees are more common.

Where fire has been excluded and the more shade tolerant Douglas-fir is present, ponderosa pine is generally considered seral. The open-grown stands develop an understory of more shade tolerant species such as Douglas-fir. These more shade tolerant species will replace the ponderosa pine if not removed whether by fire or some other means. On sites more marginal in growing conditions it can exist with other species and not be replaced by them.

The lower elevations where ponderosa pine grows are easily accessible and have been highly influenced by man's activities compared to conifers growing at higher elevations. Consequently, most ponderosa pine stands have been harvested for mining timber, lumber and railroad ties and used heavily for recreation. As a result few stands of ponderosa pine over 150 years old exist except in isolated areas that were difficult to access.

Description

Where ponderosa pine is climax and fire has been present, stands will contain clumps of large uneven-aged trees with little understory or down woody material and few if any standing dead trees (fig. 5).

Where fire has been controlled or less frequent there will be old large trees with smaller size trees in the understory giving the stand some structure. Dead down material will be present in varying amounts along with some standing dead trees. In both cases the large old trees will have irregular, open and large branched crowns and have lost their lower branches. The bark will also be thick, have large and somewhat concave

plates and have a lighter color compared to younger trees. Burls and other deformities may be present including fire scars that could be completely healed over.

Where ponderosa pine is seral due to the lack of frequent fires or the site is outside its normal range, stands will contain large trees with a multi-layer canopy and contain various amounts of standing and down dead trees (fig. 6).

It has an understory component of smaller trees including the more shade tolerant Douglas-fir filling in the openings between the groups of older ponderosa pine.

Attributes

The following table lists the tree attributes that are being used to describe Front Range ponderosa pine old growth.

Table 5—Summary of Old-Growth Attributes
Interior Ponderosa Pine – SAF Cover Type 237
(Front Range)

STANDARD ATTRIBUTES

LIVE TREES:

Upper Canopy - Older Component

Minimum DBH (inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No

DEAD TREES:

Standing

Minimum DBH (inches)	10
Number of Trees Per Acre	2

Down

Minimum Pieces Per Acre	None
-------------------------------	------

ADDITIONAL ATTRIBUTES:

Trees in Upper Canopy Are Slow

Growing	Yes
Wide Range of Vigor	Yes

QUALITY ATTRIBUTES:

Above Attributes in Excess of

Minimums	Yes
Distinctive Bark	Yes
Down Dead Trees	Yes
Distinctive Crowns in the Upper Canopy ..	Yes

INTERIOR PONDEROSA PINE - SAF COVER TYPE 237 (Black Hills)

Narrative

Black Hills ponderosa pine (*Pinus ponderosa* var. *scopulorum*) occurs in Region 2 in the Black Hills of South Dakota and Wyoming and the Bear Lodge Mountains of Wyoming. Here it forms a



Figure 5. Old-growth ponderosa pine on the Arapaho/Roosevelt NF with little understory.



Figure 6. Old-growth ponderosa pine on the Manitou Experimental Forest with some understory and down material.

unique and isolated ecotype of the interior ponderosa pine type. It usually grows in pure stands at 3,600 to 7,000 feet in elevation.

Old photographs show ponderosa pine growing in even-aged clumps or groups of trees apparently before the 1870's. These groups or clumps were separated by grassy areas or parks. This condition dominated the landscape and was similar to that of ponderosa pine in other parts of the Rocky Mountain Region where periodic low intensity fires removed competing vegetation and prevented large numbers of trees from maturing.

Where periodic, low intensity fires were not part of the ecosystem, ponderosa pine grew in a multi-storied and a more homogeneous and denser condition with standing dead and down trees.

A few old ponderosa pine stands, about 350 years old, remain in the Black Hills. Virtually all of the accessible areas have been cut over at least once since the mid 1870's. The open-grown clumps of ponderosa pine have been converted to stands with an older overstory and a young understory through harvesting and intensive management. The amount of stocking has been dramatically increased with the control of fire.

Ponderosa pine is considered a climax species in the Black Hills. After fire or other disturbances, the stand may temporarily be replaced by other plant species but will soon return to ponderosa pine.

Since little old-growth ponderosa pine remains in the Black Hills old growth will have to develop from existing stands. It will take active management to return existing stands to an old-growth condition similar to that which dominated the landscape at pre-settlement.

Where old-growth stands do exist a dense understory of younger trees has developed due to the absence of fire. This is dramatically different from what existed as old growth prior to the 1870's.

Description

Where periodic, low intensity fires have been part of the ecosystem, old-growth stands would consist of clumps or groups of trees with grasses in the openings between the clumps. They would contain large old trees with open branches, irregular and flattened crowns. The clumps or groups of trees would contain little down dead material and few small trees.

Where periodic, low intensity fires have not been part of the ecosystem, old-growth stands would contain large old trees with open branches and irregular crowns. The stands would have multiple canopy layers made up of various aged trees. They would be well stocked with trees and contain standing dead and down trees.

Attributes

The following table lists the tree attributes that are being used to describe Black Hills ponderosa pine old growth.

Table 6--Summary of Old-Growth Attributes
Interior Ponderosa Pine - SAF Cover Type 237
(Black Hills)

STANDARD ATTRIBUTES

LIVE TREES:

Upper Canopy - Older Component	
Minimum DBH..(inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	160
Variation in Tree Diameter	No
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No

DEAD TREES:

Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	None

ADDITIONAL ATTRIBUTES:

Trees in Upper Canopy Are Slow Growing	Yes
----------------------------------------------	-----

QUALITY ATTRIBUTES:

Above Attributes in Excess of	
Minimums	Yes
Distinctive Bark	Yes
Variation in Tree Diameter	Yes
Down Dead Trees	Yes

INTERIOR PONDEROSA PINE - SAF COVER TYPE 237 (Southwest)

Narrative

Southwest ponderosa pine (*Pinus ponderosa* var. *scopulorum*) occurs in Region 2 in the southwest portion of Colorado, but covers extensive areas of Arizona, New Mexico and southern Utah. As with ponderosa pine elsewhere, it occurs at the lower elevations between 6,000 and 8,000 feet. It reaches maximum development between 7,000 and 7,800 feet where it is a climax forest.

Southwestern ponderosa pine is shade intolerant. It occurs in stands that are open-grown, often poorly stocked and interspersed with meadows and parks. Fire has played a very important role in shaping ponderosa pine stands. In the past, low intensity fires would burn through ponderosa pine stands every 8-15 years, removing competing understory vegetation and down material. This resulted in irregular shaped stands of even-aged groups of trees varying in size, age and density. There is a greater variation in age groups than for ponderosa pine elsewhere as the occurrence of having good moisture, seed production and germination is quite infrequent.

At the lower elevation limits, pinyon-juniper may grow in association with ponderosa pine.

Where ponderosa pine is the sole species or low stocking and frequent fires are still part of the ecosystem, it can be considered a climax species. Some stands with trees over 450 years do exist but more commonly contain trees 300 to 350 years old.

Where periodic low intensity fires have been eliminated from the ecosystem, allowing more shade tolerant species such as Douglas-fir or white fir to survive, ponderosa pine is seral. It will eventually be replaced by more shade tolerant species. The existing open-grown stands are developing understories of Douglas-fir, white fir, and blue spruce with Gambel oak filling in the openings. These old-growth stands will eventually be replaced by these species if fire or some other low intensity disturbance is kept out of the ecosystem.

As with ponderosa pine elsewhere, it has been easy to access and has been heavily used since the mining days of the 1850's. It has been harvested for many things such as mine props, railroad ties, lumber, and firewood. Grasses growing in the open areas provided forage for livestock. Harvesting in the last 30 years or so has generally been by selection and has maintained the uneven-aged structure of old-growth stands. However, with the exclusion of fire, these stands are developing thick understories of Gambel oak, pine and Douglas-fir with a buildup of down dead material, providing excellent conditions for catastrophic fires that could completely eliminate the stands. Ponderosa pine will be replaced by the more shade tolerant species such as Douglas-fir. The dense Gambel oak understory is also difficult to remove, further complicating ponderosa pine being returned to a pre-settlement old-growth condition through management.

Description

Where fire has been present, stands will be climax and contain groups of large, old trees with little understory vegetation or down woody material and few standing dead trees. The age difference of the groups of trees would be large. Where fire is less frequent there will also be smaller size trees in the understory giving the stand some structure with various canopy layers. Dead, down material will be present in varying amounts along with some standing dead trees. In both cases the large old trees will have irregular open, large branched crowns (fig. 7). The bark will be lighter in color, almost yellow, thick and some will likely have basal fire scars.

Where ponderosa pine is seral, generally where fire has been controlled or outside of its optimum elevational range, stands will contain large trees with a multi-layer canopy with various amounts of down, dead material and standing dead trees



Figure 7. Large open-branched crown of an old ponderosa pine tree on the San Juan NF in southwestern Colorado.



Figure 8. An old-growth ponderosa pine stand on the San Juan NF with Douglas-fir and Gambel oak in the understory. Note the horse and rider in the lower left foreground.

(fig. 8). It will have an understory component of smaller trees such as Douglas-fir, blue spruce, white fir and Gambel oak, filling in the openings between the groups of the large older ponderosa pine. Eventually these species will replace ponderosa pine. There would be varying amounts of dead, down material and some standing dead trees. The large old trees will have irregular open, large branched crowns. The bark will be lighter in color, almost yellow and thick or platy.

Attributes

The following table lists the tree attributes that are being used to describe southwest ponderosa pine old growth.

Table 7—Summary of Old-Growth Attributes
Interior Ponderosa Pine – SAF Cover Type 237
(Southwest)

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches).....	18
Minimum Number of Trees Per Acre	10
Minimum Age	160
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches).....	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	None
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing.....	
	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Distinctive Bark	Yes
Down Dead Trees	Yes
Distinctive Crowns	Yes

ASPEN – SAF COVER TYPE 217

Narrative

The aspen (*Populus tremuloides*) cover type occurs throughout Region 2 and is associated with both montane and subalpine vegetation. Aspen is found within a broad elevational and moisture gradient occurring on all aspects and slopes, with the most extensive aspen forests occurring between 8,500 and 10,000 feet elevation, similar in elevation to lodgepole pine.

Aspen is the most shade intolerant tree species in the Rocky Mountain Region. Unlike the other major tree species in the Region, most aspen regeneration is by sprouting or suckering rather than by seeding. Aspen does produce seed but requires a bare mineral soil with constant mois-

ture to germinate. Rarely does this occur. Typically aspen regenerates after a major disturbance such as fire, abnormal wind or snow storms, or harvesting by clear felling. In conifer stands where aspen is a minor component, the majority of the regeneration after a stand replacing disturbance can be aspen. Aspen stands can reach an age of 160 or more years but the average life span is probably closer to 125 years.

Like lodgepole pine, aspen is generally considered a seral species. And like lodgepole pine, most aspen stands regenerate following some major stand replacing event such as fire. As the aspen matures, it will be usually replaced by the more shade tolerant Engelmann spruce and subalpine fir and in southwest Colorado also by white fir and Douglas-fir. The stand may still contain some scattered aspen.

In areas where no Engelmann spruce or subalpine fir seed source exists, the aspen stand will not be replaced by another species and can be considered climax. Two things could happen. The stand could reach its maximum life span and the overstory aspen trees rapidly fall with reproduction being sparse as aspen generally requires a major disturbance to initiate abundant sprouting. Or the overstory aspen trees could gradually fall. This path could have two possible results. The stand would not reproduce under itself. Or it would reproduce under itself, creating a multi-level canopy of various tree ages. This condition could continue for many generations. In any case it is difficult to predict which path the stand would take. Any down dead material would quickly decompose.

Description

Many people believe that aspen old growth does not exist. Using a definition of old growth where a stand must be climax to be old growth would eliminate much of the Region's aspen as old growth. However, the seral aspen condition can exhibit some old-growth characteristics. They may not last long in one place but overall in the landscape this old-growth condition can exist for quite sometime.

In a seral condition aspen old growth would be characterized as having a single canopy level of old trees. The aspen would be the overstory which would be closed with an understory of Engelmann spruce and subalpine fir. However, there could be instances where the conifers have become the overstory. Depending on the age of the understory could be a fair amount of structure and variation in tree diameters. There probably would not be much dead down material until the aspen stand began to degenerate. Then the amount of down dead material would accu-



Figure 9. An old-growth climax aspen stand on the Grand Mesa, Uncompahgre and Gunnison NF near Kebler Pass. Stand is approximately 100 years old.

mulate quickly as the aspen stand would degenerate rapidly. It is important to note that if the understory conifers are relatively young, the remaining stand may not be old growth.

Where aspen is considered climax, old growth will again include a canopy of old large aspen trees which would be closed. However, the stand would have little structure as there would be no understory conifers and little down trees or standing dead trees (fig. 9).

Once stand deterioration started, mature stems could die and fall rather quickly, or the process might take some time. An overstory of various levels with trees of various ages and some down dead trees would then exist. This condition might exist over successive generations. However, if no regeneration occurred when stems died, a single canopied, thinly stocked stand containing gaps in the canopy and down dead trees might persist until all the remaining trees had fallen.

Attributes

The following table lists the tree attributes that are being used to describe aspen old growth.

Table 8—Summary of Old-Growth Attributes
Aspen – SAF COVER TYPE 239

STANDARD ATTRIBUTES

LIVE TREES:

Upper Canopy - Older Component	
Minimum DBH (inches)	14
Minimum Number of Trees Per Acre	20
Minimum Age	100
Variation in Tree Diameter	No
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No

DEAD TREES:

Standing	
Minimum DBH (inches)	No
Minimum Number of Trees Per Acre	No
Down	
Minimum Pieces Per Acre	No

ADDITIONAL ATTRIBUTES:

Trees in Upper Canopy Are Slow Growing	Yes
Canopy Closure Greater Than 50%	Yes

QUALITY ATTRIBUTES:

Above Attributes in Excess of Minimums	Yes
Multiple Tree Canopy Layers	Yes
Multiple Tree Species	Yes
Standing Dead Trees 10" plus DBH	Yes
Down Dead Trees	Yes
Variation in Tree Diameters	Yes

PINYON-JUNIPER – SAF COVER TYPE 239

Narrative

Pinyon pine (*Pinus edulis*) and juniper (*Juniperus scopulorum*) comprise the pinyon-juniper cover type. Pinyon-juniper occurs as a forest type but more often as woodland as the trees are generally shorter than 20 feet and the crowns rarely touch. Pinyon-juniper is found in the southern and western portions of Region 2 extending just into the southern portion of Wyoming. Although pinyon-juniper usually refers to a mixture of both species it may consist of just either one. It occupies the lower and warmest elevations growing from 4,500 to 9,000 feet growing in a semiarid climate. It grows best just below the lower elevational range of ponderosa pine and may also intermix with ponderosa pine.

The stands exhibit considerable diversity in appearance and composition.

Stands may consist of all ages or one age. Dominant trees are often 400 years old. Trees 800 to 1000 years old have been recorded. The trees can be single stemmed or have a sprawling multi-stemmed character. A few stands may have closed canopies with single or both tree species, with little or no understory, but most stands are open-grown with widely scattered trees of one or both species with a wide variety of understory vegetation.

The pinyon-juniper woodland is shade intolerant. It is the climax cover type remaining on the

site until disturbed by fire. When disturbed by fire it will revert to grasses and eventually return to pinyon-juniper woodland.

The pinyon-juniper woodland has been used for grazing, firewood, building material and especially prized for its pine nuts for over 400 years. Few untouched natural stands probably exist. With the reduction in fire and possibly the reduction of competing grasses due to grazing, pinyon-juniper woodland is increasing its area and also tree densities within existing stands.

Description

An old-growth pinyon-juniper stand would be fairly open grown and contain a cohort of dominant old slow growing trees with little or no understory of grass or shrubs. The old trees would be single to multi-stemmed and shorter than the tree species at higher elevations. Being open grown it would be hard to distinguish if more than one tree canopy exists. The old trees would vary in diameter some would have dead branches/limbs including even part of the stem. There would be an occasional dead standing tree. Down dead material would exist and for quite awhile as the climate is semiarid. However a significant amount of the dead material would also exist on the live trees.

Attributes

The following table lists the tree attributes that are being used to describe pinyon-juniper old growth.

Table 9-Summary of Old-Growth Attributes
Pinyon-Juniper -
SAF COVER TYPE 239

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DRC (inches)	12
Minimum Number of Trees Per Acre	30
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DRC (inches)	10
Number of Trees Per Acre	1
Down	
Minimum Pieces Per Acre	2
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Canopy Closure Greater Than 35%	Yes

GLOSSARY OF OLD-GROWTH ATTRIBUTES

Forest Cover Type - a descriptive classification of forested land based on present occupancy of an area by tree species. Forest cover types are named after predominant tree species. Predominance is determined by basal area and the name is confined to one (ponderosa pine) or two (spruce-fir) species. The mixed-species/mixed conifer forest cover type is not a forest cover type in itself as defined by SAF but includes several forest cover types.

Attributes - The elements that are measured to determine the classification of a stand as old-growth. They are as follows:

Standard Attributes

1. Live trees:

Upper canopy - a grouping of the taller (dominant and codominant) trees in the stand. For live trees the following attributes of minimum DBH, number of trees per acre, and age refer to the upper canopy of the stand. There must be an upper canopy of trees meeting these minimums for the stand to be considered old growth.

Minimum DBH - this refers to trees in the upper canopy and not to average DBH for the stand which would generally be lower. It is the minimum DBH that would be required for the stand to be considered old growth. DBH is the diameter of a tree at 4.5 feet from the ground measured on the uphill side. It is generally outside bark. However, if the tree is dead and the bark has fallen then it would not include bark.

Minimum DRC - this is used for woodland species such as pinyon-juniper. DRC is the diameter at the root collar. The root collar is the region where the root and stem merge.

Minimum Number of Trees Per Acre - the minimum number of trees per acre in the upper canopy meeting or exceeding the above minimum DBH.

Minimum Age - the minimum mean age of the trees in the upper canopy meeting or exceeding the above DBH. This would be total tree age. Age is just one part of the equation for a stand to be old growth. A stand could meet the minimum age requirements and may still not be old growth. Age has been included as an attribute to give an idea of what age old growth is thought to begin. It is the attributes that develop with age such as stand structure, dead trees, down material, distinctive bark, net stand growth near zero and tree decadence that need to be considered. Some stands may meet the minimum age require-

ment but have not yet developed these other attributes.

Variation in Tree Diameters - there are trees of various diameters present in the stand. This would allude to an uneven aged stand and/or a stand with more than one tree species. All of which suggest a more structured stand. No diameter ranges have been suggested as little is known what they should be. However it was common consensus that such an attribute is an important characteristic of old growth.

Decadence - this refers to the trees in the upper canopy. The tops or crowns of some of the trees are broken, dead, deformed or have sparse foliage or the stems have rot and/or root rot. These are indicators that the stand could be past maturity and declining. Growth is being succeeded by mortality. The stand is not young and vigorously growing. It could also mean that the stand has been infected with some disease and that's all. But if the above attributes are present in a stand, decadence would be a further indicator of old growth. No values are listed as no data is available on how many trees should have reached senescence.

Multiple Tree Canopy Layers - more than one tree canopy layer or story is present. A canopy layer or story is roughly a horizontal stratum or layer formed by the crowns of trees. A stand can have one to many canopy layers. Generally trees of the same age or species tend to grow to the same height in a stand. This height or horizontal layer formed by the tree crowns would be a canopy layer. The tallest canopy layer representing the most crown cover in a stand would generally be the upper canopy layer.

Dead Trees

Standing - a tree, vertical or near vertical, that is supporting itself or leaning on another tree. A standing dead tree is also called a snag.

Minimum DBH - the minimum diameter at 4.5 feet that a dead tree would be considered for old growth.

Minimum Number of Trees Per Acre - the minimum number of dead trees per acre that are equal to or above the minimum DBH to be considered for old growth.

Down - tree that has fallen down, is dead and laying horizontal. May be a whole tree or section of one. All, part or none of the whole tree or section may be touching the forest floor.

Additional and Quality Attributes

Trees in Upper Canopy Are Slow Growing - trees are growing slower than in the past. This indicates the stand has reached maturity and/or may be over-mature, that is past it's peak of maximum growth. Generally the crowns are beginning to flatten and become broader and more open.

Canopy Closure Greater Than 50% - 50% or more of the ground is covered by foliage of the upper canopy in a vertical projection.

Wide Range of Tree Vigor - trees in the stand are growing at various rates from vigorous growth to almost no growth.

Net Growth Near Zero - this applies to the stand as a whole. Basically the amount of new growth is offset by trees dying.

Patchiness - a stand has breaks in the upper canopy level and/or has openings. An opening is defined as an area within the stand that contains vegetation different than the majority of the stand, such as grasses, forbs, shrubs and young trees.

Many Stages of Decomposition - this refers to the dead material either standing or down. The dead material is in various conditions of decay.

Multiple Tree Species - there is more than one tree species in the stand.

Distinctive Bark - some species of trees with age acquire bark characteristics that are much different (distinctive) than when younger and vigorously growing. The bark becomes platy that is it has large patches with deep furrows in between the patches. The bark may also be different in color for some species. Darker for lodgepole pine, reddish for spruce-fir and light tan or yellow for ponderosa pine.

Distinctive Crowns in the Upper Canopy - as they age some species of conifer trees acquire crown characteristics that are much different than when young. The crowns lose their conical shape as growth diminishes with the crowns flattening. Crowns develop holes, become misshapen and foliage develops dead areas. Branching is more open with large branches. Part or all of the crown can die. These characteristics are very evident in older ponderosa pine and lodgepole pine trees. These characteristics can also be attributable to insects or pathogens so the other attributes need to be considered as well.

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Montana Partners in Flight

Montana Bird Conservation Plan
Version 1.0 - Jan. 2000

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workshops, ecologically sensitive area of remnant grassland and shrubsteppe in the northern Great Plains (The Nature Conservancy 1999). We will build upon this effort to implement conservation measures in these polygons.

