Appendix AE

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FACTORS AFFECTING THE RELATIVE USE OF NORTHERN GOSHAWK (ACCIPITER GENTILIS) KILL AREAS IN SOUTHCENTRAL WYOMING

by

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I followed male goshawk foraging movements during the breeding seasons of 1996 and 1997. Kill sites were identified by identifying points of direct return along foraging paths. The number of locations within 300 m circles around kill sites were used as a measure of relative use. I examined four factors which could affect the relative use of goshawk kill areas: 1) prey abundance, 2) habitat characteristics, 3) landscape patterns, and 4) habitat needs of prey species. The relative use of kill areas was more frequently correlated with habitat characteristics than prey abundance. However, goshawks may be able to asses relative abundance of prey when prey are very abundant. Goshawks returned most often to sites with more mature forests, gentler slopes, lower ground coverage of woody plants, and greater densities of large conifers. Goshawk kill areas were often associated with small natural openings, as were many prey species. Goshawks returned most often to kill sites which were closer to nests, had greater coverages of conifer, greater densities of small natural openings in 1 km circles around kill sites. In 300 m circles goshawks exhibited similar use patterns, but also returned most often to areas with greater numbers of patch types.

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Chapter 1 - Introduction

Distribution and Taxonomy:

The northern goshawk (Accipiter gentilis) is a large forest raptor that inhabits boreal and temperate forests throughout the holarctic. In North America, the breeding range of the species includes forested areas in most of Canada and Alaska, the western United States (excluding the Great Plains), the northeastern United States, and the Appalachian Mountains in West Virginia. Goshawks occur in non-forested areas such as the Great Plains and the Midwest during the winter. This is particularly true when northern snowshoe hare and grouse population cycles are at their lowest (Squires and Reynolds 1997). In Wyoming, the goshawk breeds in forested mountainous areas throughout the state (Oakleaf et al. 1982). Goshawks in southcentral Wyoming are migratory, wintering Colorado and southern Utah (Squires and Ruggerio 1995).

Goshawks are the largest members of the accipiter family in North America. Like sharp-shinned and Cooper's hawks, goshawks have relatively short, rounded wings and long tails. This adaptation allows them greater maneuverability when pursuing prey through forests. However, goshawks also hunt in open habitats (Younk and Bechard 1992).

Two subspecies of goshawks breed in North America (A.O.U. 1957). Accipiter gentilis atricapillus breeds throughout North America except for Queen Charlotte and Vancouver Islands. Accipiter gentilis laingi occurs only on Queen Charlotte and Vancouver Islands and is darker and smaller in size than Accipiter gentilis atricapillus (Johnson 1989).

Population Status:

Crocker-Bedford (1990) was the first to describe goshawk breeding populations as declining, prompting a wave of goshawk research. In Arizona he described a decrease in nesting pairs of goshawks from 260 pairs in the 1950's and 1960's to 60 pairs in 1988 and attributed the decline to the loss of forested habitat. However, Kennedy (1997) found sufficient fault in Crocker-Bedford's study design to question the validity of his results.

In her review of goshawk population studies, Kennedy (1997) argues that no evidence exists to indicate goshawk populations are declining in North America for two possible reasons: (1) Goshawk populations could actually be stable or increasing; (2) population declines could be occurring but are not being detected due to type II error. The U.S. Forest Service currently lists the northern goshawk as a sensitive species, requiring the effects of management actions on goshawks to be evaluated.

Nesting Habits and Habitats:

Nesting pairs are territorial, defending approximately a 170 ha area around the nest against raptors and other goshawks (Reynolds et al. 1992, Kennedy et al. 1994). The birds form pairs, construct nests, and copulate from February to March (Squires and Reynolds 1997). Only one brood is raised per season, but renesting can occur if the nest fails (Squires and Reynolds 1997). Females do most of the incubating, and males provide the female with food during incubation. The female continues to brood during the early nestling stage and the male provides most of the food for the female and the young. As the nestlings grow the male continues to provide most of the food for the young. The female is primarily responsible for defending the nest against predators. However, she may also provide the nestlings with food depending upon the male's delivery rate. Territory and mate fidelity can be high, but changing of mates and territories may occur (see Squires and Reynolds 1997 for a summary).