Land Trusts. Land trusts are non-profit organizations that help landowners find ways to protect their land in the face of ever-growing development pressure. They work with landowners to write conservation easements (permanent deed restrictions that prevent harmful land uses), acquire land through donation and purchase, or devise other plans to maintain all kinds of open space--wetlands, wildlife habitat, ranches, shorelines, forests, scenic views, farms, watersheds, historic estates, and recreational areas. There are at least 10 land trusts operating on a statewide, regional or local level in Montana (Appendix C), including the Montana Land Reliance, Trust for Public Lands, Five Valleys Land Trust, the Nature Conservancy, and the Rocky Mountain Elk Foundation. Well over 600,000 acres have been protected through conservation easements in Montana, the highest state total in the United States (Montana Fish, Wildlife and Parks 1999).

THE PRIORITIZATION PROCESS

Species Prioritization

Partners in Flight uses a system that identifies species of conservation priority in each of its planning units, rather than writing planning information about all species. It is assumed that if conservation measures are focused on these species and their habitats, the other species in the area will benefit as well.

We identified a pool of species from among the breeding avifauna, which represents priorities for conservation action within Montana (Table 2). Note that a species may be considered a priority for several different reasons, including global threats to the species, high concern for regional or local populations, or high state responsibility for conserving large or important populations of the species. The different potential reasons for priority status are represented by shaded cells in Table 2. Our primary means of prioritizing species was through the PIF prioritization scores generated by the Colorado Bird Observatory (Hunter et al. 1993, Carter et al. 1998). This system ranks species according to seven measures of conservation vulnerability. These include four global measures (i.e., they do not change from area to area), as well as measures which are specific to each physiographic area or state. A total rank score is then derived, which is a measure of overall conservation priority; scores for all breeding species in Montana are found in Appendix B.

The Partners in Flight Species Prioritization scheme was first developed in 1991, and has been continually reviewed and refined in the years following inception (Carter et al. 1998). The system ranks each species of North American breeding bird based upon seven measures of conservation "vulnerability". These factors include relative abundance (interspecific; RA), size of breeding (BD) and non-breeding (ND) ranges, threats to the species in breeding (TB) and non-breeding (TN) areas, population trend (PT), and relative density (intraspecific; AI) in a given planning unit compared to the maximum reached within its range. Each species is given a score of 1-5 in each category, with 1 indicating the least amount of vulnerability with regard to that parameter and 5 the most. Scores in each category are then summed to produce a composite score potentially ranging from 7-35. Species with relatively high overall scores (e.g. >22) are considered most vulnerable to extinction (although they often are not endangered at present) and usually need conservation measures or at least need to be carefully monitored through their ranges.

We used the following criteria to help us select priority bird species in Montana:

Species of importance in Montana. (PA 64, 39) Species scoring ≥ 22 in the PIF system, for Montana or either physiographic area overlapping the state. Indicates a species of moderate or high global vulnerability, and with relatively high abundance as well as declining or uncertain population trend in the physiographic area or in Montana.

Species showing significant declines. Species for which BBS data sample sizes are adequate to indicate significant declines over the period 1966-1996 (CBO scores of 5/1 or 5/2 for population trend (PT) and population trend uncertainty (PTU) in PA 39, PA 64 or MT). Species whose populations are declining range wide may or may not be declining in a given planning unit. It is important to focus active management in those areas where declines should be stabilized or reversed and to identify the factors responsible for stable or increasing trends in other areas so that similar conditions can be achieved where needed.

High responsibility species. (by Physiographic Area) Species with relatively high proportion ($>20\%$) of their global population for either of the physiographic areas overlapping Montana. Percent of population calculated from percent of range area, weighted by BBS relative abundance (see Rosenberg and Wells, in press). Percent of geographic range used for species with inadequate relative abundance data. Signifies high responsibility for long-term conservation of species, even if not currently threatened. Physiographic areas with large percentages are able to take greater conservation responsibility for that species because affecting an increase or decrease in a population trend has greater potential impacts in areas where numbers of individuals are greater.

Special status. (FWP, NHP, BLM, USFS, Watch List) We included for consideration any bird species listed by one of the following entities as being of management concern. Typically, a species was not considered high priority if it appeared on only one of the following lists; those appearing on 3 or more were considered a priority even if other criteria were not met:

S	Montana Fish, Wildlife and Parks Species of Special Concern
N	Montana Natural Heritage Program Sensitive Species
B	Bureau of Land Management Special Status Species
F	U.S. Forest Service (Region 1) Sensitive Species
W	National Audubon's National Watch List

Special Consideration. (Local Concern) Species of justifiable local concern or interest. These were generally habitat obligates or species of immediate concern, as identified by Montana PIF (P). May represent geographically variable population or be representative of specific habitat of conservation concern. These were generally selected based on the specific expertise of planning participants.

Additional listed species. Species on federal endangered or threatened list not meeting any of the above criteria.

Montana Priority Levels

We assigned each of the 141 species in Table 2 to one of the following four priority levels. All species designated as levels I-III are treated in this plan. Generally, level I species are the highest priority and are the focus of proposed conservation actions. Most biological objectives are integrated, however, and addresses multiple species needs. The names of these levels (e.g. "Conservation Action") should not therefore be considered mutually exclusive.

I. Conservation Action. Generally high overall scores (>22), declining population trends (PT/PTU

- of 5/1 or 5/2), and/or high area importance (PA % Pop.>20). These are the species for which Montana has a clear obligation to implement conservation
- II. Monitoring Species.** Species in need for which we have responsibility, but with lesser threat or stable/increasing populations in the state. As compared to level I, these species have generally lower overall scores, in many cases because they are poorly sampled by the BBS. Montana has a high responsibility to monitor the status of these species, and/or to design conservation actions.
 - III. Local Concern.** Species of concern (often designated as such by participating agencies) which rank lower, are not in imminent risk, or which are near-obligates for high priority habitat. Presence of these species may serve as added criteria in the design and selection of conservation or monitoring strategies.
 - IV. Non-Priority.** Formerly suggested for inclusion in the planning effort, but recommended for deletion because of occurrence as rare migrants only, extremely peripheral occurrence, or lack of imminent risk (widespread, generalist, increasing).

BIRD CONSERVATION PRIORITIES IN MONTANA

Priority Bird Species List

Our prioritization process led to the selection of the following 107 species (one group) that merited priority status in the state. These included 14 species at priority level I, 43 at level II, and 51 level III, or "local concern" species:

Level I (n=14)

Common Loon
Trumpeter Swan
Harlequin Duck
Sage Grouse
Piping Plover
Mountain Plover
Interior Least Tern
Flammulated Owl
Burrowing Owl
Black-backed Woodpecker
Olive-sided Flycatcher
Brown Creeper
Sprague's Pipit
Baird's Sparrow

Level II (n=43)

Horned Grebe
White-faced Ibis
Barrow's Goldeneye
Hooded Merganser
Bald Eagle
Northern Goshawk
Ferruginous Hawk
Peregrine Falcon
Ruffed Grouse
Columbian Sharp-tailed Grouse
Long-billed Curlew
Marbled Godwit
transient shorebirds
Franklin's Gull
Caspian Tern
Common Tern
Forster's Tern
Black Tern
Black-billed Cuckoo
Yellow-billed Cuckoo
Black Swift

Vaux's Swift
Calliope Hummingbird
Lewis's Woodpecker ✓
Red-headed Woodpecker ✓
Red-naped Sapsucker ✓
Williamson's Sapsucker ✓
Three-toed Woodpecker ✓
Pileated Woodpecker ✓
Willow Flycatcher
Hammond's Flycatcher
Cordilleran Flycatcher
Winter Wren
Veery
Loggerhead Shrike
Red-eyed Vireo
Lazuli Bunting
Brewer's Sparrow
Lark Bunting
Grasshopper Sparrow
McCown's Longspur
Chestnut-collared Longspur
Black Rosy-finch

Level III (n=51)

Clark's Grebe
American White Pelican
American Bittern
Black-crowned Night-heron
Northern Harrier
Sharp-shinned Hawk
Swainson's Hawk
Blue Grouse
White-tailed Ptarmigan
Yellow Rail
Killdeer
Black-necked Stilt
Willet
Wilson's Phalarope
Eastern Screech-owl

Western Screech-owl
Great Gray Owl
Boreal Owl
Short-eared Owl
Common Poorwill
Chimney Swift
Rufous Hummingbird
Downy Woodpecker
Least Flycatcher
Clark's Nutcracker
Chestnut-backed Chickadee
Sedge Wren
American Dipper
Golden-crowned Kinglet
Townsend's Solitaire
Varied Thrush
Gray Catbird
Sage Thrasher
Cassin's Vireo
Plumbeous Vireo
Warbling Vireo
Nashville Warbler
Townsend's Warbler
Ovenbird
American Redstart
MacGillivray's Warbler
Green-tailed Towhee
Chipping Sparrow
Clay-colored Sparrow
Lark Sparrow
LeConte's Sparrow
Nelson's Sharp-tailed Sparrow
Song Sparrow
Bobolink
Red-winged Blackbird
Yellow-headed Blackbird
Brewer's Blackbird
Orchard Oriole
Cassin's Finch
Red Crossbill

Rockies. Its nomadic nature makes it hard to monitor and to manage for. Habitat manipulations that influence cone production have implications for the species' productivity. Montana has potential as an excellent area to investigate the relationships between crossbill races, tree species forest management.

Distribution. The Red Crossbill is distributed throughout the west from eastern New Mexico north to Alaska then east across southern Canada (north of the Great Plains region) and northern United States. Breeding has been documented throughout most of Montana with the exception of the northeast corner (Montana Bird Distribution Committee 1996).

Habitat Requirements. The Red Crossbill is found within a wide variety of mature coniferous forests and mixed deciduous/coniferous forest. Usually they are associated with mature open canopy tree stands. They have been found in types ranging from dry savannah ponderosa pine, Douglas-fir, up to grand fir and subalpine fir types. Gap analysis (Redmond et al. 1998) identified 6.5 million ha of Crossbill habitat in the State.

Ecology. The Red Crossbill is a very nomadic species with its distribution and reproduction tied to the coniferous seed crop production. Breeding can occur at almost any time of the year. Research has indicated that there are up to 6 distinct forms of Red Crossbills, which differ in song type and in morphology. Though little is known of the individual distribution of these types in the state, each is apparently adapted to feed on the cones of a different tree species. Several of these (potential species) do occur in Montana.

Management Recommendations. Any silvicultural treatments which emphasize seed production in conifers are likely to improve habitat suitability for this species. In Dry Forest, maintaining some element of Douglas-fir is important for those crossbills adapted to feed on its smaller seeds, in addition to those adapted to feeding on ponderosa pine. Douglas-fir is also most likely the preferred tree for nesting.

DF

Habitat and Population Objectives: Dry Forest

Mature Ponderosa Pine Restoration. Restoration activities in dry forest habitat types are important due to the dramatic changes in tree species composition and stand structure that have affected most dry forest habitat in western North America. An awareness and understanding of these changes, and the desirability of restorative activities in ponderosa pine habitat, is ubiquitous in Forest Service regions in the American West. The political will (or feasibility) and financial resources to accomplish restoration, however, vary throughout the West (Amundson 1998; Denton 1998; Dick 1998; Shafer 1998)

Habitat Objectives for Dry Forest

- Retain all current old-growth stands that meet minimum regional old-growth characteristics (Table 8). Restore historic structural characteristics with no elimination of large trees or snags.
- Manage for the long-term maintenance of 25% of dry forest habitat (per 4th order watershed) as old growth based on mean values of regional old-growth characteristics (Table 9). Values for old-growth characteristics should be no lower than 25% below mean values; and 50% of old-growth stands should meet or exceed regional mean values for old-growth elements.

25%

Table 8. Minimum values of old-growth characteristics, Dry forest habitats (ponderosa pine and Douglas-fir), USFS Region 1 (Green et al. 1992)

<u>Forest Types</u>	<u>Ave. Age of Large Trees</u>	<u># Large Trees</u>
Warm, dry ponderosa pine (west side)	170 yr	8 trees/ac \geq 21 in dbh
Cool, dry Douglas-fir (west side)	170 yr	8 trees/ac \geq 21 in dbh
Warm, dry ponderosa pine (east side)	180 yr	4 trees/ac \geq 17 in dbh
Cool, dry Douglas-fir (east side)	200 yr	5 trees/ac \geq 19 in dbh

- Restore the role of fire, and use thinning as necessary, to restore historic conditions.
- Retain all snags and broken-top trees \geq 9 in dbh and all large trees \geq 17 in dbh in harvest units.
- Manage for single- and double-storied stands with open conditions (<50% cover) in dry forest habitat of all age classes.

Table 9. Mean values of old-growth characteristics, Dry forest habitats (ponderosa pine and Douglas-fir), USFS Region 1 (Green et al. 1992)

<u>Forest Type</u>	<u>Ave. Age of Large Trees</u>	<u># of Large Trees</u>	<u># Standing Dead Trees</u>
Warm, dry ponderosa pine (west side)	246 yr	17 trees/ac \geq 21 in dbh	6 trees/ac \geq 9 in dbh
Cool, dry Douglas-fir (west side)	232 yr	18 trees/ac \geq 21 in dbh	7 trees/ac \geq 9 in dbh
Warm, dry ponderosa pine (east side)	215 yr	24 trees/ac \geq 17 in dbh	7 trees/ac \geq 9 in dbh
Cool, dry Douglas-fir (east side)	229 yr	31 trees/ac \geq 17 in dbh	10 trees/ac \geq 9 in dbh

- Manage for a variety of habitat conditions at the landscape level, particularly varied understory conditions, to meet the needs of the Flammulated Owl and Lewis's Woodpecker:

Priority Species Objectives.

The absence of suitable nest sites is usually considered the limiting factor for cavity-nesting species (Thomas et al. 1975). Retention of all existing large snags and broken-top trees, and management for adequate numbers over the landscape is a critical objective in order to maintain viable populations of Lewis's Woodpeckers and Flammulated Owls. The retention of all snags and broken-top trees \geq 9 in. dbh and all

habitat.

Distribution. The Townsend's Warbler breeds from southeastern Alaska, south through western Canada to central and northeastern Oregon, northern Idaho, northwestern and southcentral Montana, and northwestern Wyoming. In Montana, it only breeds in the western quarter of the state (Montana Bird Distribution Committee (1996). It winters in central and southern California, western Mexico, and the highlands of Central America.

Habitat Requirements. Townsend's Warblers nest in coniferous forests or mixed coniferous/deciduous forests where coniferous trees comprise a predominant feature of the habitat (Bent 1953, Erskine 1977). Surveys in northern Idaho and Montana detected them most frequently in cedar-hemlock forests, followed in order by mixed conifer, spruce-fir, Douglas fir, riparian shrub (probably adjacent or within forest), lodgepole pine, and ponderosa pine (Hutto 1995). In those surveys, they were less abundant in drier and more open forest cover types and in forest patches that have been harvested. They were more likely to occur on points with a few or lots of snags within 10 m (30 ft) of the survey points and were nearly 5 times more common on points with a lot of dead and down material (Hutto 1995). In a review of several studies, Hejl et al. (1995) listed the Townsend's Warbler as an old-growth associate in studies in Montana, Idaho, and Oregon, although another Idaho study found them present but not clearly associated with old-growth, mature, or immature forests. Hejl et al. (1995) found Townsend's Warblers to be less abundant in clearcut or partially cut forest than in uncut forest.

Ecology. Townsend's Warblers build cup-shaped nests in and near the tops of coniferous trees on a branch well away from the trunk. They feed mostly on insects (e.g., weevils, bugs, leafhoppers, caterpillars) and spiders, gleaning them from the foliage or hawking them from the air (Ehrlich et al. 1988, Groves et al. 1997). Herman and Bulger (1979) found breeding densities of 10-47 pairs/40 ha (100 ac) in Oregon mixed-coniferous forests.

Management Issues. Hutto (1995) stated that the Townsend's Warbler is probably one of the more sensitive species to timber harvesting activity as evidenced by a continuous decline in probability of occurrence with increasing amounts of timber removed. It appears from Hutto's data that they are found more frequently on points where no edge is within 100 m (305 ft). Management at the landscape level should allow for retention and recruitment of mature mixed conifer stands.

Habitat and Population Objectives: Moist Douglas-fir and Grand fir

Habitat Objectives - Old Growth:

- Existing old-growth stands (> 170 years, meeting minimum criteria for region and forest type: Green) should be retained whenever possible, especially in areas that are in likely refugia from stand-replacement fires.
- Maintain mature or overmature stands for recruitment into old growth, toward goal of 20% of the

20%

habitat type managed for old-growth conditions; these should be located in likely refugia from fire or in areas providing connectivity to isolated old-growth stands.

- Abnormally dense young to mature stands surrounding old growth could be targets for forest health treatment (thin-from-below or partial cut) to reduce the risk of fire spread into old-growth stands.
- Old-growth should be well-scattered throughout forest lands rather than grouped into adjacent areas (McClelland et al. 1979); stands may be of variable size but most should be at least 50-100 acres (McClelland et al. 1979), imbedded within an area of 364-1000 acres of mature or partial cut forest managed snag and log retention (McClelland et al. 1979, Bull and Holthausen 1993). Some larger blocks, especially in mesic areas where historically more likely (see Pileated Woodpecker).
- Encourage retention of snags and logs in all silvicultural treatments [Bull and Holthausen recommended > 8 snags/ha, at least 20% of which are > 50 cm, and . 100 logs/ha, with a preference for logs > 38 cm]
- Refrain from sanitation cutting of insect-killed trees within the 20% of lands managed for old-growth; limit firewood cutting to snags less than 40 cm and discourage use of larch, ponderosa pine, and broadleaf species (McClelland et al. 1979).

Prescribed Fire: (see also section on Burned Forests)

- Expand the opportunity for allowing lightning fires to burn.
- Re-ignite suppressed lightning fires when conditions come back into prescription.
- Use broadcast burning to restore normal fuel conditions so that lightning fires can be allowed to burn.
- Capitalize on opportunities to develop stand conditions that approximate those created by stand-replacement fire regimes.

Timber Harvest:

- Vary timber harvest methods, using more even-age prescriptions ("messy" clearcuts and seed-tree cuts) in more mesic sites that would have historically had stand-replacement fire regimes. Retain seed trees permanently, preferably large larch (> 40 cm), and retain snags and occasional clumps of green trees.
- Produce a diversity of stand structures in mixed and variable fire regime types. Some regular thinning methods may be appropriate, but vary with more heterogeneous stand prescriptions. Leave clumps of intact forest, snags, and large logs.

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Management Recommendations for the Northern Goshawk in the Southwestern United States

**Richard T. Reynolds¹, Russel T. Graham,
M. Hildegard Reiser, Richard L. Bassett, Patricia L. Kennedy,
Douglas A. Boyce, Jr., Greg Goodwin, Randall Smith, and E. Leon Fisher**

**Rocky Mountain Forest and Range Experiment Station and
Southwestern Region Forest Service, U.S. Department of Agriculture²**

¹ Author affiliations are listed in Appendix 6.

² The Rocky Mountain Station is headquartered in Fort Collins, Colorado, in cooperation with Colorado State University; the Southwestern Region is headquartered in Albuquerque, New Mexico.

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VEGETATIVE STRUCTURAL STAGES:
Successional stages for a mixed-species forest ecosystem

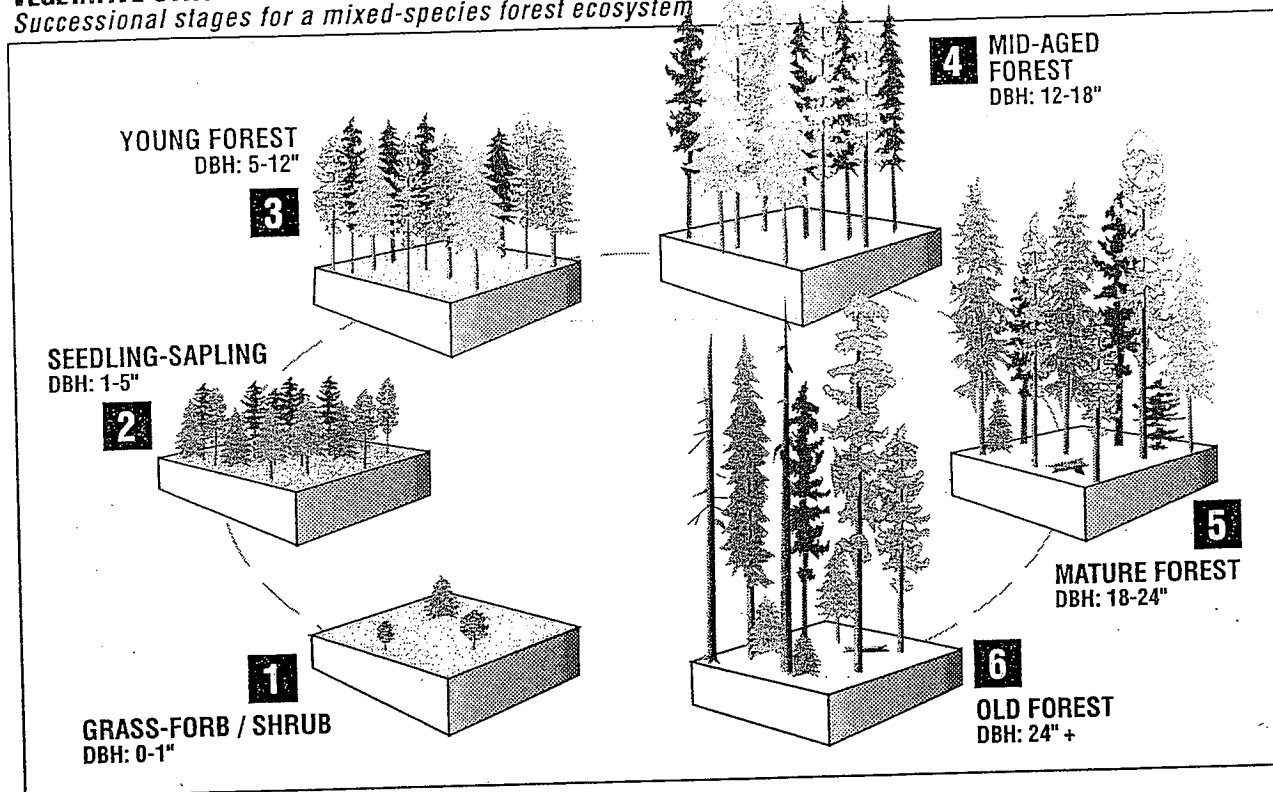


Figure 1. Forest vegetation structural stages and their associated diameter breast height (DBH) ranges.