At the biogeographic scale (Wiens et al. 1986), goshawks breed in temperate and boreal forest ecosystems. At the stand or nest site scale, goshawks nest in mature forest stands with high canopy closure, moderate slopes, and open understories (Reynolds et al. 1982, Hayward and Escano 1989, Siders and Kennedy 1994). Nests can often be found near water (Bull and Hohmann 1994, Hargis et al. 1994) and small forest openings (Speiser and Bosakowski 1987).

Foraging Habits and Habitats:

Goshawks are considered short duration sit-and-wait predators. When hunting, goshawks search for prey from a perch for a short period of time, then fly to another perch. Flight time between perches is from 24 seconds (Widén 1984) to 3.5 minutes (Kennedy 1991). When prey is flushed, goshawks chase it persistently with reckless abandon (Squires and Reynolds 1997). In Europe, captive goshawks are most successful capturing wood pigeons when attacking small flocks or single pigeons, and when the distance at which pigeons detect attacking goshawks is short (Kenward 1978).

Goshawks take a wide range of vertebrate prey (Squires and Reynolds 1997). However, most authors show that ground squirrel to hare-sized mammals and robin to grouse-sized birds are the most common prey items. Goshawk food habits depend upon region, season, and vulnerability and availability of prey (Squires and Reynolds 1997). Goshawks feed primarily upon red squirrels, golden-mantled ground squirrels, northern flickers and American robins during the breeding season in southcentral Wyoming (Squires in prep.). Snowshoe hares comprise the majority of prey taken during high points in the snowshoe hare cycle during the breeding season in southwest Yukon, Canada (Doyle and Smith 1994). Food habits are poorly understood outside the breeding season.

Few authors have investigated goshawk habitat use. Goshawks used a wide range of habitat types in three North American studies (Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994). However, they used mature forests most often. Goshawks used areas with trees > 51 cm d.b.h. (Austin 1993), greater canopy coverage, greater basal areas and greater tree densities (Bright-Smith and Mannan 1994, Hargis et al. 1994) in greater proportion than their availability. In Europe goshawks preferred mature forests in a boreal forest matrix (Widén 1989) and forest edges in an agricultural matrix (Kenward 1982).

Only Beier and Drennan (1997) differentiate foraging from other non-nesting activities. Additionally, Beier and Drennan (1997) are the only authors to measure prey abundance and habitat characteristics in goshawk foraging areas. They show goshawks use foraging areas with greater canopy closure, greater tree density, and greater density of larger trees (>40.6 cm d.b.h.), but are not associated with prey abundance. The authors suggest that higher densities of large trees allow goshawks to surprise prey while also allowing room for maneuverability.

During the breeding season, goshawks use areas which range from an average of 570 ha (Kennedy et al. 1994) to 6908 ha (Austin 1993) with the male's home range being larger than the female's (Squires and Reynolds 1997). Within home ranges are areas used more intensely than others. These are core areas. Kennedy et al. (1994) show core areas of goshawks to comprise roughly 32% of the home range. Samuel et al. (1985) define core areas as sites used more intensively than other portions of the home range. These sites may be safe havens, and reliable food sources. Despite the potential importance of core areas to foraging male goshawks, no authors describe how goshawks choose them.

Study Objectives:

The goal of this study was to determine how male goshawks use core foraging areas during the breeding season. My study was a field study, and many factors were not controlled (Ratti and Garton 1996). The results from this study were used to identify trends and generate hypotheses regarding goshawk foraging. The hypotheses I generated also apply to other raptors.

Several factors can potentially influence a goshawk's use of core foraging areas. These include prey availability (as defined by prey abundance and habitat characteristics) and landscape characteristics. This study attempts to address these issues in the following objectives:

1. Measure the prey abundance and habitat characteristics of goshawk kill sites (Chapter 2).
2. Measure the landscape characteristics surrounding goshawk kill sites (Chapter 3).
3. Measure habitat use of goshawk prey (Chapter 4).
4. Describe goshawk nest behavior, food habits, and delivery frequency (Chapter 5).

John Squires (Forest Sciences Lab, U.S. Forest Service, Missoula, Montana) and Stanley Anderson (Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, Wyoming) have studied goshawk nesting habitat, food habits, and foraging ecology from 1993 to 1997. This study was conducted during the summers of 1996 and 1997 as one facet of the Squires and Anderson project.

Study Area:

The study was conducted on the Medicine Bow National Forest in the Sierra Madre and Medicine Bow Ranges in southcentral Wyoming (see Fig. 1). The U. S. Forest Service manages most of the land in the forested areas, while the surrounding sagebrush and grasslands are managed as rangelands by private citizens, corporations, the State of Wyoming, or the Bureau of Land Management.

Elevation in the Sierra Madres and Medicine Bow Ranges varies from approximately 1828 m to 3749 m. Temperature in the Medicine Bow National Forest varies considerably with season (Alexander et al. 1987). Temperatures in the months of May through August are generally 60-70° F during the day, and 30-40° F at night. Mean annual precipitation varies from 38 cm at 1,830 m elevation, to 64 cm at 3,050 m elevation (Alexander et al. 1987). Most precipitation occurs from October through May as snow at elevations above 2,440 m. At lower elevations most precipitation occurs as rain from April through September (Alexander et al. 1987). Snow prevents vehicle travel on most roads in the Medicine Bow National Forest in May, with most roads clearing by mid June.

Lodgepole pine (Pinus contorta) dominates forest landscapes on the Medicine Bow National Forest. Lodgepole pine and aspen (Populus tremuloides) dominate the lower elevation forests, both species reaching maximum abundance at 2590 m to 3050 m. Ponderosa pine (Pinus Ponderosa) and Douglas fir (Pseudotseuga menziesii) can dominate lower elevation forests near the Colorado border. Ponderosa pine was historically more common in the Medicine Bow National Forest, however, fire and timber management reduced its distribution (Alexander et al. 1987). Limber pine (Pinus flexilis) occurs at the same elevation as lodgepole pine and aspen, but is only found on warm sites with rocky and shallow soils (Alexander et al. 1987), usually along ridgetops and south facing slopes. Sub-alpine fir (Abies lasiocarpa) and Englemann spruce (Picea engelmanni) are dominant from 2740 m to timberline (Alexander et al. 1987). Goshawk nests are found almost exclusively in lodgepole pine and aspen forests.

Although lodgepole pine and aspen dominate the lower elevation forest, they are rarely contiguous. Most lodgepole pine and aspen stands are interspersed with natural meadows, clearcuts and roads. \Of the four national forests in Wyoming, the most board feet per year from 1950 to 1991 were harvested from the Medicine Bow National Forest. In 1991 the Medicine Bow National Forest harvested approximately twice the amount of timber board feet compared to other national forests in Wyoming (Knight 1994).