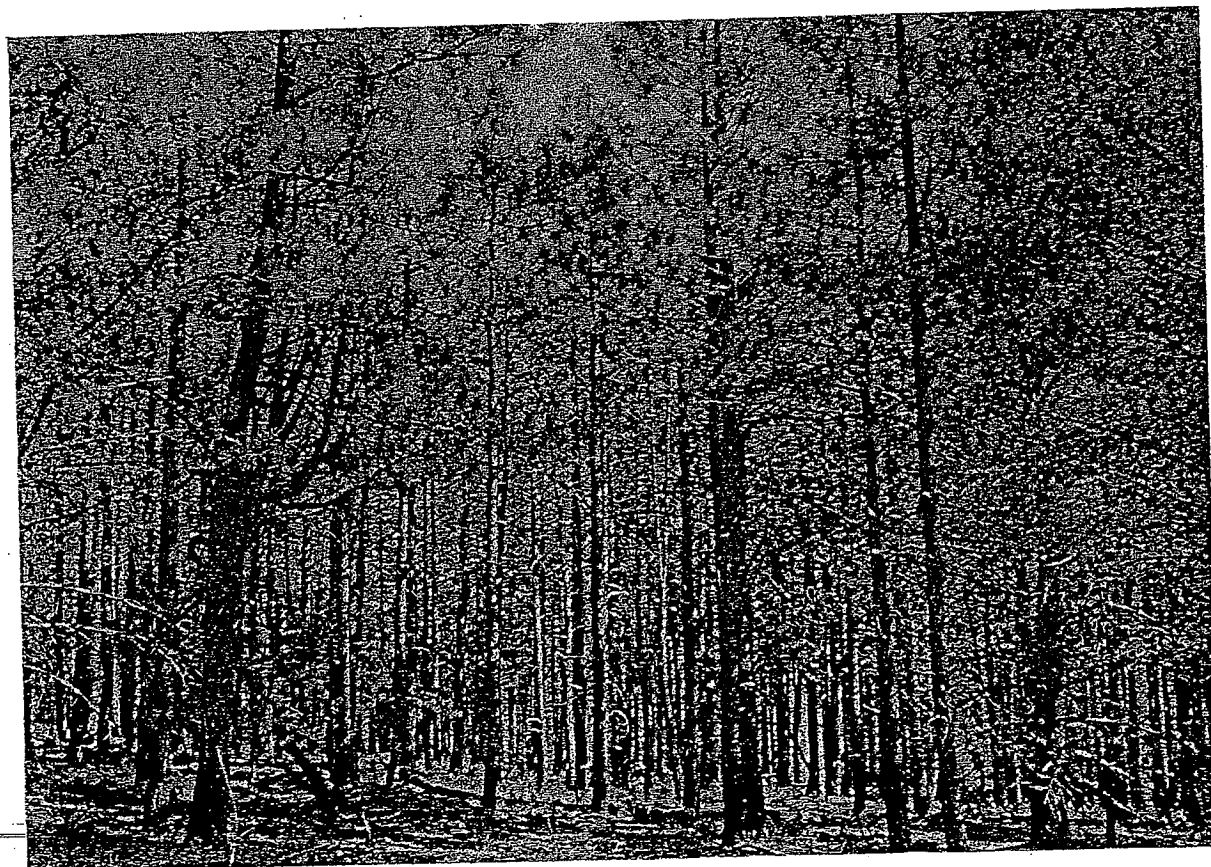


Figure 2. Dense "thicket" of small-diameter trees.

goshawk pair, and represents an area of concentrated use by the family from the time the young leave the nest until they are no longer dependent on the adults for food (up to two months). These areas are important for fledglings; they provide hiding cover and prey on which to develop hunting skills. PFAs have patches of dense trees, developed herbaceous and/or shrubby understories, and habitat attributes (snags, downed logs, small openings) that are critical for many goshawk prey (Fig. 4).

The foraging area is approximately 5,400 acres in size, and surrounds the PFA. Hunting goshawks evidently use available habitats opportunistically. This opportunism suggests that the choice of foraging habitat by goshawks may be as closely tied to prey availability as to habitat structure and composition. Goshawks hunt from tree perches by scanning lower portions of the forest (ground, lower canopy) for prey. Because of visual limitations in dense forest environments, an open understory enhances detection and capture of prey (Fig. 5). Raptor (hawks, falcons, owls) populations are often limited by availability and abundance of their prey. The recommendations presented here are based on information available on how foraging goshawks use

their habitat, and was supplemented with information on the habitats, foods, and cover of important goshawk prey.

Goshawk Prey

A comparison of goshawk diets from disparate areas within North America showed that, while as many as 50 species are eaten, about 20 are common in the diets. Fourteen species were important in the diet of southwestern goshawks. Information on the distribution, habitat, special habitat needs, home range size, and populations of these 14 prey species were gleaned from the literature. A synthesis of this information provided a set of "desired forest conditions" that would result in sustainable populations of each prey. Because no single prey species is likely to be abundant enough to support goshawks, especially during the winter and extreme environmental fluctuations (periods of drought), habitats for and populations of all 14 prey are necessary.

Selected goshawk prey include squirrels, rabbits, woodpeckers, jays, and grouse. Specific habitat attributes used by these species include: snags,

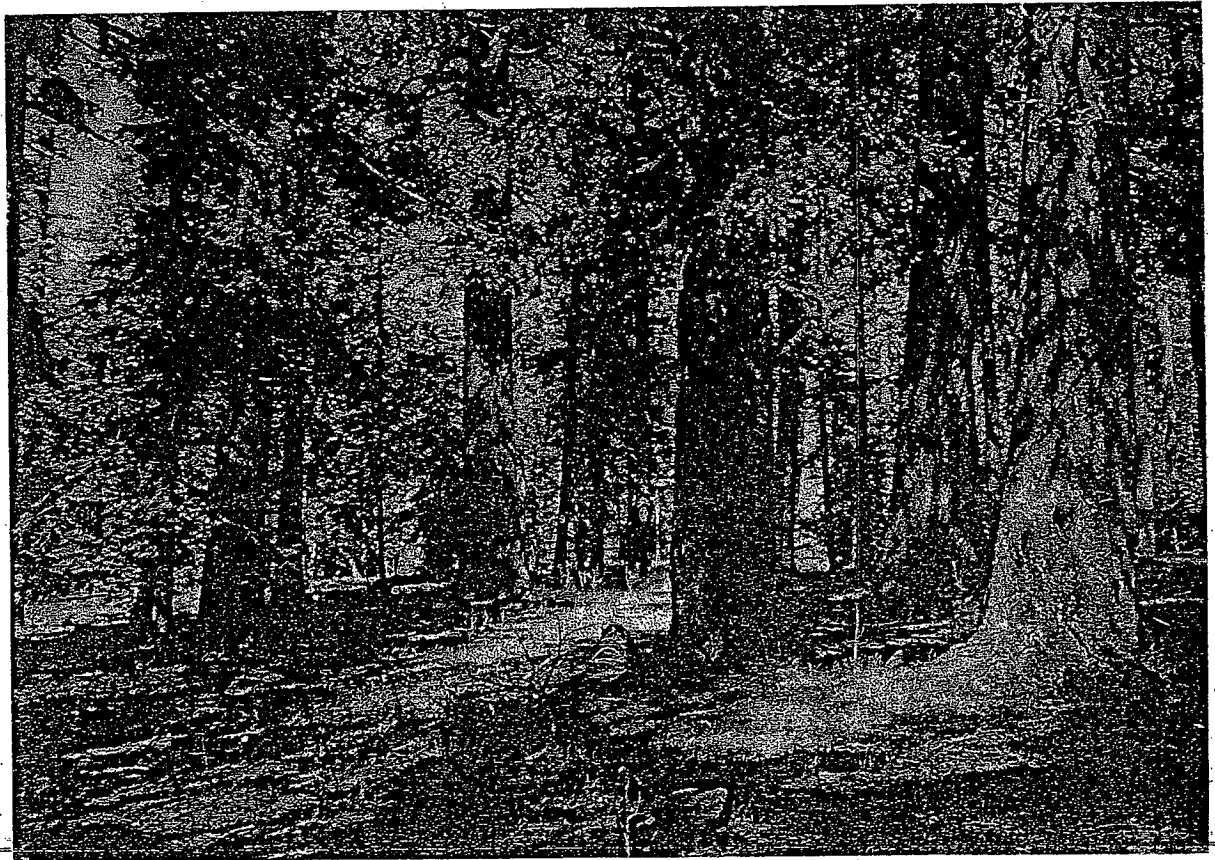


Figure 4. PFAs have patches of dense trees, developed herbaceous and/or shrubby understories, and habitat attributes (snags, downed logs, small openings) that are critical for many goshawk prey.

browsing and grazing have accentuated this loss. In addition to these changes, timber harvesting, which began in the 1800s, has focused on large trees, resulting in few remaining mature and old forests and associated habitat attributes.

Management Recommendations

The present conditions in southwestern ponderosa pine and mixed-species forests reflect the extent of human interference with natural processes. Given the improbability of returning to the previous frequencies of natural disturbances, some active management (mainly thinning and prescribed fire) will be necessary to produce and maintain the desired conditions for sustaining goshawks and their prey. In some spruce-fir forests, natural processes are still functioning and little or no management may be necessary to maintain the desired conditions.

These recommendations were specifically designed to provide breeding season habitat for the goshawk and its prey. It is not known whether goshawks in the Southwest winter on their nesting home ranges; if they do winter there, then these recommendations will provide habitat and food year-round.

Nest Areas (30 acres each)

Three suitable nest areas should be maintained per home range. In addition, three replacement nest areas per home range should be in a development phase, using intermediate treatment and prescribed fire. Suitable areas may be lost because of insect epidemics, catastrophic fire, or other factors. Nest areas are typified by one or more stands of mature or old trees and dense forest canopies. No adverse management activities should occur at any time in suitable nest areas. Desired forest conditions for the nest stands and management recommendations for maintaining and developing nest stands within nest areas are presented in Tables 1 and 2.

Post Fledging-Family Areas (PFA) (420 acres)

The PFA contains a variety of forest conditions and prey habitat attributes. Interspersed small openings, snags, downed logs, and woody debris are critical PFA attributes. To sustain the desired canopy cover, size of trees, and the specified portions of different forest ages within the PFA, regeneration of 10 percent of the PFA may be required every 20 years. Other management tools, such as prescribed fire and removing understory trees, are suggested for sustaining other critical elements of goshawk habitat

(Table 2).

Small openings in the forest are desired habitat for some prey species and are required for forest regeneration (Fig. 6). If forested openings are 1 acre or greater in Ponderosa pine and mixed species, then 3 to 6 large mature and/or reserve old trees per acre should be left in groups. If spruce-fir forest openings are 0.5 acres or greater, a group of 6 reserve trees are required per 0.5 acres. Reserve trees are not necessary in smaller openings; this component can be met in adjacent forested areas. Ponderosa pine and other seral conifers can be planted, and, depending on forest type, aspen and oak regeneration are encouraged. Snags, downed logs, and woody debris should be present throughout the PFA.

All management activities in the PFA should be limited to the period from October through February. Prescribed burning is the preferred method for management of woody debris. Thinning from below (removing understory trees) is preferred for maintaining desired forest structures, and a variable spacing of trees is preferred for developing group trees with interlocking crowns. Road densities should be minimized, and permanent skid trails should be used in lieu of permanent roads. Forage utilization should average 20 percent by weight and should not exceed 40 percent in any area to maintain grass and forb layer. Browse utilization should average 40 percent by weight (Table 2). These recommendations are designed to provide foods (leafy material, berries) and cover for goshawk prey.

Foraging Area (5,400 acres)

Both the desired conditions and the management recommendations for the foraging area are similar to the PFA. The distribution and proportion of vegetative structural stages and the requirements for habitat attributes such as reserve trees, snags, and downed logs are the same as the PFA. Because the foraging area need not provide hiding cover for fledgling goshawks, a more open canopy is preferred -- 40 percent in the mid-aged forests and 40 to 60 percent in the mature and old forests, depending on the forest type. Openings (up to 4 acres), for herbaceous and shrubby understory development and tree regeneration, are desired in ponderosa pine and mixed-species forests; smaller openings are desired in spruce-fir forests (Table 1). Specific management recommendations to obtain the desired conditions for the foraging area are identical to the PFA (Table 2).

Table 1. Desired forest conditions in three forest types for sustaining northern goshawks and their principal prey species in the Southwest.

Attribute	Nest Area ^a	Home-Range Components			Foraging Area		
		Ponderosa Pine	Mixed-Species	Spruce-fir	Ponderosa Pine	Mixed-Species	Spruce-fir
VSS distribution ^b							
grass/forb/shrub VSS 1 (%)	0 ^c	10 ^c	10 ^c	10 ^c	10 ^c	10 ^c	10 ^c
seedling-sapling VSS 2 (%)	0	10	10	10	10	10	10
young forest VSS 3 (%)	0	20	20	20	20	20	20
mid-aged forest VSS 4 (%)	0	20	20	20	20	20	20
mature forest VSS 5 (%)	100	20	20	20	20	20	20
old forest VSS 6 (%)	100	20	20	20	20	20	20
Canopy cover							
mid-aged forest VSS 4 ^c	NA ^d	1/3 60+	60+	60+	40+	1/3 60+	1/3 60+
		2/3 50+				2/3 40+	2/3 40+
mature forest VSS 5 (%)	50-70+	50+	60+	70+	40+	50+	60+
old forest VSS 6 (%)	50-70+	50+	60+	70+	40+	60+	60+
Years to mid-aged VSS 6	200-300	200-250	200-300	200-300	200-250	200-300	200-300
Opening size							
maximum size (acre)	NA	2	2	1	4	4	1
width--maximum (ft)	NA	200	150	125	200	200	125
Reserve trees ^e							
number of groups/acre	A ^f	1	1	2 ^h	1	1	2 ^h
number (per group)	NA	3-5	6	6	3-5	6	6
opening threshold ^g (acres)	NA	>1	>1	>0.5	>1	>1	>0.5
Snags (no/acre)	NR ⁱ	2	3	3	2	3	3
Downed logs (acre)	NR	3	5	5	3	5	5
Woody debris (tons/acre)	NR	5-7	10-15	10-15	5-7	10-15	10-15

^a Suitable nest areas only; attribute values may vary by forest type.

^b VSS; Vegetation Structural Stages, a forest description based on the tree diameter distribution within a stand. For example, if the majority of the stems of a stand (based on basal area) were located in the 12-18 inch diameter class, the stand would be classified as a VSS 4. General diameter limits are: VSS 1= 0-1" DBH; VSS 2= 1-5" DBH; VSS 3= 5-12" DBH; VSS 4= 12-18" DBH; VSS 5= 18-24" DBH; VSS 6= 24"+ DBH. DBH = Diameter at Breast Height (4.5 ft.).

^c Proportion of the area.

^d NA; not applicable.

^e Reserve trees; standing trees left after harvesting that will be allowed to become snags and downed logs.

^f A; applicable, clumpiness, or groups of large trees is also desirable.

^g When threshold size is exceeded, reserve trees are necessary.

^h One group per 0.5 acres.

ⁱ NR; not required, but presence of these features are not detrimental.

majority of stems based area

Table 2. Management recommendations for sustaining habitat for northern goshawks and its principal prey species in the Southwest.

Attribute	Home Range Components ^a		
	Nest Area	PFA	Foraging Area
Number of areas	6	1	1
Suitable ^a	3	NA	NA
Replacement ^a	3	NA	NA
Size (acre)	30 (Total = 180)	420	5,400
Management season ^b	Oct-Feb	Oct-Feb	Year-long
Regeneration of forest			
Conifer	None	Yes	Yes
Aspen & Oak	None	Yes	Yes
Planting	None	Yes	Yes
Thinning from below ^a	Non-uniform spacing	Non-uniform spacing	Non-uniform spacing
Transportation system			
Road	Minimum density	Minimum density	Minimum density
Skid trails	Permanent	Permanent	Permanent
Forage utilization ^a (%)	20/40 ^c	20/40 ^c	20/40 ^c
Woody debris treatment	In Order of Preference		
Prescribed burning ^{a,d}	1	1	1
Lopping & Scattering ^a	2	2	2
Hand piling ^a	3	3	3
Machine grapple piling ^a	3	3	3
Dozer piling ^a	None	4	4

^a Refer to glossary of terms.

^b For PFAs surrounding active nest areas, months in which management activities are allowed.

^c Average forage utilization (percent by weight) in herbaceous layer/shrub layer; utilization should not exceed 40% of grasses and forbs and 60% of shrubs.

^d Not applicable in spruce-fir forest type.

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a landscape.

Desired Conditions

- ✓ **Size:** Approximately 30 acres (3 suitable and 3 replacement totaling 180 acres per home range).
- ✓ **Location:** Along drainages, base of slopes, and on northerly aspects.
- ✓ **Stand structure:** See Table 5, page 14.

Management Recommendations

- ✓ Maintain at least 3 suitable nest areas per home range. Selection priority:
 - 1) the active nest area; and
 - 2) the most recently used historical nest areas.

When possible, all historical nest areas should be maintained.

- ✓ Provide at least 3 replacement nest areas (in addition to the 3 suitable nest areas) per home range.
- ✓ All nest areas are best located approximately 0.5 miles from each other (Fig. 9).
- ✓ No adverse management activities in nest areas at any time.
- ✓ Minimal human presence in active nest areas during the nesting season, March 1 - September 30.

- ✓ Preferred treatments for maintaining stand structure in nest areas:

- **In suitable nest areas:** thin unwanted understory trees, with non-uniform spacing, in using prescribed fire (except for spruce-fir), and/or hand operated tools.

- **In replacement nest areas:**

- 1) thin from below (remove trees from the understory), with non-uniform spacing in the three youngest VSS to maintain low densities to promote faster tree growth and crown development, and
- 2) allow for stand density increases in the three older VSS to develop interlocking crowns (Fig. 10).

- ✓ Replacement nest areas should be first selected from stands in the PFA that resemble vegetation and landform of suitable nest areas.

- **To decrease fuel hazards,** in order of priority:

- 1) Use periodic prescribed fires (except in spruce-fir).
- 2) Logging and scattering of thinning debris is preferred if prescribed fire cannot be used.
- 3) Piling of debris should be limited. When necessary, hand piling should be used to minimize compaction within piles and to minimize displacement and

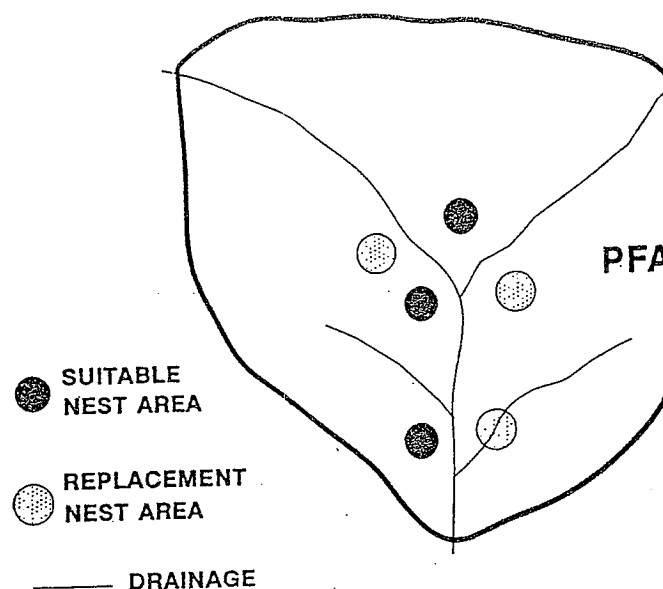


Figure 9. Schematic diagram of suitable and replacement nest areas within a post-fledgling family area. The foraging area surrounds the PFA.

destruction of the forest floor and the herbaceous layer.

- 4) Grapple or dozer piling is not recommended.
- ✓ Manage road densities at the lowest level possible to minimize disturbance in the nest area. Where timber harvesting has been prescribed to achieve desired forest condition, use small, permanent skid trails in lieu of roads.
- ✓ Wildlife and livestock utilization of grasses and forbs should average 20% by weight and not exceed 40% in any area, and shrub utilization should average 40% by weight and not exceed 60% in any area. These levels of utilization should maintain native food and cover for many of the prey species (Schmutz 1978, Wasser 1982).

Post-fledgling Family Area (PFA)

Management Objectives

- ✓ Provide hiding cover (from predators, siblings, and weather) for goshawk fledglings.
- ✓ Provide habitat for prey and foraging opportunities for the adults and fledgling goshawks during the fledgling-dependency period.

Desired Conditions, All Forest Types

- ✓ **Size:** Approximately 420 acres (not including the acres in suitable and replacement nest areas). Although portions of natural and permanently created openings close to forest edges may be

A thin VSS 1-3

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Executive Summary

The northern goshawk (*Accipiter gentilis atricapillus*) (hereafter called the "goshawk") is the largest North American member of the genus *Accipiter*, which includes both the sharp-shinned hawk (*Accipiter striatus*) and the Cooper's hawk (*Accipiter cooperii*). It breeds in coniferous, deciduous, and mixed forests throughout much of North America.

The goshawk is a forest habitat generalist that uses a variety of forest types, forest ages, structural conditions, and successional stages. It preys on small- to medium-sized birds and mammals (robins and chipmunks to grouse and hares), which it captures on the ground, in trees, or in the air. A single goshawk may consume one-to-two prey per day.

The principal forest types occupied by the goshawk in the Southwest are ponderosa pine, mixed-species, and spruce-fir. There is a concern that populations and reproduction of the goshawk are declining in these forests and elsewhere in the western United States. These declines may be associated with forest changes caused by timber harvesting. However, fire suppression, livestock grazing, drought, and toxic chemicals may be involved. Because of the concerns over the effects of timber harvesting, the goshawk was listed as a "sensitive species" by the Southwestern Region of the Forest Service, U.S. Department of Agriculture in 1982.

The Northern Goshawk Scientific Committee

The Northern Goshawk Scientific Committee (GSC) was established by the Regional Forester of the Southwestern Region in the fall of 1990. Its charter was to develop a credible management strategy to conserve the goshawk in the southwestern United States. This report describes the process used, findings, and recommendations of the scientific committee. In developing the recommendations, we used available information on goshawk biology, behavior, diet, and habitat. Information about goshawk foraging habitat was augmented with information on the habitat and foods of its main prey species. From this the GSC developed a set of "desired forest conditions" that, in their best estimate, will sustain goshawk populations in the Southwestern Region.

Because information on goshawk biology is limited, and our ability to produce and sustain certain forest conditions over long periods is unknown, the

development of the "desired forest conditions" for the goshawk and its prey required certain assumptions:

- 1) goshawks and their prey populations are limited by the availability of their foods and habitats,
- 2) the availability of abundant, sustainable prey populations reduces the probability that food is limiting,
- 3) extreme fluctuations of goshawk populations caused by changes in the abundance of one or more prey will be dampened when a wider variety of prey species are available,
- 4) the foods and habitats of goshawk prey in southwestern forests are similar in adjacent regions, and
- 5) the forest attributes and age-classes of southwestern forests described herein can be sustained with scientific management.

These assumptions reveal areas where research is needed on goshawk and forest ecology.

The following are key concepts fundamental to the GSC recommendations:

- Forests within goshawk nesting home ranges should be an interspersed mosaic of structural stages -- young to old forests -- to increase the diversity of habitat for goshawks and their many prey species. Six vegetation structural stages (VSS) were used to describe regeneration, growth, and development of forests in the Southwest (Fig. 1). The proportions of the VSS and their interspersion in the forest is how the GSC described the forest mosaic.
- The extent to which southwestern forests were modified by Native Americans before European settlement is not well known. Since European settlement, management practices (such as timber harvesting, livestock grazing, and fire control) have changed the structure and species composition of forests. Today, much forested area consists of dense "thickets" of small-diameter trees (Fig. 2). Forests containing these thickets are prone to catastrophic, tree-killing fire, and insect and disease outbreaks. Because of inter-tree competition for moisture, nutrients, and light, these thickets will not mature into large trees. To accelerate the

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development of mature forests and large trees, tree cutting and prescribed fire should be used to thin forest stands, concentrating growth on the remaining trees.

- Large trees, snags, and large downed logs provide important habitats for many plants and animals, and provide organic matter to the soil resource. Every acre of a goshawk nesting home range should contain a few large trees in clumps that are never removed. These trees live out their lives, die (become snags), fall, and decompose.
- Forest regeneration, growth, and development varies among locations because site specific productivity differs greatly throughout the Southwest. Therefore, no single management prescription is likely to develop or sustain the desired forest conditions on all sites within a landscape. In fact, the desired forest conditions may not be attainable on sites with low productivity, and may be easily attained on sites with high productivity.

Components of the Nesting Home Range

Three components of a goshawk's nesting home range (about 6,000 acres) were identified: nest area, post fledging-family area (PFA), and foraging area. The size of these home range components has been determined from behavioral and radio-telemetry studies of goshawks.

The **nest area** (approximately 30 acres), which may include more than one nest, is typically located on a northerly aspect in a drainage or canyon, and is often near a stream. Nest areas contain one or more stands of large, old trees with a dense canopy cover (Fig. 3). A goshawk pair occupies its nest area from early March until late September. The nest area is the center of all movements and behaviors associated with breeding from courtship through fledging. Most goshawks have two to four alternate nest areas within their home range; alternate nest areas may be used in different years, and some may be used for decades.

The **post fledging-family area (PFA)** (approximately 420 acres) surrounds the nest area. Because of its size, it typically includes a variety of forest types and conditions. The PFA appears to correspond to the territory (defended area) of a

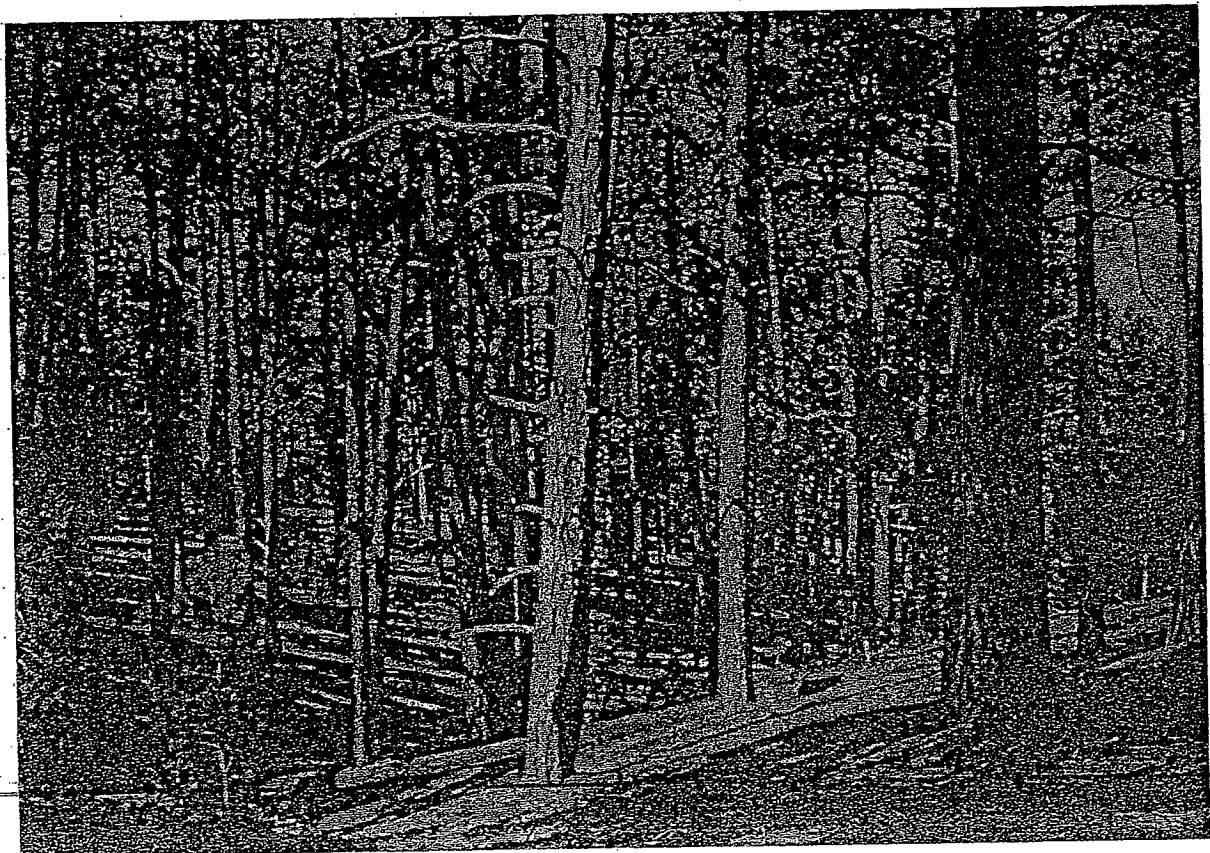


Figure 3. Nest areas contain one or more stands of large, old trees with a dense canopy.



Figure 5. Because of visual limitations in dense forest environments, an open understory enhances detection and capture of prey by goshawks.

downed logs, woody debris, large trees, openings, herbaceous and shrubby understories, and an intermixture of various forest vegetative structural stages. Prey populations within goshawk foraging areas will be abundant and sustainable when:

- 1) the specific habitat attributes are provided,
- 2) forests contain large trees and have relatively open tree understories,
- 3) forest openings are small (1/3 - 2 acres) to medium (2-4 acres) in size,
- 4) patches of dense, mid-aged forests are scattered throughout, and
- 5) the majority of forests are in the "mid-aged," "mature," and "old" structural stages.

Present Forest Conditions

Southwestern forests have been altered from pre-settlement conditions by fire suppression, timber harvesting, livestock grazing, mining, and recreational uses. Prior to fire suppression in the western United States, ponderosa pine forests were burned by low-intensity surface fires at 2- to 15-year intervals. Fires burned at lesser frequencies in

mixed-species forests (5-22 years). These fires maintained forests that were relatively open and dominated by mature trees by regularly burning and killing small trees. In spruce-fir forests, fire intervals were much longer (60-400 years) and fires were often catastrophic, stand-replacing events.

Habitat changes resulting from fire suppression in ponderosa pine and mixed-species, and to a lesser extent spruce-fir forests, are:

- 1) the replacement of open, single-storied stands by dense multistoried stands through tree regeneration,
- 2) loss of natural openings by tree invasion, and
- 3) changes in the abundance and composition of plant species in both the understory and overstory due to plant succession.

Accumulated fuels and dense forest conditions resulting from fire suppression have also increased the potential loss of goshawk habitat through catastrophic wildfire and epidemic infestations of insects and diseases. Increased shading from the dense regeneration has also reduced herbaceous and shrubby understories that provide important foods and cover for goshawk prey. Livestock and wildlife

and very dense understories, goshawk populations may effectively be diminished because:

- 1) impaired ability of goshawks to visually

- scan for prey,
- 2) restricted flight access to prey, and/or
- 3) greater escape cover for prey.

Conservation of the Northern Goshawk: Approach

To identify, describe, and ultimately manage goshawk habitat in the Southwestern Region, three critical spatial components of a goshawk's nesting home range were identified: nest area, post-fledging family area (PFA), and foraging area.

The description of goshawk habitat in each of these components is based on the biology and ecology of goshawks and their main prey species. In contrast to our knowledge of the summer nesting biology of the goshawk, almost nothing is known of its winter ecology. Therefore, the habitat descriptions herein focus on the nesting home range and habitat. However, there is limited radio-telemetry evidence that adult goshawks in New Mexico winter on or near their nesting home ranges (Kennedy unpub. data, Reynolds pers. obs.). If this proves true for goshawks in the Southwest in general, then providing nesting habitat will also provide some winter habitat needs.

Nest Area

Nest areas are easily identified by their unique vegetation structure. Nest areas include one or more forest stands, several nests, and several landform characteristics. Nest areas are occupied by breeding goshawks from early March until late September, and are the focus of all movements and activities associated with nesting (Reynolds 1983). Boundaries of nest areas were determined by observing the behavior of the adults, the movements and behavior of newly fledged young, and the locations of prey plucking areas and roosts (Reynolds et al. 1982). The size (20-25 acres) and shape of nest areas depend on topography and the availability of patches of dense, large trees (Reynolds 1983).

Suitable nesting habitat is critical in the reproductive biology of goshawks. Nest areas are often used more than one year, and some are used intermittently for decades (Reynolds 1983, Crocker-Bedford 1990). Many pairs of goshawks have two to four alternate nest areas within their home range. All previously occupied nest areas may be critical for maintaining nesting populations because they contain the habitat elements that attracted the goshawks originally. Additionally,

replacement nest areas are required because goshawk nest stands are subject to loss from catastrophic events and natural decline.

Goshawk nest stands have a relatively high tree canopy cover and a high density of large trees (Bartelt 1974, McGowan 1975, Hennessy 1978, Shuster 1980, Reynolds et al. 1982, Saunders 1982, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Kennedy 1988, Hayward and Escano 1989) (Table 5). Most nest stands are either on slopes with northerly exposures (NW to NE) or in drainages or canyon bottoms protected by such slopes. Studies suggest that the dense vegetation in these stands provide relatively mild and stable micro-environments, as well as protection from predators of goshawks (other goshawks, great-horned owls, red-tailed hawks, coyotes, bobcats, raccoons, humans) (Reynolds et al. 1982, Moore and Henny 1983). Information on tree height, diameter, and canopy closure of goshawk nest areas in interior ponderosa pine and mixed-species forests is provided by Reynolds et al. (1982), Moore and Henny (1983), Crocker-Bedford and Chaney (1988), Kennedy (1988), and Patla (1990).

The structure of the vegetation within nest areas is associated with the forest type, and tree age, size, and density, and the developmental history of the stand. Within the Southwestern Region, nest areas occur within a range of forest growth-site potentials (Table 5). Nest areas in locations with low growth potential will have smaller (diameter and height) trees than locations with high potential. Table 5 presents minimum attributes required for goshawks on locations with "low" and "high" site productivity.

Post-fledging Family Area (PFA)

In a radio-telemetry study of the post-fledging behavior of goshawks, Kennedy (1989, 1990) described an area used by the adults and young from the time the young leave the nest until they are no longer dependent on the adults for food. This "post-fledging family area (PFA)" surrounds the nest area and, although it generally includes a variety of forest conditions, the vegetation structure resembles that found within nest stands. PFAs vary in size from

Table 5. Structural attributes for suitable northern goshawk nest stands in the Southwest¹.

Forest Cover Type ²	Piñon-Juniper	Interior Ponderosa		Mixed-Species		Aspen	Engelmann Spruce-Subal
		Pine					
Site Index ³		<55	≥55	<50	≥50		
Trees/Acre ⁴	60-100	40	30	45	35	20	35
Mean DBH/DRC (in.) ⁵	12	16	22	15	20	16	20
Age (yrs.) ⁵	200+	200+	200+	200+	200+	80+	150+
Total BA (sq. ft/acre) ⁶	60	120	140	110	130	50	140
Overstory canopy cover (%)	60+	50+	60+	50+	60+	60+	70+
VSS ⁷	5A-6	5B-6	5B-6	5B-6	5B-6	5B-6	5B-6

¹ The entire nest area may not support all of these structural attributes.

² Forest cover types, SAF codes (Eyre 1980); Ponderosa pine 237; Mixed-species 209, 210, 211, 216; Aspen 217; Engelmann spruce-Sub 206; Piñon-juniper 239.

³ Site Index (SI) = base age of 100 years; SI used for interior ponderosa pine = ponderosa pine; SI used for mixed-species = Douglas-fir.

⁴ Number of live trees in the main canopy.

⁵ Arithmetic average of the ages of dominant and codominate trees in the stand; DBH = diameter at breast height; DRC = diameter at root.

⁶ BA = basal area.

⁷ VSS = Vegetation Structural Stage.

300 to 600 acres (mean = 415 acres) and may correspond to the territory (a defended area) of a pair of goshawks (Kennedy 1989). PFAs provide the young hawks with cover from predators, and sufficient prey to develop hunting skills and feed themselves in the weeks before juvenile dispersal. Thus, forests in the PFAs should contain overstories with a canopy cover greater than 50%, and well-developed understories and habitat attributes (e.g., snags, nest trees, foods) critical in the life-histories of goshawk prey species.

Foraging Area

It is difficult to identify and describe goshawk foraging habitat because of the size of the home range and the dearth of information on what habitats are preferred.

As in most raptors, there are differences in the duties of the goshawk sexes during nesting: males hunt for the family while females stay close to the nests -- first to incubate eggs, then to brood and protect young. Information on nesting home range size and habitats used while foraging must therefore primarily come from studies of foraging males. The extent to which the foraging areas of adjacent pairs overlap is unknown.

Goshawks prey on birds and mammals in the larger body-size classes available to forest-dwelling hawks (Storer 1966, Reynolds and Meslow 1984). Generally speaking, because larger species of

vertebrates have less dense populations than smaller species, predators of large prey must hunt over areas in order to meet their energy requirements (Schoener 1983). This body size/home range relationship is demonstrated in the North American *Accipiter*: the smallest, the sharp-shinned hawk, feeds on small birds and has nesting home range about 1,200 acres; the Cooper's hawk, which feeds on birds and mammals of intermediate size, has home ranges of about 4,000 acres; and the northern goshawk, the largest *Accipiter*, has ranges of about 5,000-6,000 acres (Reynolds 1983, Kennedy 1989) (Table 3).

The size of nesting home ranges of goshawks has been estimated by:

- 1) repeatedly observing adult males leaving their nest areas above the forest canopy and noting the distance and direction traveled (Reynolds 1983);
- 2) Assuming home ranges are circular and using one-half the mean distance between nests as the radius of the home range (Newton et al. 1977, Reynolds 1983);
- 3) plotting the locations where some prey species were trapped and marked and whose remains were subsequently found at goshawk nests (Eng and Gullion 1962); and
- 4) monitoring the movements of adults using radio-telemetry (Kennedy 1991,

Austin in prep).

Radio-telemetry is the most accurate of these estimates, but radio-tracking of such a wide-ranging bird in mountainous terrain is most difficult. The task is made more difficult because goshawks, as well as other *Accipiters*, are short-sit-and-wait-short-flight predators (Fischer 1986, Kenward 1982, Kennedy 1991). That is, goshawks search their immediate surroundings for prey from a tree-perch for a short period (seconds) and then make a short flight to a new perch (Kenward 1982, Widen 1985). This searching behavior is an adaptation to living in forests where the area searched from a single perch is limited. Because of visual limitations, perches are changed frequently. Goshawks move rapidly through their home range in this manner, making it difficult to triangulate on radio-marked hawks.

Limited radio-telemetry evidence suggests that goshawks prefer mature forests for foraging. For example, Fischer (1986) found that a radio-tagged male in Utah preferentially foraged in "mature" Douglas-fir/white fir stands. Widen (1989), studying radio-marked goshawks (*A. g. gentilis*) in winter in intensively managed conifer forests in Sweden, found that both sexes of goshawks preferentially foraged in forests greater than 60 years of age. Application of this information in management recommendations is limited because of the small

sample size in Utah, and uncertainties as to the similarities in foraging behavior of European and North American goshawks.

Additional information on the composition and structure of goshawk foraging habitat was gleaned from information on the habitat requirements of goshawk prey species. This approach is justified because:

- 1) raptor populations are often limited by prey populations, and
- 2) choice of foraging habitat by goshawks is predicated, at least in part, on habitats where prey are abundant and accessible.

We designed foraging areas consisting of forest conditions that would provide a high overall diversity and abundance of prey. Because not all 14 selected prey species occur in each of the forest types in the Southwest, three separate designs -- for ponderosa pine, mixed-species, and spruce-fir -- were required (Table 6). Sufficient prey habitats are provided so there is food to support goshawks in all seasons, especially during winter when fewer prey are available, and in years when prey populations are low due to factors such as drought or deep snow cover. Because no single prey species will be abundant enough to support goshawks, especially during winter, habitats for all 14 prey species are provided.

Synthesis of Desired Forest Conditions

Forests can be described by either:

- 1) community associations or
- 2) forest cover types (Daubenmire and Daubenmire 1968, Larson and Moir 1986, Larson et al. 1987, Bassett et al. 1987).

An integrative approach, combining vegetation and forest growth, has been developed for the Southwest (after Thomas et al. 1979) and is a generalized description of forest age and tree size from seedling to old forests. To describe the southwestern forests we defined 6 vegetation structural stages (VSS) that were based primarily on tree diameters (Fig. 1). These stages are:

- VSS 1, areas dominated by grasses, forbs, and shrubs;
- VSS 2, forests dominated by seedlings and saplings;
- VSS 3, young forests;
- VSS 4, mid-aged forests;
- VSS 5, mature forests; and
- VSS 6, old forests.

Nest Area

Nest areas are a key component of goshawk home ranges. In each of the three southwestern forest types, goshawks nest in older-aged stands that have a high density of large trees, high tree canopy cover, and high basal areas (Table 5, Fig. 7, and Fig. 8). Nest areas are usually on cool, shady slopes or canyon sides, and are often near streams.

Post-fledging Family Area (PFA)

Post-fledging family areas (PFAs) contain patches of dense, large trees that provide protection for fledglings and small trees for hiding cover near the ground. Because newly fledged young have poorly developed flight, their spatial movements tend to be centered around the nest. With time, fledglings become proficient foragers and are fed less and less by their parents. To provide learning opportunities, prey should be abundant throughout the PFA; thus prey habitat should be intermixed with dense hiding

of bark beetles (*Dendroctonus* spp.) is present in many ponderosa pine and mixed-species forests (Hedden et al. 1981, USDA Forest Service 1988, Rogers and Conklin 1991). The threat of western spruce budworm (*Choristoneura occidentalis*) outbreaks is also increasing in the multi-storied stands being perpetuated in the mixed-species forests (USDA Forest Service 1985, Swetnam and Lynch 1989) (Appendix 5, page 79).

The individual and cumulative effects of these forest modifications on the habitat of goshawks and their prey are poorly understood. However, we believe these modifications affect habitat use by the goshawk and the availability (abundance and vulnerability) of goshawk prey. Specifically:

- 1) in areas of thick tree regeneration, access to prey may be limited (Reynolds 1989),
- 2) increased tree canopy cover results in a

loss of herbaceous and/or shrubby foods (Cooper 1960, Stein 1988) and therefore, reductions in populations of the many herbivorous prey of the goshawk,

- 3) reductions in the amount of older forests reduces the abundance of those prey that require large trees (Szaro and Balda 1979b, Patton et al. 1985, Sullivan and Moses 1986, Brawn and Balda 1988),
- 4) reductions of large snags decreases the abundance of those prey dependent on them (Balda 1975, Brawn and Balda 1988), and
- 5) creating large openings in forests results in the reduction of the abundance of fruiting fungi, and lower populations of prey that feed on fungi (States 1985, Pederson et al. 1987).

Management Recommendations for the Home Range

The present forest conditions above reflect the extent of human influence on natural processes. Several types of active management such as thinning and prescribed fire should speed the process of producing and maintaining the desired conditions for sustaining goshawks and their prey. For example, if wild stands of ponderosa pine are not thinned naturally (by fire) or artificially (by tree cutting) they typically stagnate and will not develop into large, mature trees (Appendix 4, Table 5; page 84). When thinned regularly, trees can reach 10 inches in diameter within 80 years, depending on forest site. In some forests (such as spruce-fir), natural processes are still functioning, and little or no active management will be necessary to reach the desired conditions (Stromberg and Patten 1991).

There are three key components in the goshawk's home range: nest areas, post-fledging family area, and foraging area. Management objectives, desired conditions, and management recommendations based on goshawk nest habitat and foraging behavior, and the food and habitat of selected goshawk prey for each home range component has been specified.

Across the Southwestern Region there is considerable variation in site-specific growth potential. This variation is associated with elevation, slope, aspect, soil, available moisture and nutrients, and disturbance-history. Therefore, sites have widely varying capabilities to produce the desired forest conditions; on certain sites desired conditions cannot be attained, while on others the conditions can be exceeded. Although high growth-potential sites have

the greatest capabilities to produce nest areas, low potential sites may still provide foraging habitat with enough time.

Because trees and forests require many years to grow, and because much research is needed to improve our understanding of goshawk habitat use, it is prudent to minimize the possibility of immediate loss of goshawk habitat. Therefore, the following management recommendations are conservative; that is, they are designed to produce forest conditions that will sustain goshawk populations by minimizing long-term loss of their habitat due to unfavorable environmental conditions such as long periods of drought. Therefore, the largest areas (acres) reported in the literature (Table 3, page 9), rather than the average or the smallest, were used when developing the management recommendations for the nest area, PFA, and foraging area.

The opportunities to produce, maintain, and enhance goshawk habitat may not be equally applied on all forested lands because of "reserved forest land" designations, such as wilderness, research natural areas, National Parks, and "area limitations" related to slope and soil type. Desired conditions might be achieved in some of these areas through the application of allowable management tools (fire, hand-thinning).

Nest Area

Management Objectives, All Forest Types

- ✓ Provide long-term nesting habitat for goshawks in

INTERMEDIATE TREATMENT:
Thinning from Below

Nest stands *PFA*

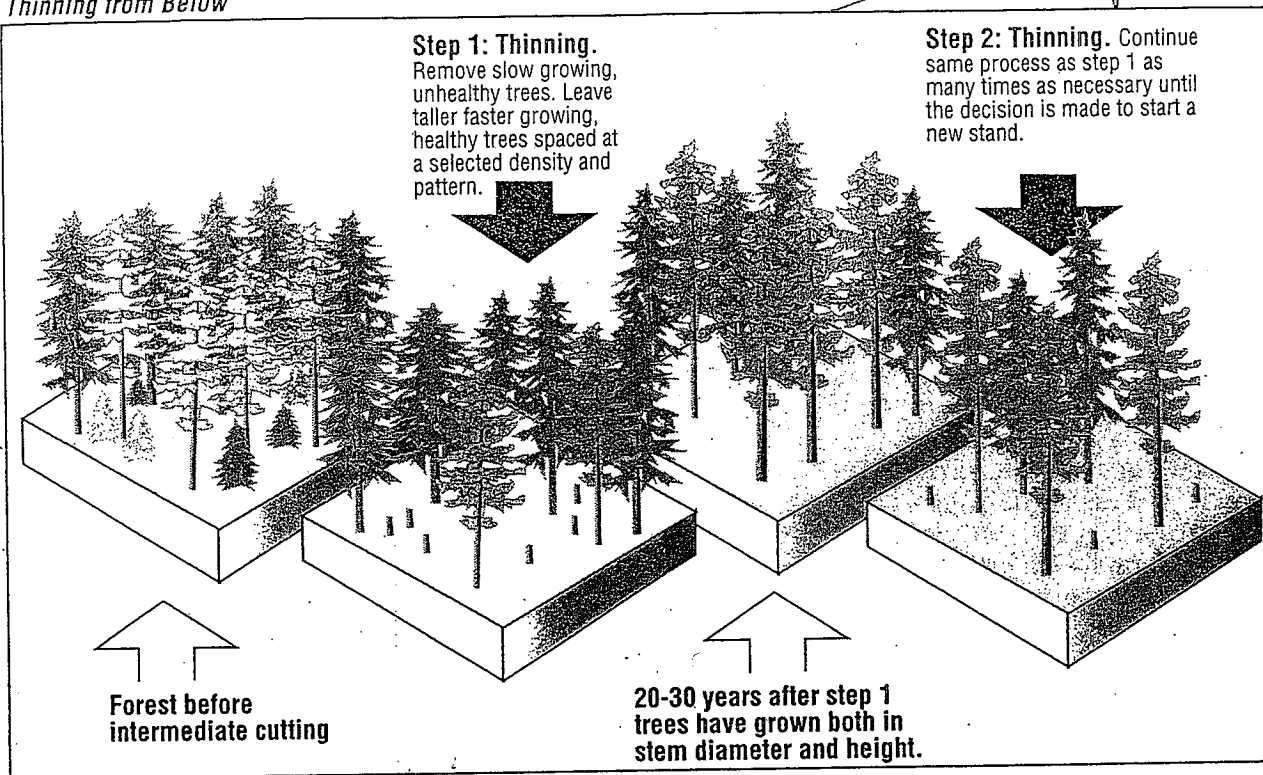


Figure 10. Thinning from below (removing trees from the understory) to achieve desired forest conditions.

utilized for foraging by goshawks, these areas are not counted as part of the PFA. Also, do not count created openings (such as forest health, fire) greater than two acres in size as part of the PFA.

- ✓ **Location:** Approximately centered around suitable and replacement nest areas (Fig. 9).
- ✓ **Stand structure:** A mosaic of vegetation structural stages (VSSs) interspersed throughout the PFA in small patches.

- The majority (60%) of the PFA should be in the three older VSSs (4, 5, 6), approximately 20% in each. Of the remaining 40%, 20% should be in young forest (VSS 3), and 10% in the seedling/sapling (VSS 2), and 10% in grass/forb/shrub stages (VSS 1). The approximate proportions that can be maintained in the different VSS classes depend on:

- 1) the years required for tree establishment and development,
- 2) diameter growth rates, and
- 3) tree longevity (Appendix 5, page 82).

The number of years spent in each VSS will depend on the intensity of management (Appendix 5, page 82).

- The large-tree component throughout the PFA should include: snags, downed logs, and mature and old, live trees in clumps

or stringers with interlocking crowns.

- A developed herbaceous and/or shrub understory throughout the PFA should emphasize native species, especially grasses.
- ✓ **Woody debris:** Present throughout the PFA.
- ✓ **Soil conditions:** Developed, intact forest soils with emphasis on organic surface layers (humus, litter and soil wood) within the natural turnover rates. These conditions should provide for the sustainability of mycorrhizae.

Additional Desired Conditions, Ponderosa Pine Forest Type

- ✓ **Stand structure:** The portions of the PFA in the mature and old VSSs have a minimum canopy cover of 50%. One-third of the area in the mid-aged portion has a minimum canopy cover of 60%, and the remaining two-thirds has a minimum canopy cover of 50%. This distribution provides hiding cover for fledgling goshawks and moist forest soils for development of fungi.

- **Snags:** At least 2 large (≥ 18 inch DBH, ≥ 30 feet tall) snags per acre throughout the PFA. These dimensions meet the minimum requirements for the majority of prey species.

- **Downed Logs:** At least 3 large (≥ 12 inch

diameter mid-point, ≥ 8 feet long) downed logs per acre throughout the PFA. Downed logs of this number and size are important for many prey species.

- **Live trees:** A minimum of 3-5 mature and old, live trees per acre in groups or stringers with interlocking crowns. Interlocking crowns allow squirrels to move from tree crown to tree crown (Appendix 3, page 53).

Additional Desired Conditions, Mixed-species and Spruce-fir Forest Types

- ✓ **Stand structure:** Those portions of the PFA in the mature and old VSS have a minimum canopy cover of 60% in mixed-species and 70% in spruce-fir. In the mid-aged portion of the PFA, the minimum canopy cover is 60% for both forest types. This distribution provides hiding cover for fledgling goshawks and moist forest soils for development of fungi.

- **Snags:** At least 3 large (≥ 18 inch DBH, ≥ 30 feet tall) snags per acre throughout the PFA.
- **Downed logs:** At least 5 large (≥ 12 inch diameter mid-point, ≥ 8 feet long) downed logs per acre throughout the PFA.
- **Live trees:** Because the mixed-species (upper elevations) and spruce-fir forest types contain red squirrel habitat, a higher density of mature and old trees with interlocking crowns in clumps is required. A minimum of 1 group of 6 mature and old trees per acre in mixed-species, and at least 1 intact group (with at least 6 mature or old trees per group) per half-acre (2 groups per acre) in spruce-fir is required (Appendix 3, page 53).

Management Recommendations, All Forest Types

- ✓ In cases where the PFA of one goshawk pair overlaps the foraging area of another pair, the management recommendations for the PFA take precedence.
- ✓ No adverse management activities in PFAs during the nesting season, March 1 - September 30. Minimize human presence during nesting.
- ✓ Preferred treatment for maintaining stand structure in the PFA: Thin from below (Fig. 10). In the three youngest VSSs, these treatments should result in lower stand densities (basal areas) to promote fast tree growth, crown development, herb and/or shrub development. Treatments should also allow for irregular spacing of trees in the three older VSS's, allow stand densities (basal areas) to increase (Appendix 5, Table 5; page 84).

Provide for or preserve existing clumps of trees with interlocking crowns in the three older VSSs by avoiding uniform spacing of trees. Other treatments (such as sanitation, liberation, improvement) could be used when and where appropriate to create desired conditions.

- ✓ **Roads** Manage road densities at the lowest level possible to minimize disturbance in the PFA. Where timber harvesting has been prescribed to achieve desired forest conditions, use small, permanent skid trails in lieu of roads.
- ✓ Wildlife and livestock utilization of grasses and forbs should average 20% by weight and not exceed 40% in any area, and shrub utilization should average 40% by weight and not exceed 60% in any area. This level of utilization should maintain native foods and cover for many of the prey species (Schmutz 1978, Wasser 1982).

Additional Management Recommendations, Ponderosa Pine Forest Type

- ✓ Create small openings (2 acres or less) with regeneration cuts. Small openings are preferred to large openings because the PFA is a transition in vegetative structure from the nest area (no openings) to the foraging area with medium-sized openings (see Foraging Area). Openings should be irregular in shape and no greater than 200 feet in width to assure goshawk foraging opportunities in openings within them. If openings are greater than 1 acre, identify and retain 3 to 5 mature and old trees per acre (reserve trees) with interlocking crowns. In openings less than 1 acre, the large-tree component can be met in adjacent forested areas. Interlocking crowns provide squirrel habitat and food, minimize blowdown, and increase drought resistance. Scatter openings throughout the PFA wherever possible to develop the desired interspersed structural stages (Fig. 11 and Fig. 12).
- ✓ Encourage aspen and oak regeneration. These trees are desirable for woodpeckers and other prey species (Appendix 3, page 53). Animal exclosures may be necessary to develop and maintain tree regeneration.
- ✓ Planting of ponderosa pine, in addition to relying on natural regeneration, is recommended.
- ✓ Leave 5 - 7 tons per acre of woody debris (greater than 3 inches in diameter) and downed logs distributed across areas, after timber harvesting, for small animal habitat and to maintain long-term productivity (Harvey et al. 1987, Graham et al. in press). Treatments, in order of priority:
 - 1) Use periodic prescribed fires to regenerate where needed and to develop desired stand conditions, recycle

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MARTEN SUBNIVEAN ACCESS POINT USE: RESPONSE TO SUBNIVEAN PREY LEVELS

STUART S. SHERBURNE,¹ Utah Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Utah State University, Logan, UT 84322-5290

JOHN A. BISSONETTE, National Biological Survey, Utah Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Utah State University, Logan, UT 84322-5290

Abstract: Because marten (*Martes americana*) require subnivean access for cover, prey access, and homeothermic reasons, we developed a predictive model to explain their differential use of subnivean access holes in Yellowstone National Park. We included prey biomass and percent ground cover of coarse woody debris (CWD) as explanatory variables in a logistic regression model because of their biological importance to marten in winter. Taken singly, relative prey biomass yielded the best univariate predictive model ($P = 0.001$). However, we included CWD in a multivariate model because of its biological significance. Coarse woody debris provides structure that intercepts snowfall, creating subnivean tunnels, interstitial spaces, and access holes, and was found at used and unused access points. Mean prey biomass was 205.4 g/400 m² (SE = 20.26) and 108.2 g/400 m² (SE = 10.73) at used and unused points ($P < 0.001$), respectively, while mean percent ground cover of CWD was 24.7 (SE = 2.30) and 18.5% (SE = 1.18) at used and unused access points ($P = 0.017$), respectively. As CWD increased by 5%, the probability of use by marten increased 1.12 times, and for every 50 g increase in relative prey biomass, marten were 1.37 times more likely to use that access point. Prey biomass varied ($P < 0.001$) among subnivean access points, and marten chose between different access points primarily on the basis of prey abundance levels. Older growth forests with accumulated CWD will enable marten to forage effectively in winter.

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Key words: marten, *Martes americana*, predation, prey, subnivean access, Wyoming.

In winter, marten require subnivean access (Pulliainen 1981, Buskirk 1984, Buskirk et al. 1989), but the mechanisms that determine use of some access points over others are unclear. Food availability, escape cover, and homeothermic requirements have been hypothesized as important factors affecting use of subnivean access points. There also is a relationship between use of access points and the presence of CWD. Coarse woody debris breaks the snow surface and provides access to the subnivean zone. Buskirk et al. (1989) found that 49% of marten resting sites and 63% of resting episodes were associated with CWD. Corn and Raphael (1991) reported higher CWD levels at used access points than at randomly sampled points. Buskirk et al. (1989) suggested that marten used subnivean access points primarily to reach CWD that provides thermal insulation. Marten in Wyoming (Buskirk et al. 1989) used access sites associated with CWD when ambient temperatures were coldest. Buskirk et al. (1988) reported that a mean depression in body temperature of 2.9 C

produced an estimated energy savings of 4%. Taylor (1993), and Taylor and Buskirk (Univ. Wyoming, Laramie, unpubl. data) reported that subnivean cavities associated with CWD offered a warmer microenvironment when convective losses were high outside the cavity. The energy savings associated with resting in subnivean spaces instead of above the snow was approximately 23% (S. W. Buskirk, Univ. Wyoming, Laramie, pers. commun.). Studies of marten temporal activity patterns, however, have shown that they were most active at night during winter (Lensink et al. 1955, Zielinski 1981, Zielinski et al. 1983) when temperatures were coldest. These observations imply that other mechanisms may contribute to access point use.

Marten and other mustelids have metabolic rates that are 20-100% higher than those of other mammals with similar body size (Brown and Lasiewski 1972, Iversen 1972, Casey and Casey 1979, Korhonen et al. 1983). Brown and Lasiewski (1972) attributed the increased basal metabolic rate of weasels (*Mustela frenata*) to their elongated body shape, which, combined with relatively thin and poorly insulative fur (Casey and Casey 1979), sacrificed energetic ef-

iciency. Harlow (1991) required several separate findings of 1 that marten have line be completely metabolic need to be active is to equal or exceed t and Lasiewski 1972, Harlow 1991). Zielinski marten activity coin their principle prey, of their natural hist between use of subn abundance.

Our objective was influenced subnivean ically the relationship nivean access and re also attempted to d in marten's choice the hypotheses that points by marten w clumped subnivean was positively corre CWD.

We thank the U tional Park Service State University for thank B. K. Gilbert gestions and comm drafts, and S. L. D data analysis discus sonnel at Yellowsto larly the rangers an Canyon area of the sistance and suppor evaluated by the Utah State Univer and adherence to e lines. All data wer able field methodo ican Society of M

STUDY AREA

We chose the C lowstone National it contained a va provided a road r cess to marten hab was dominated b torta) with small fir inclusions. Dur grees of fire intens partially burned,

¹ Present address: 28 North Main, Upton, MA 01568.

relative prey biomass, sized results of the log-Wald test statistic (W) obtained by comparing estimate of the slope and its standard error. Hence, the critical transformed relative pre-root function prior cross product (odds) relative prey biomass strength of the association interpretation of the upon access point use.

is 205.4 g/400 m² (SE 10 m² (SE = 10.73) at $t = 4.24$, 105 df, $P < 0.001$; mean percent ground cover (SE = 2.30) and 18.5% unused access points ($t = 4.24$), respectively. When CWD levels at each point were low, intermediate, or high, that use of subnivean access points was associated ($P < 0.001$) to prey biomass and to a lesser extent to increasing CWD (Table 1).

Regression indicated that prey biomass was a good predictor of access point use ($W = 3.96$, $P < 0.001$). CWD was an adequate predictor of access point use ($W = 3.96$, $P < 0.001$) in a multivariate model, but prey biomass was the response variable (Fig. 1), was adequate prey biomass showing $V = 3.74$, $P < 0.001$). Prey biomass was not significant in the logit model ($P = 0.072$). Log odds ratios were 1.37 times more likely to use access point with every 50 g increase in prey biomass. CWD, canopy cover, and snow depth were not significant predictors of access point use.

and relative prey biomass in a multivariate logistic re-

gression models explaining use of subnivean access points by marten. Coarse woody debris provided marten with access to the subnivean zone. Buskirk (1984) and Buskirk et al. (1989) noted that CWD may provide thermal benefits. Their data suggested a threshold temperature effect may exist. As temperatures decrease marten appear to use access points more frequently for thermal advantage. As a consequence, total time spent active should decrease. Indeed, in more northerly and colder climates, marten appeared to increase activity during warmer seasons (Zielinski 1981, Buskirk 1983). Bissonette et al. (1988), Fredrickson (1990), and G. S. Drew (Natl. Biol. Surv., pers. commun.) documented periods of apparent total inactivity by marten at times of very cold temperatures (< -25 C).

Use of access points also could be influenced by predators. Mammalian and avian predators kill marten. In Newfoundland, marten responded to terrestrial predators by climbing trees (Bissonette, unpubl. data). Most raptors migrated south of Newfoundland in winter, leaving 4 owl species (great horned [*Bubo virginianus*], boreal [*Aegolius funereus*], snowy [*Nyctea scandiaca*], and northern hawk-owl [*Surnia ulula*]) (Bull and Farrand 1977) as primary avian predators. We believe marten responded to owl predation by using subnivean cover; however, we do not have data to support this hypothesis. Choice of habitat (i.e., forest, meadows, clear-cuts), however, was influenced by predators (Drew and Bissonette, unpubl. data).

In our study area, CWD was abundant and widespread, and potential subnivean access points were abundant. Marten bypassed a number of potentially available subnivean access points before using a seemingly similar point. When used and unused points were compared, relative prey biomass and CWD were the only variables that differed. Canopy cover, percent ground cover, and snow depth were not related to access point use. Prey biomass consistently showed a stronger relationship to access point use than CWD. While CWD provided access to prey by providing structure that intercepted snow fall, thus creating passages, it was the presence of prey that dictated differential access point use by marten. We found no relationship between relative prey biomass and CWD levels. Marten appeared to be able to discriminate between access points with high prey levels and those with low prey levels.

The pattern of marten choice of access points

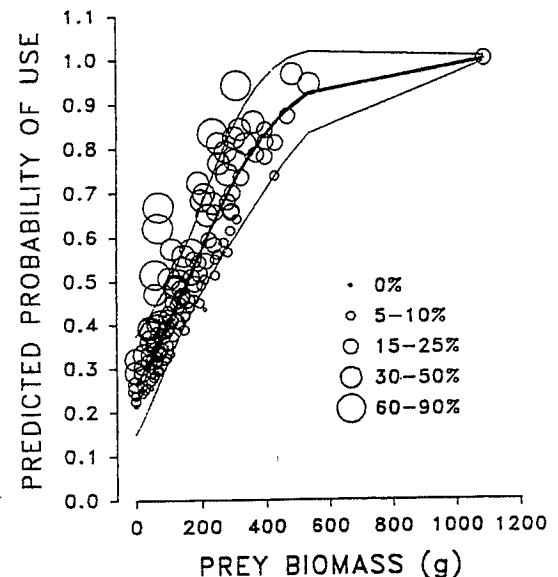


Fig. 1. Probability of access point use by marten in Yellowstone National Park, 1989–91, as a function of prey biomass (g) and coarse woody debris (% cover). Area of open circles is proportional to coarse woody debris level. The dark solid line describes the relationship between prey biomass found at subnivean access holes and the predicted probability of use of the access point by marten. The lighter solid lines represent 95% confidence intervals.

on the basis of prey abundance appears clear. However, we do not yet understand how marten make their selection. At least 2 possible mechanistic explanations appear worth investigating. Marten may use either auditory or olfactory cues to assess presence of small mammals in subnivean locations. Some voles may group together during winter (Cranford 1984) providing stronger olfactory cues than if they existed solitarily. Similarly, voles or other small mammals in groups may emit a higher frequency and volume of auditory cues than do single conspecifics. Field and laboratory experiments are needed to explain how marten are able to distinguish between access points with higher subnivean prey levels.

MANAGEMENT IMPLICATIONS

The world's coniferous forests, the source of most industrial wood production, covered 1.1 billion ha or 27% of the world's total forest area in 1985 (Hinrichsen 1987:59); 26% of these forests were in North America. Because of the growing worldwide demand for wood products, increasing pressure is being placed on older growth forests. In many parts of North America,

timber harvest levels approach or have exceeded sustainable levels. Postel and Heise (1988) reported that between 1963 and 1982, forest cover in the contiguous United States dropped 10%, to 233 million ha. The United States and Canada accounted for 35% (590 million m²) of the worldwide production of coniferous tree species in 1988, and demand levels are projected to increase 18–53% by 2030 (Postel and Ryan 1991). Marten are habitat specialists (Bissonette et al. 1989, Brainerd 1989), occurring primarily in mature coniferous habitat (Soutiere 1979, Steventon and Major 1982, Raine 1983, Bateman 1986), and their population status and health are linked closely to forest trends. As mature coniferous forest is cut and replaced by early seral stages, marten habitat is lost. The impacts are most severe in winter because marten require subnivean access to their prey. Only older-growth forests with accumulated CWD provide the forest floor structure necessary to enable marten to forage effectively during winter. Managers need to be cognizant of the large-scale cumulative effects of habitat alteration to avoid long-term population declines in core sensitive species (Bissonette et al. 1989) such as marten.

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SEXUAL SEGREGATION AND AVOIDANCE OF

ROBERT B. WIELGUS,¹ Dept. Biology, Fred L. Bunnell, Centre for Wildlife Research, BC V6T 1Z4, Canada

Abstract: We examined southwestern Alberta, 1992 avoidance hypothesis predicted that occupied areas because differences in use of habitats of available habitat. Dispersal concentrated in the female-occupied areas in the summer, whereas 2, 1, Grizzly bear females select females avoid males and survival could decline.

Key words: Alberta, grizzly bear, marten, avoidance hypothesis.

Grizzly bears have their historic range, but habitat fragmentation and habitat loss of the species' range.

¹ Present address: Centre for Biology, Faculty of Forestry, Columbia, 193-2357 Mt. 1Z4, Canada.



Management and Conservation Article

Seasonal Resource Selection of Canada Lynx in Managed Forests of the Northern Rocky Mountains

JOHN R. SQUIRES,¹ United States Department of Agriculture Forest Service, Rocky Mountain Research Station, 800 E Beckwith, Missoula, MT 59801, USA

NICHOLAS J. DECESARE, College of Forestry and Conservation, University of Montana, Missoula, MT 59812, USA

JAY A. KOLBE, Montana Fish, Wildlife and Parks, P.O. Box 1288, Seeley Lake, MT 59868, USA

LEONARD F. RUGGIERO, United States Department of Agriculture Forest Service, Rocky Mountain Research Station, 800 E Beckwith, Missoula, MT 59801, USA

ABSTRACT We investigated seasonal patterns in resource selection of Canada lynx (*Lynx canadensis*) in the northern Rockies (western MT, USA) from 1998 to 2002 based on backtracking in winter (577 km, 10 M, 7 F) and radiotelemetry (630 locations, 16 M, 11 F) in summer. During winter, lynx preferentially foraged in mature, multilayer forests with Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) in the overstory and midstory. Forests used during winter were composed of larger diameter trees with higher horizontal cover, more abundant snowshoe hares (*Lepus americanus*), and deeper snow compared to random availability; multilayer, spruce–fir forests provided high horizontal cover with tree branching that touched the snow surface. During winter, lynx killed prey at sites with higher horizontal cover than that along foraging paths. Lynx were insensitive to snow depth or penetrability in determining where they killed prey. During summer, lynx broadened their resource use to select younger forests with high horizontal cover, abundant total shrubs, abundant small-diameter trees, and dense saplings, especially spruce–fir saplings. Based on multivariate logistic-regression models, resource selection occurred primarily at a fine spatial scale as was consistent with a sight-hunting predator in dense forests. However, univariate comparisons of patch-level metrics indicated that lynx selected homogenous spruce–fir patches, and avoided recent clear-cuts or other open patches. Given that lynx in Montana exhibit seasonal differences in resource selection, we encourage managers to maintain habitat mosaics. Because winter habitat may be most limiting for lynx, these mosaics should include abundant multistory, mature spruce–fir forests with high horizontal cover that are spatially well-distributed.

KEY WORDS Canada lynx, ecological scale, forest management, habitat selection, logistic regression, *Lynx canadensis*, Montana, resource selection.

The Canada lynx (*Lynx canadensis*) was federally listed in the contiguous United States as a threatened species under the Endangered Species Act in 2000 (U.S. Fish and Wildlife Service 2000). Although inadequate regulatory protection was cited as the primary reason for federal listing, human alteration of forest abundance, composition, and connectivity was identified as the most influential factor affecting lynx habitat. Configuring landscapes to maintain persistent lynx populations at the southern extent of the species' range is difficult due to our limited knowledge of lynx resource selection and the natural patchiness of southern boreal forests (Agee 2000, Aubry et al. 2000b, Ruggiero et al. 2000b).

Conserving lynx requires that we consider the regional population rather than the species as the appropriate taxonomic level for resource planning (Ruggiero et al. 2000b). Changes in carnivore habitat quality can be driven at the regional scale by gradients of human disturbance (Mladenoff et al. 1995, Kerley et al. 2002, Beckmann and Berger 2003), forest management and changes in vegetation structure (Nielsen et al. 2004a, b; Fuller et al. 2007), reduced metapopulation connectivity (Coulon et al. 2004), and prey density (Sullivan and Sullivan 1988, Bull et al. 2005, Griffin and Mills 2007). Given these diverse environmental factors, resource selection by carnivores may vary considerably across a species' distribution (Ruggiero et al. 2000b). Emphasizing

populations reduces mismatches in ecological scale while preserving ecotypic variation and is consistent with the statutory requirements of the National Forest Management Act of 1976 and the Endangered Species Act of 1973 (Ruggiero et al. 1994, McKelvey et al. 2000c). Moreover, because lynx exhibit broad differences in resource selection across their range, analyzing population-level information across a species' range can provide a stronger basis for conservation planning.

Most understandings of lynx ecology are based on northern populations in Canada and Alaska, USA (Buskirk et al. 2000b, Mowat et al. 2000). Northern lynx habitat consists of a homogenous landscape dominated by boreal forest, whereas elevation gradients in the habitat of southern lynx populations create naturally heterogeneous forest types and more fragmented habitat patches (Aubry et al. 2000a). Lynx in the contiguous United States also confront greater human disturbance (Aubry et al. 2000a, Murray et al. 2008a). Lynx populations in the contiguous United States occur in western subalpine forests in Washington, Wyoming, and Montana, mixed conifer forests in Minnesota, eastern mixed conifer forests in Maine, and include a reintroduced population in Colorado.

Results from northern studies (see Mowat et al. 2000) led Ruggiero (2000) to describe suitable lynx habitat as mixed forests dominated by early successional stages, though at the time he acknowledged that few studies in southern populations were available for comparison. Lynx from

¹ E-mail: jsquires@fs.fed.us

Table 3. Multivariate analysis of resource selection of lynx at winter kill-sites compared to travel routes in northwestern Montana, USA, 1998–2002. The full model^a included all important ($P < 0.25$) variables identified based on univariate logistic regression compared to preferred, statistically similar^b reduced model.

Variable	Coeff. (β)	SE	Z	P
Full model				
Lodgepole pine	-0.805	0.961	0.701	0.402
Spruce-fir	0.469	0.593	0.625	0.429
Snag	-1.332	1.906	0.488	0.485
Horizontal cover	0.015	0.008	3.290	0.070
Reduced model				
Horizontal cover	0.018	0.008	5.495	0.019

^a Global Likelihood Ratio Test $\beta = 0$: $\chi^2 = 5.743$, $P = 0.017$.

^b Likelihood Ratio Test between full vs. reduced models = $-2[-94.191 - (-95.55)] = -2.72$, $df = 3$, $P = 0.437$.

winter, but at slightly higher elevations (summer use 136 ± 24 m higher compared to winter, $P < 0.05$). These forests, like in winter, were located below the alpine zone and above low-elevation, dry forest types dominated by ponderosa pine. High horizontal cover ($\bar{x} = 65\%$, $SD = 23.3$) was the most important resource that lynx selected during summer with primary components of horizontal cover including total sapling density (standardized coeff. = 0.343), proportion of subalpine fir (< 8 cm dbh; 0.185) and pole-sized trees (8–18 cm dbh; 0.162) in the overstory, and proportion of false huckleberry (0.14), alder (0.13), and logs (0.13) in the understory; these variables collectively accounted for 41% of variation in horizontal cover (adjusted $R^2 = 0.413$, $n = 1,178$, $F = 70.144$, $df = 12$, $P < 0.001$). Lynx generally avoided conifer forests containing a high proportion of Douglas-fir trees, grass in the understory, or snags (Table 4). Tree (> 10 cm dbh) density in forests used by lynx during summer was 0.07 stems/m² ($SD = 0.05$). Density of saplings (stems 2.5–7.6 cm dbh) averaged 0.44/m² ($SD = 0.51$); 82% of saplings were conifers and 18% were deciduous trees or shrubs. Total tree basal area was 20.02 m²/ha ($SD = 16.66$). During summer, the proportion overstory size classes of trees in forests used by lynx were 0.66 pole ($SD = 0.26$), 0.21 mature ($SD = 0.17$), and 0.06 large ($SD = 0.12$).

Univariate logistic comparisons indicated that lynx selected stands with abundant spruce-fir in the overstory ($\bar{x} = 0.46$, $SD = 0.34$; $\beta = 1.00$, $Z = -5.23$, $P < 0.001$) and mid-story ($\bar{x} = 0.56$, $SD = 0.39$; $\beta = 0.57$, $Z = 4.48$, $P <$

0.001) during summer, but these variables contributed little to the overall model log-likelihood so were not included in the multivariate model. Consistent with lynx using young forests during summer, diameter of trees in selected stands averaged 17.3 cm diameter at breast height ($SD = 6.1$), which was smaller ($\beta = -0.09$, $Z = -4.54$, $P < 0.001$) than diameter of trees in random plots ($\bar{x} = 19.0$, $SD = 6.9$) within lynx home ranges. Lynx tended to avoid forests composed of mature (18–28 cm dbh; $\beta = -0.49$, $Z = -2.04$, $P = 0.041$) and large diameter trees (> 28 cm dbh; $\beta = -0.74$, $Z = -2.40$, $P = 0.016$) during summer. Lynx did not select ($\beta = -0.00$, $Z = -1.13$, $P = 0.257$) habitats according to their proximity to dirt-gravel forest roads that were gated or the subset of roads open to vehicular traffic ($\beta = -0.00$, $Z = -1.05$, $P = 0.295$).

Resource Selection at Hierarchical Scales

Selection for patch metrics was insufficient to justify their inclusion into our multivariate resource-use models based on their low contribution to model log-likelihoods. However, lynx did exhibit some selection for patch characteristics based on univariate tests. Lynx selected ($P < 0.05$) forest patches of spruce-fir forests at most spatial scales during winter (50 m = logistic coeff. = 0.15; 150 m = 0.13; 250 m = 0.12; 500 m = 0.10; 750 m = 0.09) and summer (50 m = 0.38; 150 m = 0.63; 250 m = 0.80; 500 m = 0.79; 750 m = 0.71; 1,000 m = 0.67). Lynx also tended to select basin-like patches such as drainages. Lynx exhibited seasonal differences in their response to patch-level metrics describing open habitat (primarily clear-cuts), patch richness, and dry forests. During winter, lynx avoided clear-cuts and openings across spatial scales (50 m = -0.54; 150 m = -0.36; 250 m = -0.29; 500 m = -0.26; 750 m = -0.26; 1,000 m = -0.25), whereas in summer there was no evidence of avoidance. During winter, lynx selected habitats with low patch richness (50 m = -0.07; 150 m = -0.03; 250 m = -0.04; 500 m = -0.05; 750 m = -0.05; 1,000 m = -0.05) compared to summer when patch richness (i.e., habitat heterogeneity) was not a factor in selection. During summer, lynx also strongly avoided dry-forest patches across scales (50 m = -0.25; 150 m = -0.29; 250 m = -0.33; 500 m = -0.32; 750 m = -0.33; 1,000 m = -0.32) compared to winter when this patch metric was not a factor. At winter kill-sites, lynx were insensitive to patch size ($\beta = -0.609$, $Z = -0.85$, $P = 0.394$) or distance to patch edges ($\beta = 0.001$, $Z = 0.33$, $P = 0.745$) in determining where they successfully captured prey.

DISCUSSION

Lynx exhibit substantial regional differences in resource selection across the contiguous United States (Koehler 1990, Fuller et al. 2007, Moen et al. 2008, Vashon et al. 2008b). Appreciating these differences is fundamental to management and conservation of southern lynx populations. In contrast to populations in Canada (O'Donoghue et al. 1998a, Mowat et al. 2000) and other southern populations in the contiguous United States (Parker et al. 1983, Fuller et al. 2007, Vashon et al. 2008b), lynx in the Rocky Mountains

Table 4. Lynx selection of summer resources based on multivariate logistic regression, Seeley Lake, Montana, USA, 1998–2002.^a

Variable	Coeff. (β)	SE	Z	P
Horizontal cover	0.011	0.003	3.35	0.001
Douglas fir (%)	-0.685	0.224	-3.06	0.002
Grass (%)	-0.655	0.234	-2.80	0.005
Spruce-fir saplings	0.481	0.183	2.63	0.009
Total shrubs	0.031	0.012	2.61	0.009
Sapling density (m ²)	0.562	0.233	2.41	0.016
Snags	-0.955	0.464	-2.06	0.040
Trees 8–18 cm dbh	0.345	0.187	1.85	0.065

^a Global Likelihood Ratio Test $\beta = 0$: $\chi^2_{18} = 180.336$, $P \leq 0.001$.

of Montana selected mature, multistoried forests composed of large-diameter trees with high horizontal cover during winter. These forests were composed of mixed conifers that included lodgepole pine, Douglas-fir, and western larch, but predominately consisted of Englemann spruce and subalpine fir in the overstory and midstory. Forest structures used by lynx in Montana differed markedly from those used by lynx in Alaska and Canada where mature forests were used in proportion to availability and selection was for regenerating (>20 yr) forests (Murray et al. 1994, Staples 1995, Mowat et al. 2000). Regenerating forests used by lynx in Montana during winter were old enough to have developed a multistoried structure with high horizontal cover that supported hares.

During summer, however, lynx broadened their resource use to include early succession forest with high horizontal cover from abundant shrubs, abundant small-diameter trees, and dense spruce-fir saplings. Lynx use of early succession forests during summer in Montana was similar to habitat structures used by other southern populations during winter (Parker et al. 1983, Koehler 1990, Fuller et al. 2007, Vashon et al. 2008b). Seasonal differences in resource selection was not absolute in that lynx in summer still used mature forest, but the gestalt of selection shifted to an earlier successional stage of forest development compared to winter. We collected summer relocation data during daylight hours compared to winter backtracks that also included use of habitat during the night. We do not believe this strongly biased our sample of habitat use, but we could not statistically evaluate the issue. We did not observe seasonal movements to new spatial use areas. Thus, lynx selected a mosaic of forest stages to meet their seasonal resource needs within home ranges (Koehler and Aubry 1994, Aubry et al. 2000a, Buskirk et al. 2000b, Vashon et al. 2008a).

How should managers prioritize their management actions given that lynx use a mosaic of forest structures composed primarily of mature multistory forests during winter and earlier succession forests during summer? We believe the answer to this question rests in the recognition that winter is the most constraining season for lynx in terms of resource use. Starvation mortality was most common during winter and early spring on our study area (J. R. Squires, Rocky Mountain Research Station, unpublished data) and lynx in winter used a narrow subset of available habitat compared to summer. Winter is also a time in the northern Rockies when lynx return to home ranges from exploratory movements elsewhere (Squires and Laurion 2000, Squires and Oakleaf 2005). Contrary to Murray et al. (2008a), spruce-fir forests in mature and old-growth age classes can support high hare densities in the northern and southern Rocky Mountains during winter (Wolfe et al. 1982, Griffin 2004, Malaney and Frey 2006, Zahratka and Shenk 2008). Thus, within heavily managed landscapes of the northern Rockies, we believe that managers should prioritize retention and recruitment of abundant and spatially well-distributed patches of mature, multilayer spruce-fir forests.

Lynx in the northern Rockies, like those in other southern populations (see Vashon et al. 2008b for an exception),

depend on low-density hare populations ($\bar{x} = 0.6$ hares/ha; Griffin 2004, Mills et al. 2005, Zahratka and Shenk 2008). These low hare densities are similar to the cyclic lows of northern populations (Hodges 2000a, b), during which lynx populations in Alaska and Canada experience low recruitment, expanded spatial-use areas, and increased mortality (Poole 1994, Mowat et al. 1996, Slough and Mowat 1996, O'Donoghue et al. 1997); Ruggiero et al. (2000a) recommended that a density of 0.5–1.0 hares/ha was necessary for lynx populations to persist, which is similar to hare densities at Seeley Lake (Griffin 2004, Griffin and Mills 2009). Thus, lynx in Montana depend on a winter prey base at or slightly above the threshold required for persistence; minor reductions in hare density could disproportionately impact lynx.

We hypothesized that lynx would select dense habitats that support high hare densities given this population's almost complete reliance on snowshoe hares during winter (Squires and Ruggiero 2007) and the patterns of resource selection observed for other populations (O'Donoghue et al. 1998a, Mowat and Slough 2003, Vashon et al. 2008b). An alternative hypothesis was that lynx selected habitat based primarily on prey vulnerability rather than abundance. We believed that lynx selected mature, spruce-fir forest during winter in response to high hare abundance rather than to meet other ecological needs (e.g., predator avoidance, thermoregulation). Snowshoe hares at Seeley Lake exhibited source-sink dynamics among forest-structure classes (Griffin 2004, Griffin and Mills 2009). During winter and concurrent with our study, Griffin (2004) found in Seeley Lake that mature-dense forests supported the highest hare densities ($\bar{x} = 0.53$ hares/ha, $SD = 0.53$) compared to other forest-structure classes. However, during summer, Griffin (2004) found that young-dense forests supported the highest hare densities ($\bar{x} = 0.64$ hares/ha, $SD = 0.44$) compared to mature-dense forests (0.34 hares/ha, $SD = 0.41$). Thus, seasonal changes in resource use we observed for lynx in Montana mirrored patterns of hare abundance.

Consistent with the seasonal changes in hare density reported by Griffin (2004, Griffin and Mills 2009), lynx exhibited the strongest selection for dense horizontal cover compared to other resource metrics, regardless of season or scale. During winter, multilayer spruce-fir forests with branching that descended to the snow surface provided the dense horizontal cover necessary to support hares (Hodges 2000a, b). During summer, lynx selected young mixed-conifer forests with high horizontal cover composed primarily of spruce-fir and larch. Commercial foresters at Seeley promoted larch recruitment, which likely reduced winter hare density in regenerating clear-cuts, because larch is a deciduous conifer. Forests that were thinned as a silvicultural treatment were generally avoided by lynx. High horizontal cover from dense lateral foliage coupled with high stem density in high-elevation spruce-fir forests (especially subalpine fir) was similarly found to support the highest hare densities in New Mexico (Malaney and Frey 2006). The highest horizontal cover that lynx used in

the northern Rockies of Montana was at spring-summer den sites (Squires et al. 2008).

Both vegetative structure and prey density affect lynx foraging behavior, which can vary across spatial scales (Murray et al. 1994, 1995; O'Donoghue et al. 1998a; Hopcraft et al. 2005). Our finding that lynx in winter killed prey in areas with greater horizontal cover than was present on their general foraging paths suggests that prey abundance, rather than vulnerability, may drive predation patterns. In contrast, lynx in Maine selected forests with intermediate to high hare density and intermediate cover values (Fuller et al. 2007); lynx avoided dense stands (>14,000 conifer stems/ha) that supported the highest hare density. Stem density at Montana kill-sites (3,200 stems/ha) was considerably below the level (>14,000 stems/ha) that provided refugia for hares in Maine (Fuller et al. 2007). The predation strategy of lynx in Montana was also consistent with a low vegetation density, in that chasing prey (55% of kills) was more prevalent than ambushing (45%; Squires and Ruggiero 2007). In southwest Yukon Territory, Canada, lynx chased hares more frequently in sparse stands and ambushed prey in dense stands (Murray et al. 1995).

Ecological theory suggests that wildlife relate to their environment at hierarchical scales ranging from sites (<1 ha) and patches (1 ha to hundreds of hectares) to landscapes (hundreds to thousands of hectares) and regions (>10,000 km²; Johnson 1980, Bissonette 1997, Murray et al. 2008a). Given that the relationship between organisms (Mitchell et al. 2001, McLoughlin et al. 2002), including carnivores (Chamberlain et al. 2003, Apps et al. 2004, Squires et al. 2008), and their environment is scale-dependent, identifying the appropriate scales at which resources are perceived is fundamental to understanding ecological processes and species distributions (Morris 1987, Carlie et al. 1989). Lynx are similar to other organisms in selecting resources at both fine and coarse spatial scales (Murray et al. 2008b, Squires et al. 2008, Vashon et al. 2008a). However, patch-level metrics provided insignificant improvements in our multivariate resource models to warrant inclusion. The importance of fine-scale metrics suggests that lynx primarily selected resources at fine spatial scales, which is consistent with a sight-hunting predator evolved to capture prey in deep snow and dense cover. However, lynx did exhibit some sensitivity to patch-level metrics based on univariate relationships. For example, lynx selected patches of spruce-fir forest across all scales and seasons. Lynx also selected basin-like patches, such as drainages, regardless of season. However, lynx use of drainages may be attributed to statute or agency policy for establishing streamside management zones to protect riparian areas on federal, state, and private lands, which required managers to retain mature forest patches in buffers along the streams that lynx used to navigate the larger matrix of less suitable habitat, especially in winter (Natural Resource Conservation Service 2007).

Lynx exhibited seasonal differences in patterns of selection for other patch-metrics, including open patches (primarily created by clear-cutting), patch richness, and dry-forest

patches. During winter, lynx strongly avoided clear-cuts and open patches across all spatial scales, whereas in summer there was no evidence of avoidance. Clear-cuts and openings in winter are covered with deep snow and provide little horizontal cover for hares compared to summer, when dense deciduous shrubs and saplings support hares (Griffin 2004). Lynx also exhibited seasonal differences in selection for patch richness by foraging in homogeneous patches of mature forests dominated by spruce-fir (low patch richness) in winter, compared to summer, when lynx were insensitive to this metric. During winter, lynx were also insensitive to patch size or distance to patch edges in determining where they successfully captured prey. Such insensitivity to patch edges contrasted with studies in Alaska where lynx preferentially hunted in edge habitat (Kesterson 1988, Staples 1995).

Seeley Lake had an extensive road network associated with commercial timber harvest that may substantially impact wildlife (Forman and Alexander 1998). Dirt or gravel roads received little traffic, except for a paved, 2-lane highway that bisected the study area. S. Tomson (unpublished data) estimated that 8 vehicles/day traveled low-volume roads (98% of road length) and approximately 55 vehicles/day traveled the remaining (2%) high-volume forest roads. Spur roads that extended off primary timber haul roads were mostly gated and may have received <20 vehicle trips/year. Similar to McKelvey et al. (2000b), we found no evidence that lynx were sensitive to forest roads, including roads used by snowmobiles during winter. Dense forest vegetation at Seeley Lake concentrated snowmobile use on roads and trails, with some dispersed use occurring in clear-cuts already avoided by lynx. We concluded that seasonal resource-selection patterns of lynx were little affected by forest roads with low vehicular or snowmobile traffic.

MANAGEMENT IMPLICATIONS

Lynx in the northern Rockies exhibited a strong selection for spruce-fir forests. Managers should prioritize retention of a habitat mosaic of abundant and spatially well-distributed patches of mature, multilayer spruce-fir forests and younger forest stands. Given the positive correlation between hare abundance and horizontal cover (Keith et al. 1984; Hodges 2000a, b), management actions that reduce horizontal cover, such as precommercial thinning, degrade lynx habitat. Recovery of high-elevation, spruce-fir forests following harvest or thinning tends to be slow due to short growing seasons, cold temperatures, high winds, and deep snow (Fiedler et al. 1985, Long 1995). Therefore, reducing horizontal cover within multistory spruce-fir forests through thinning or harvest may degrade lynx habitat for many decades.

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SNAG AND DOWN WOODY ASSOCIATED SPECIES

INTRODUCTION

Snags, broken-topped live trees, down logs, and other woody material are required by a wide variety of species for nesting, denning, roosting, perching, feeding, and cover (Bull et al. 1997). Snags and down, dead, material are also used for communication purposes:

- Singing, (songbirds),
- Drumming (grouse and woodpeckers),
- Calling (squirrels, jays, birds of prey), and
- Sight recognition posts.

Small mammals and birds use standing and down dead material for food storage and for hunting. Down logs and stumps are important for travel, both below the snow in the winter, and as travel cover throughout the year. It is estimated that about one third of the bird and one third of the mammal species that live in the forests of the Rocky Mountains use snags for nesting or denning, foraging, roosting, cover, communication, or perching. On the Flathead National Forest, at least 42 species of birds and 10 species of mammals are dependent on dead wood habitat for nesting, feeding, or shelter (USDA 1999b). The more mobile species that depend on dead wood habitat include black bears, Canada lynx, wolverines, marten, fisher, bats, woodpeckers, and small owls. Less mobile species that depend on dead wood include snowshoe hares (the primary prey of Canada lynx), red-backed voles (the primary prey of marten, fisher, boreal owl, and several other species), shrews, bryophytes, lichen, fungi, and protozoa. As down woody material further decays, it plays an important role in nutrient cycling, soil fertility, and erosion control.

Snags and their management have become a major conservation issue in managed forests across the western United States. Biologists have recognized for a long time that snags and down woody material provide important wildlife habitat, but only in the last decade or so have managers begun to understand that not only is tree decay an important ecological process that affects wildlife habitat (Bull et al. 1997), but snags and dead wood are an essential, important part of the larger ecosystem. The number, species, size, and distribution of available snags strongly affect snag-dependent wildlife. An insufficient number of suitable snags may limit or eliminate populations of cavity-using species (Saab et al. 1998; Thomas et al. 1979).

Although various sizes of snags and down woody are used, larger birds and mammals require larger dead trees. The larger-diameter down trees provide stable and lasting structure and offer better protection from weather extremes (Bull 2002). Longer down woody pieces provide better runways, shelter, and under-snow access.

Several wildlife species that use snag and down woody habitats on the Flathead National Forest are USFS Region One Sensitive Species, including the bald eagle, black-backed woodpecker, fisher, flammulated owl, Townsend's big-eared bat, and wolverine. One of the TES Species on the Flathead National Forest, the Canada lynx, has a strong habitat association with down woody material (denning).

Snags are essential habitat for at least 42 species of birds and 10 species of mammals in Montana. Table 3- 88 displays specific habitat relationships and Montana NHP rankings for wildlife species in Montana associated with snag, "defective" live tree, or down woody habitat.

GLACIER LOON FUELS REDUCTION AND FOREST HEALTH PROJECT
WILDLIFE - SNAG AND DOWN WOODY ASSOCIATED SPECIES

CHAPTER 3

TABLE 3- 88 SPECIES THAT USE SNAGS, "DEFECTIVE" LIVE TREES, AND/OR DOWNED LOGS.

SPECIES	GLOBAL & STATE RANKS (MTNHP 2009) *	SNAG DBH (INCHES)	SNAG HEIGHT (FEET)	DOWNED LOGS?	OCCURRENCE
✓ American Kestrel (N)	G5, S5B	17	20		Known current
✓ Bald Eagle (S)	G5, S3, SOC	25	40		Known current
Barred Owl (former MIS)	G5, S4	25	30		Known current
Barrow's Goldeneye	G5, S4, potential SOC	25	10		Known current
Big Brown Bat	G5, S4	17	20		Known current
✓ Black-backed Woodpecker (S)	G5,S3 (SOC)	17	10		Known current
✓ Black-capped Chickadee	G5, S5	9	10		Known current
Bobcat	G5, S5	-	-	yes	Known current
Boreal Chickadee	G5,S3 (SOC)	9	10		Known current
✓ Boreal Owl (former S)	G5, S4	17	10		Known current
✓ Brown Creeper	G5, S3, SOC	15	20		Known current
Bufflehead	G5, S5B	17	10		Known current
Canada lynx (T)	G5, S3, SOC	-	-	yes	Known current
✓ Chestnut-backed Chickadee	G5, S4	9	10		Known current
-Common Goldeneye	G5, S5	25	10		Known current
Common Merganser	G5, S5B	17	10		Known current
Dark-eyed junco	G5, S5B	-	-	yes	Known current
✓ Downy Woodpecker	G5, S5	11	10		Known current
Fisher (S)	G5, S3, SOC	25	30	yes	Known current
✓ Flammulated Owl (S, N)	G4, S3B, SOC	17	10		Known current
Great Horned Owl	G5, S5	25	30		Known current
✓ Hairy Woodpecker	G5, S5	17	20		Known current
✓ Harlequin Duck (S)	G4, S2B, SOC	-	-	yes	Known current
Hooded Merganser	G5, S4, potential SOC	17	10		Known current
House Finch	G5, S5	15	10		Known current
House Sparrow	G5, undesired species	15	20		Known current
✓ House Wren (N)	G5, S5B	15	10		Known current
✓ Lewis' Woodpecker	G4, S2B (SOC)	17	30		Known current
- Little Brown Myotis	G5, S4	17	10		Known current
Long-eared Myotis	G5, S4	17	10		Known current
Long-legged Myotis	G5, S4	17	10		Known current
Long-tailed Weasel	G5, S5	-	-	yes	Known current
✓ Marten (former MIS)	G5, S4	17	20	yes	Known current
✓ Mountain Bluebird	G5, S5B	15	10		Known current
✓ Mountain Chickadee	G5, S5	9	10	yes	Known current
Northern Alligator Lizard	G5,S3 (SOC)	-	-	yes	Known current
✓ Northern Flicker	G5, S5	17	10		Known current
✓ Northern Flying Squirrel	G5, S4	17	20		Known current
Northern Goshawk (former S)	G5,S3 (SOC)	-	-	yes	Known current
✓ Northern Hawk Owl	G5, S4, potential SOC	25	10		Known current
Northern River Otter	G5, S4	-	-	yes	Known current
Northern Waterthrush (N)	G5, S5B	-	-	yes	Known current
Osprey	G5, S5B	17	40		Known current

GLACIER LOON FUELS REDUCTION AND FOREST HEALTH PROJECT

CHAPTER 3

WILDLIFE - SNAG AND DOWN WOODY ASSOCIATED SPECIES

TABLE 3- 88 SPECIES THAT USE SNAGS, "DEFECTIVE" LIVE TREES, AND/OR DOWNED LOGS.

SPECIES	GLOBAL & STATE RANKS (MTNHP 2009) *	SNAG DBH (INCHES)	SNAG HEIGHT (FEET)	DOWNED LOGS?	OCCURRENCE
Painted Turtle	G5, S4	-	-	yes	Known current
✓ Pileated Woodpecker (former MIS)	G5, S3 (SOC)	25	60		Known current
✓ Pygmy Nuthatch	G5, S4	17	30		Known current
✓ Pygmy Owl	G5, S4	17	30		Known current
✓ Raccoon	G5, S5	25	10		Known current
✓ Red-breasted Nuthatch	G5, S5	17	20		Known current
✓ Red-naped Sapsucker (N)	G5, S4B	17	20		Known current
Rubber Boa	G5, S4	-	-	yes	Known current
Ruffed Grouse	G5, S4	-	-	yes	Known current
✓ Saw-whet Owl	G5, S4	17	20		Known current
Silver-haired Bat	G5, S4, potential SOC	17	20		Known current
Southern Red-backed Vole	G5, S4	-	-	yes	Known current
Spruce Grouse	G5, S4	-	-	yes	Known current
Striped Skunk	G5, S5	-	-	yes	Known current
Swainson's Thrush (N)	G5, S5B	-	-	yes	Known current
Tailed Frog	G5, S4	-	-	yes	Known current
✓ Three-toed Woodpecker	G5, S4	17	20		Known current
✓ Tree Swallow (N)	G5, S5B	15	20		Known current
Vaux's Swift (N)	G5, S4B	25	40		Known current
✓ Violet-Green Swallow	G5, S5B	15	20		Known current
Western Bluebird	G5, S4B	15	10		Known current
Western Jumping Mouse	G5, S4	-	-	yes	Known current
✓ Western Screech Owl	G5, S3, potential SOC	17	20		Known current
Western (Townsend's) Big-eared Bat (S)	G4, S2 (SOC)	?	?		Known current
✓ White-breasted Nuthatch	G5, S4	17	20		Known current
✓ Williamson's Sapsucker (N)	G5, S4B	17	20		Known current
Wilson's Warbler (N)	G5, S5B	-	-	yes	Known current
Wolverine (S)	G4, S3 (SOC)	-	-	yes	Known current
Wood Duck	G5, S5B	25	10		Known current
Yuma Myotis	G5, S3, potential SOC	17	10		Known current

T=Threatened; S=Sensitive Species; N=Neotropical migratory bird; Natural Heritage Program Rank: G=species range-wide (global); S=state wide; 2=At risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state. 3=Potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though it may be abundant in some areas. 4=Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. 5=Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range. B=State rank modifier indicating breeding for a migratory species. SOC=Montana Species of Concern.

ANALYSIS AREA

OLD GROWTH ASSOCIATED WILDLIFE

INTRODUCTION

Old growth is defined in Amendment 21 of the Forest Plan as "a community of forest vegetation that has reached a late stage of plant succession." The generic description is as follows:

- The age of the dominant cohort of trees is significantly older than the average time interval between natural disturbances (interval will vary depending upon forest cover type and habitat type);
- Forest composition and structure are different from younger stands;
- Rates of change in composition and structure of the stand are slow relative to younger forests;
- There is a significant showing of decadence (wide range of defect and breakage in both live and dead trees).

In The Dictionary of Forestry (Helms 1998), old growth forests are described as having:

- Large trees for the species and site;
- Accumulations of large dead standing and fallen trees;
- Decay or breakage of tree tops, boles, or roots;
- Multiple canopy layers;
- A wide variation in tree size and spacing; and
- Canopy gaps and understory patchiness.

The characteristics of old growth forest described above provide habitat for many plant and animal species. Old growth forests are an important component of biological diversity. For the purpose of this discussion, old growth associated species includes any wildlife species that use the various attributes of old growth forests for some or all of their ecological needs. These needs could include nesting, denning, security, or foraging habitat. For some species, closed canopy old growth provides snow capture and reduces snow depths, insulates the animals from cold winds, and provides protection from predators. Some species, such as the fisher, are strongly tied to canopy cover and mature forest structure for the majority of their habitat needs. More open canopies, or open understories, provide foraging opportunities for prey and predator species alike. Wildlife may use interior old growth habitat as shelter from sun, heat, dryness, or wind and old growth cover may provide protection from predators. Some old growth associated wildlife species need only a portion of their home range to be in old growth; examples include the Canada lynx, northern goshawk, and American marten. Other species such as southern red-backed voles, chestnut-backed chickadee, Swainson's thrush, and northern flying squirrels, have relatively small home range sizes (less than 100 acres), with the necessary proportion of this home range being in old growth unknown.

The following table displays 31 old growth associated species that may be found in the Swan Valley, along with their associations with various old growth habitat characteristics (USDA 1999b).

TABLE 3- 87 HABITAT REQUIREMENTS OF OLD GROWTH ASSOCIATED WILDLIFE SPECIES. (BASED ON WARREN 1998 AND LRMP AMENDMENT 21 FEIS).

SPECIES	COVER TYPE IN AFFECTED AREA	CANOPY	EDGE	LARGER PATCHES	SNAG	DOWN LOG	OCCURRENCE
American Marten	Mixed mesic, lodgepole, spruce/fir forests	Closed	-	+	X	X	Known current
Bald Eagle (S)	Mixed mesic forests, near large lake or river	Open		+	X		Known current
Black-backed Woodpecker (S)	Lower Montane & Montane; post-fire or insect-epidemic forests	Open			X		Known current
Boreal Owl	Mixed mesic and spruce/fir forest mosaic	Closed			X	X	Known current
Brown Creeper	Mixed mesic, lodgepole, and spruce/fir forests	Closed	-		X		Known current
Canada Lynx (T1)	Mixed mesic, lodgepole, and spruce/fir forests; gentle terrain		+2	+	X3	X	Known current
Chestnut-Backed Chickadee	Mixed mesic and spruce/fir forests, especially cedar-hemlock	Closed	-4		X		Known current
Fisher (S5)	Mixed mesic and lodgepole forests	Closed				X	Known current
Flammulated Owl (S, F ⁶)	Lower Montane and Montane, single-story.	Open			X		Known current
Golden-crowned Kinglet	Mixed mesic, lodgepole, and spruce/fir forests	Closed		+	X		Known current
Hairy Woodpecker	Mixed mesic, lodgepole, and spruce/fir forests	Open			X	X	Known current
Hammond's Flycatcher (F)	Mixed mesic and spruce/fir forests	Closed					Known current
Harlequin Duck (S)	Swift mountain streams, riparian old growth (weak association)	Open				X	Known current
Hermit Thrush	Dry mixed mesic and spruce/fir forests	Open		+			Known current
Lewis' Woodpecker	Lower Montane ponderosa pine and old burns	Open			X		Known current
Northern Flying Squirrel	Mixed mesic and lodgepole forests			+	X	X	Known current
Northern Goshawk	Single or multistory old growth; clear forest floor	Closed		+	X		Known current
Pileated Woodpecker	Mixed mesic forests	Closed		+	X	X	Known current
Pine Grosbeak	Mixed mesic, lodgepole, and spruce/fir forests						Known current
Pygmy Nuthatch	Large single-story ponderosa pine and mixed mesic forests	Open			X		Known current
Red-Breasted Nuthatch	Mixed mesic, lodgepole, and spruce/fir; relatively dry	Open		+	X		Known current
Silver-haired Bat	Mixed mesic and lodgepole forests; caves and snags				X		Suspected
Southern Red-backed Vole	Mixed mesic, lodgepole, and spruce-fir forest				X	X	Known current
Swainson's Thrush (F)	Mixed mesic and lodgepole forest with shrub understory			+			Known current
Tailed Frog	Cold, high gradient headwater streams					X	Known current

TABLE 3- 87 HABITAT REQUIREMENTS OF OLD GROWTH ASSOCIATED WILDLIFE SPECIES. (BASED ON WARREN 1998 AND LRMP AMENDMENT 21 FEIS).

SPECIES	COVER TYPE IN AFFECTED AREA	CANOPY	EDGE	LARGER PATCHES	SNAG	DOWN LOG	OCCURRENCE
Three-toed Woodpecker	Mixed mesic, lodgepole, and spruce/fir forests; post-fire				X		Known current
Townsend's Warbler	Mixed mesic and lodgepole forest; dense understory	Closed	-	+			Known current
Varied Thrush	Mixed mesic and spruce/fir forests, especially cedar-hemlock	Closed		+			Known current
Vaux's Swift (F)	Mixed mesic and spruce/fir forests; large hollow snags				X		Known current
White-breasted Nuthatch	Large single-story ponderosa pine	Open			X		Known current
Winter Wren	Mixed mesic and spruce/fir forests, especially cedar-hemlock		-	+	X		Known current
¹ T = Threatened ² + = Positive correlation (where known) ³ X = Important Habitat Component ⁴ - = Negative correlation (where known) ⁵ S = Sensitive ⁶ F = Forest-dwelling Neotropical migrant with apparently declining populations							

ANALYSIS AREA

SPATIAL BOUNDS

The effects analysis area for direct, indirect, and cumulative effects to old growth associated wildlife species is the Glacier Loon Project Area (37,320 acres). This area is large enough to include the home ranges of old growth associated species, and is representative of the effects of fire, natural tree mortality, timber harvest, and road management across the landscape. At the same time, this analysis area is small enough to not obscure the effects of the alternatives. A multi-scale assessment has also been conducted to address habitat diversity concerns.

TEMPORAL BOUNDS

The length of time for effects from the proposed fuels reduction and forest health treatments is approximately 1 to 5 years. This is based on the probable contract length for the proposed project, and the timeframes for related activities.

DATA SOURCES, METHODS, AND ASSUMPTIONS USED

Data used included stand exams, field surveys of snags and down woody logs, old growth surveys, project area field visits, research literature, and GIS and dataset information for features, such as general forest attributes, habitat type, and forest type.

MEASUREMENT INDICATORS

The effects analysis will focus on:

1. Effects to old growth habitat, and
2. Potential effects to old growth associated wildlife species.



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Science

FINDINGS

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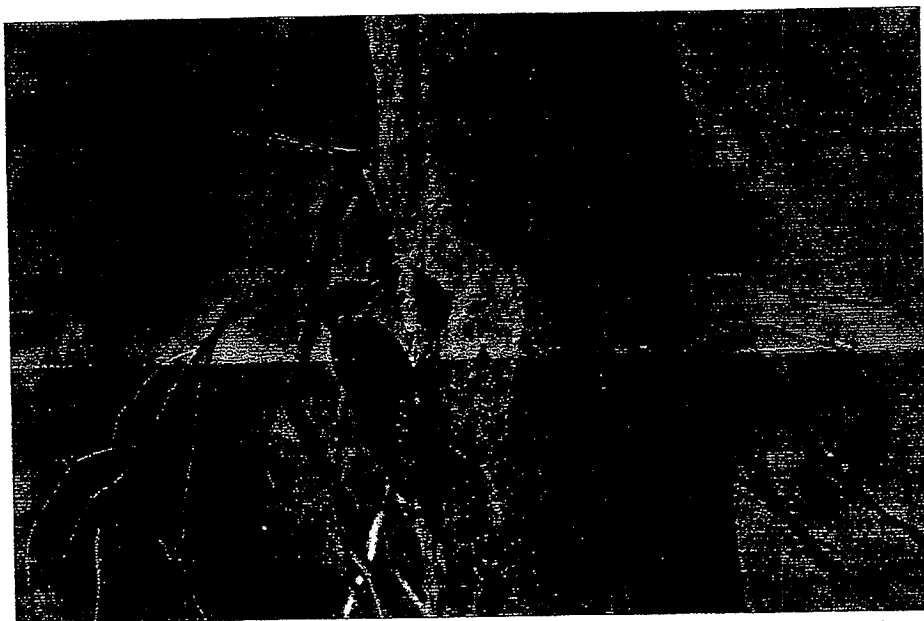
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"Science affects the way we think together."

Lewis Thomas

Woodpecker Woes: The Right Tree Can Be Hard to Find



Teresa Lorenz

A female black-backed woodpecker perches at a nest excavated in a live ponderosa pine in central Washington. Although the tree diameters used by this species for nesting differed (ranging from 8 to 34 inches), it consistently selected nest sites with softer interior wood.

"In order to see birds, it is necessary to become part of the silence."

—John Keats

Somewhere in Washington's eastern Cascade Range a bird perches motionless against a burned tree. It's an American three-toed woodpecker (*Picoides dorsalis*), sporting black back feathers, a white mustache stripe, and a yellow cap. About the size of a large banana, the bird has evenly spaced white flecks on the sides of its chest and on its primary and secondary feathers.

The bird was extracting beetle larvae from another burned tree when a larger, louder black-backed woodpecker (*P. articus*) drove it away. But here, on this burned tree, it drums, "This one is mine. Stay away."

Soon it will pick a spot on the tree, say 30 feet above the forest floor, and bore rapidly into the wood with its chisel-like bill until it excavates a deep pocket. The bird and its mate will roost and nest in this safe place until its favorite food runs out, perhaps in 4 or 5 years. By then, another forest fire might provide a new supply of wood-boring insects.

IN SUMMARY

Woodpeckers and other cavity-excavating birds worldwide are keystone species. These birds excavate their nests out of solid wood, and because their nests are often well protected against predators and the environment, other species use and compete for their old, vacant nests. The presence of cavity-excavating birds in forests has far-reaching effects on species richness and ecosystem health.

Given the species' importance, Teresa Lorenz, a research wildlife biologist with the U.S. Forest Service Pacific Northwest Research Station wanted to find out why cavity-excavating birds do not use many trees seemingly suitable for nesting. This puzzle has eluded researchers for decades. Lorenz and her colleagues also wanted to know what role wood hardness plays in the birds' nest site selection.

The resulting study in the eastern Cascades of Washington found that cavity-excavating birds preferred to nest in trees with significantly softer interior wood. The researchers also found that at-risk species were nesting within burned areas where up to 96 percent of the trees had unsuitably hard wood. This suggests that many trees and snags previously considered suitable for cavity-excavating birds actually may not be.

In dry forests, prescribed mixed-severity fire may be a useful tool for creating suitable nesting habitat for cavity excavators.

In the woodpeckers' absence, other birds or small mammals like owls, squirrels, and bats move in. The new tenants disperse seeds and spores that help new plants and fungi grow. When the dead, burned trees—also called snags—fall to the ground, wood-living bees and wasps take up residence. Fungi and lichens flourish on the fallen tree's gnarly surface, and occasionally a marten hides behind the log.

Because of the woodpeckers' crucial role in maintaining healthy forests, researchers want to understand how these cavity-excavating birds choose trees to nest in. When forest managers know what these birds like, they can take steps to ensure that forests have these kinds of trees.

"Woodpeckers are ecosystem engineers," says Teresa Lorenz, a research wildlife biologist with the Pacific Northwest Research Station. "Many small animals compete for their vacated nests because they are so protected from the elements and other predators."

Ecosystem engineers are organisms that significantly modify, maintain, or destroy a habitat. In the woodpeckers' case, the species help build and maintain a habitat for other species by excavating nests in live and dead trees. When forest managers find many different woodpecker species in a forest, it often signals the presence of a thriving and diverse community of plants and animals.

KEY FINDINGS

- Across 818 snags in Yakima, Kittitas, and Chelan Counties in Washington's eastern Cascade Range, trees not used by birds had wood five times harder than trees that were. Such trees could not be used by birds simply because their wood was too hard for the birds to excavate.
- Within burns used by at-risk woodpeckers, the majority (86 to 96 percent) of seemingly suitable trees contained unsuitably hard wood; wood hardness limits nest site availability for these declining species.
- Researchers found no reliable visual cues to distinguish between suitable and unsuitable trees. Currently, the most effective management solution is to provide large numbers of snags, which can be difficult without the aid of fire.
- In dry forests, a mixed-severity fire that kills trees is an important but underappreciated strategy for providing enough snags for cavity-dependent species. Low-severity prescribed fires may not provide enough snags for these species.
- Suitable snags are limited, such that snag availability drives landscape-level habitat-selection by some species. For example, white-headed woodpeckers selected severely burned patches for nesting, which was initially puzzling because this species does not characteristically forage in burns.

Cavity-nesting birds typically nest in recent burns. More than 50 years ago, studies suggested that woodpeckers picked trees solely based on external tree- or habitat-level factors, like the size of the tree, the tree species, or what the vegetation cover is like near the nest.

Other studies pointed to wood decay, but used only visual indicators to assign a snag decay class as a proxy for measuring this. Lorenz felt there was a missing piece: few studies actually measured wood inside the trees where cavity-excavating birds had chosen to nest.

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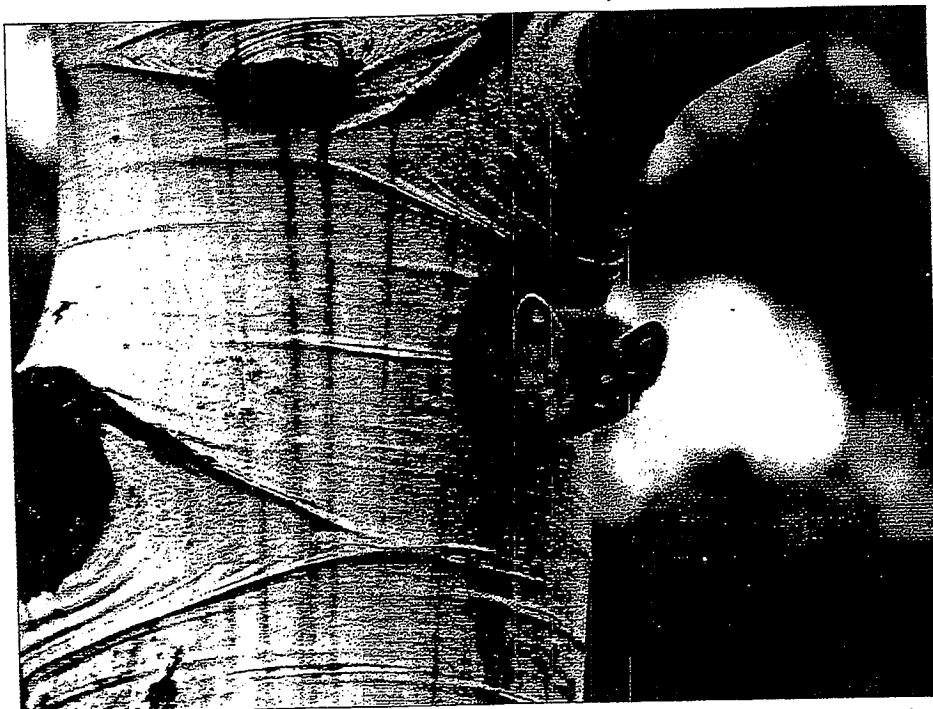
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Cheryl Jennings, layout: cjennings@fs.fed.us

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A pine marten looks out of a pileated woodpecker nest cavity. Many species require or prefer vacated woodpecker cavities, but cannot excavate the cavity themselves. Thus, they rely on woodpeckers to construct habitat for them.

Teresa Lorenz

Matsuoka's Method

The idea for the study came to Lorenz and her colleagues in summer 2011, when they were investigating how far woodpecker nestlings wandered from their nests soon after they fledged. Using hole saws, they drilled into trees to get to the nestlings, to band them. "We noticed an enormous variation in the thickness of the wooden plug," Lorenz says. "Sometimes the nestling would be just inside the bark of the tree. Other times we had to drill through 4 inches of wood. We had all these hypotheses as to what was going on."

A colleague suggested that the variation could be due to the properties of the wood in the tree. Intrigued, they checked the literature. What if wood hardness had something to do with the birds' preference when looking for trees to nest in? Lorenz and her colleagues did not find many studies that addressed this question. "We were surprised that nobody had considered that this wood inside the tree was influencing where the birds were nesting," Lorenz says. So, she decided to investigate the question for her Ph.D. dissertation at the University of Idaho.

The problem was there weren't many reliable methods for measuring wood hardness in a forest setting. "But we found an obscure article in the *Japanese Journal of Ornithology* and this guy had figured out an ingenious way to measure the hardness of wood inside a tree, using a cordless drill, a foot-long drill bit, and an increment borer, without destroying the nest or harming the tree," Lorenz says.

An increment borer is a tool used by foresters and other researchers to extract a section of wood tissue so they can count a tree's annual rings and determine its age. Japanese researcher Shigeru Matsuoka's method involves inserting this tool into a pre-drilled hole above the nest cavity opening. The torque required to spin the increment borer would represent wood hardness. With the most important aspect of her field methods squared away, Lorenz set out with colleague Philip Fischer to gather field data in the eastern Cascade Range in Washington.

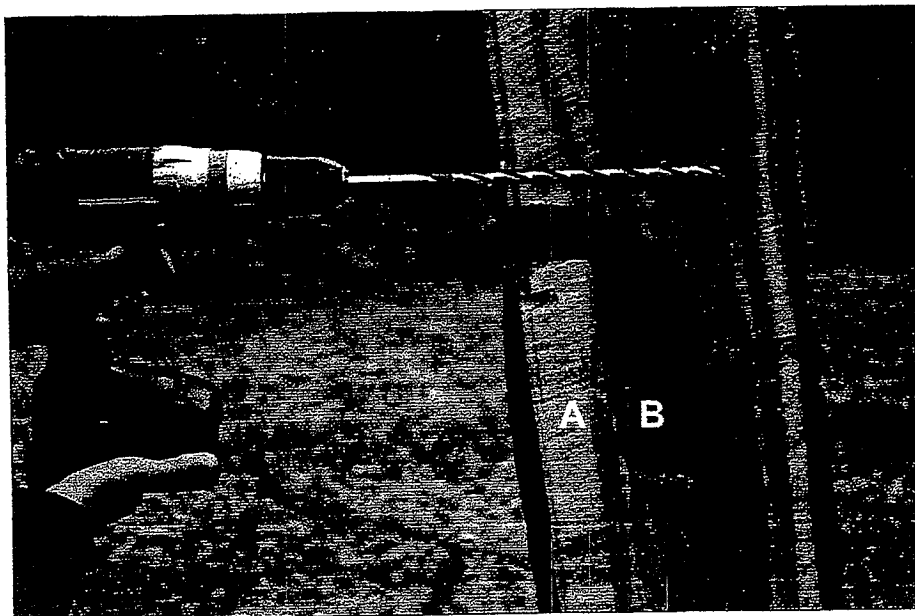
Lorenz had selected six species of cavity-excavating birds for the study. She picked three strong excavators: the three-toed woodpecker, the black-backed woodpecker, and the hairy woodpecker. She also picked a weaker guild of excavators, namely the northern flicker (*Colaptes auratus*), the white-headed woodpecker (*Picoides albolarvatus*), and Williamson's sapsucker (*Sphyrapicus thyroideus*).

This photo shows the longitudinal section of an American three-toed woodpecker (*Picoides dorsalis*) nest and the procedure the study used to quantify wood hardness. First, the researchers use a drill to create a small hole about one-third inch in diameter above the nest cavity opening (top). Then they record the torque required to spin an increment borer into the predrilled hole (bottom). The area marked "A" represents the nest sill, and the area marked "B" represents the nest cavity body.

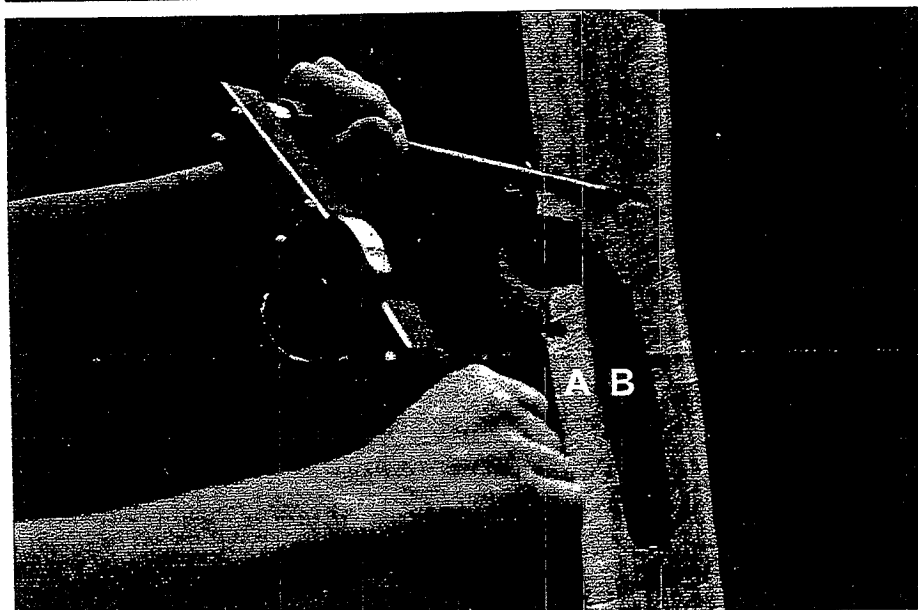
They searched for nests in all major forest types for 3 years from March to July, 2011 through 2013, hiking through ponderosa pine, Douglas-fir, and western hemlock in lower elevations and through higher elevation forests of grand fir, subalpine fir, and western larch. Lorenz and Fischer located adult birds by broadcasting playbacks of their calls and drumming. "Then, we followed the adults until they led us to their nest cavities," Lorenz says. They marked the

locations of occupied nests on portable GPS units. If they noted fresh woodchips on the ground surrounding the nests, they marked those as current-year excavations. They found nests in forest patches ranging from unburned to severely-burned.

Lorenz and Fischer covered a lot of ground. Each of their 10 study sites were 1,483 to 7,413 acres in size. "You get in really good shape," Lorenz says.



Teresa Lorenz



Teresa Lorenz

Soft Pockets

Each carrying about 30 pounds of equipment, Lorenz and Fischer returned in summer to make their measurements. After ensuring the nests had been vacated by the birds, the researchers would scale a tree on climbing ladders to measure wood hardness. They drilled 2 inches above the nests because Matsuoka's study suggested this spot would be representative of the excavated wood.

"In the beginning, we had assumed that wood at the nests would be entirely soft, but that wasn't the case," Lorenz says. "There was some variability when we first started drilling into the trees. Some had hard surfaces. But when you get into the tree a bit, that's when you find these soft pockets. Other times, the soft pockets were close to the surface of the tree, and other times the tree was soft from the get go."

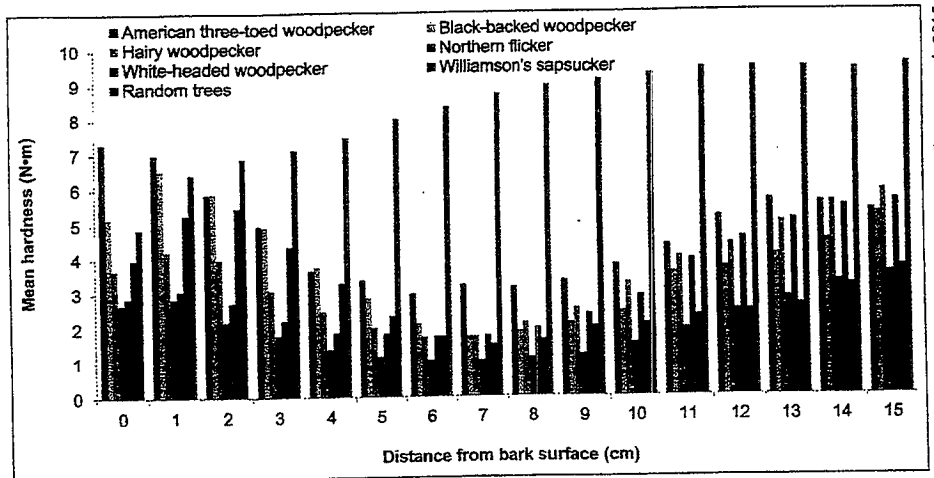
To determine if a tree's external features are reliable indicators of interior wood hardness, the researchers measured wood hardness in random trees within different decay classes.

Then the researchers measured vegetation features that were hypothesized to influence cavity-excavating birds' nest site selection in past studies, such as diameter at breast height of the nest tree; nest and tree height; orientation of the nest cavity entrance; proportion of the ground covered by shrubs; tree and snag density at the nest sites; and tree species. For nests found in snags, they examined the remaining bark, tree growth form, and other features to determine the tree's species.

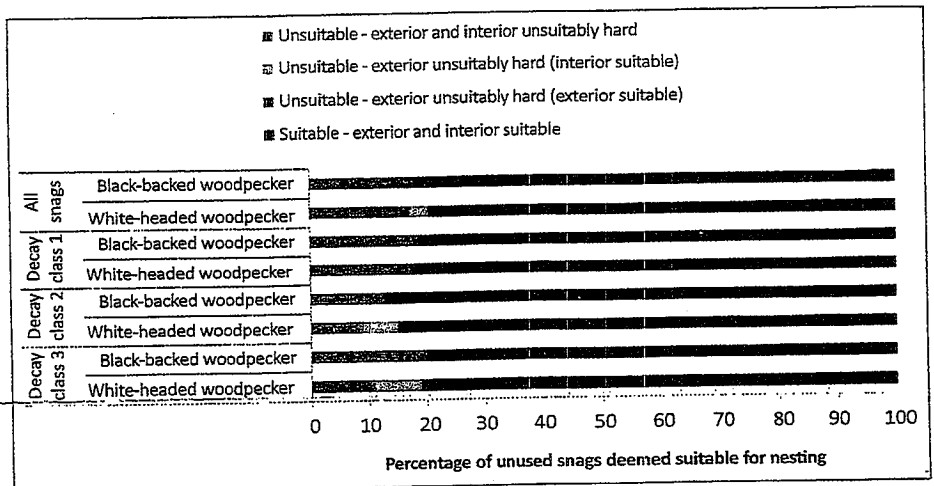
"It was a pretty brutal field season," Lorenz says. "We worked from 6 a.m. to 4 p.m. And it got really hot in these sites."

Lorenz and Fischer also used remote sensing data. To estimate prefire canopy cover at nest sites found in snags, they used gradient nearest neighbor classified Landsat satellite imagery captured between 2 and 8 years prior to each fire.

Lorenz was concerned about seeing an effect in nature, measuring it, but finding a lot of variability. "What if we went to another tree and that pattern didn't hold?" Lorenz says. "But in this study, we were able to measure so many trees that we were confident that the effect we were seeing was real. And it has major management implications."



Mean hardness at nests for six species of woodpecker compared to random sites in central Washington, from 2011 to 2013.



A small percentage of snags are suitable for woodpecker nesting. This chart shows the percentage of 360 unused snags in black-backed woodpecker and white-headed woodpecker nesting territories that were deemed suitable for nesting, based on wood hardness, in central Washington, from 2011 to 2013.

Drawn to Snags

Lorenz and her colleagues found that cavity-excavating birds preferred to nest in trees with significantly softer interior wood. They found that across 818 snags, trees not used by birds had wood five times harder than trees that were. These trees could not be used by birds simply because of the birds' physical limitations in pecking ability.

They found that at-risk species, namely the black-backed and the white-headed woodpeckers, were nesting within burns that contained 86 to 96 percent of trees with unsuitably hard wood. This suggests that past studies that did not measure wood hardness counted many sites as available to cavity-excavating birds when actually they were unsuitable. "By not accounting for wood hardness, managers may be overestimating the amount of suitable habitat for cavity-excavating bird species, some of which are at risk," Lorenz says.

In their study plots, the researchers did not find reliable visual cues to distinguish between suitable and unsuitable trees. Snag decay class was a poor indicator of internal wood properties—and this was not the first study to demonstrate that fact, although it was the first study to do so in ornithology (past studies had been done by foresters and published in forestry journals).

"Currently, the best solution we can recommend is to provide large numbers of snags for the birds, which can be difficult without fire," Lorenz says. According to the researchers' calculations, if one of every 20 snags (approximately 4 percent) has suitable wood, and there are five to seven species of woodpeckers nesting in a given patch, approximately 100 snags may be needed each year for nesting sites alone. This does not account for other nuances, like the fact that most species are

territorial and will not tolerate close neighbors while nesting, or the fact that species like the black-backed woodpecker need more foraging options. Overall, more snags are needed than other studies have previously recommended.

Based on their results, Lorenz and her colleagues see the critical role that mixed-severity fires play in providing enough snags for cavity-dependent species. Low-severity prescribed fires often do not kill trees and create snags for the birds. In addition to benefiting the cavity nesters, a mixed-severity prescribed burn could also aid species that, historically, did not prefer to nest in snags. During their field work, Lorenz and Fischer observed that white-headed woodpeckers, a species traditionally associated with old-growth forest, used prescribed burns presumably because of shortages in suitable nest sites.

"I think humans find low-severity fires a more palatable idea. Unfortunately or fortunately, these birds are all attracted to high-severity burns," Lorenz says. "The devastating fires that we sometimes have in the West almost always attract these species of birds in relatively large numbers."

Many studies have shown that a severely burned forest is a natural part of western forest ecosystems. Snags from these fires attract insects that love to burrow beneath charcoal bark. And where there are insects, there are birds that love eating these insects.

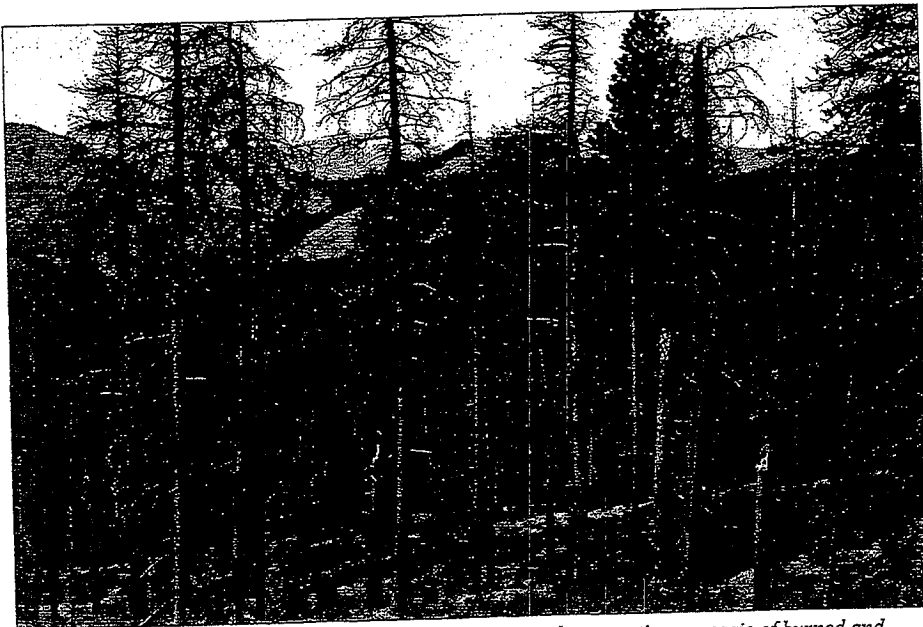
Lorenz and her colleagues stress that providing snags that woodpeckers can excavate is crucial for forest ecosystem health in the Pacific Northwest, where more than 50 wildlife species use woodpecker-excavated cavities for nesting or roosting.

"This study was just the beginning of what I hope will be decades of research," Lorenz says. Picking up on what she learned in this study, Lorenz is now collaborating with Forest Service colleague Michelle Jusino to investigate a kind of fungi that follows forest fires. "There is some mechanism by which the death of a tree somehow enables some species of fungi to decay the wood," she says. The research is bound to take her back into the forests of the Pacific Northwest, where woodpeckers follow forest fires in a timeless cycle of change.

*"The powerful play goes on
and you may contribute a verse."*
—Walt Whitman, *Leaves of Grass*

LAND MANAGEMENT IMPLICATIONS

- Providing snags that woodpeckers can excavate is important for forest ecosystem health in the Pacific Northwest, where more than 50 wildlife species use woodpecker-excavated cavities for nesting or roosting.
- Mixed-severity prescribed-fire may be useful in creating breeding habitat for the white-headed woodpecker, a species traditionally associated with old-growth forest.



Teresa Lorenz

The prescribed burn conducted in this stand flared up in patches, creating a mosaic of burned and unburned trees (a mixed severity burn) that is still used by white-headed woodpeckers and black-backed woodpeckers 10 years after the fire. Tree death is usually required to initiate the process of wood decay—which softens the wood, making it suitable for woodpecker excavation.

For Further Reading

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Writer's Profile

Natasha Vizcarra is a science writer based in Boulder, Colorado. She can be reached through her website at www.natashavizcarra.com.