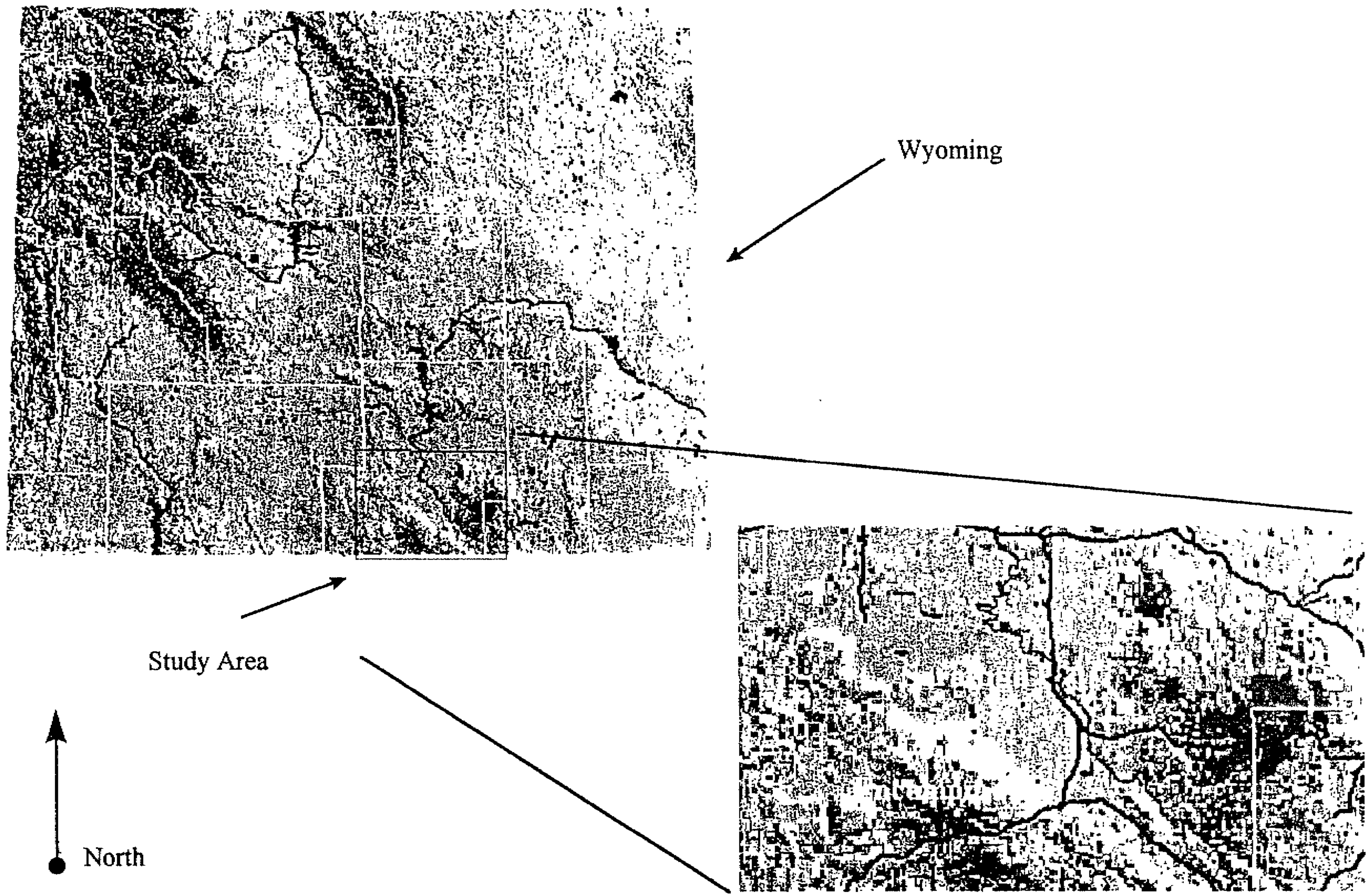

Figure 1. Location of the study area in the Medicine Bow National Forest, southcentral Wyoming. Green and yellow represent mountainous areas.

Literature Cited

Alexander, R.R., G.R. Hoffman, and J.M. Wirsing. 1986. Forest vegetation of the Medicine Bow National Forest in southeastern Wyoming: a habitat classification. U.S. Forest Service Research Paper RM-271, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

American Ornithologists' Union. 1957. Check-list of North American Birds. Fifth ed. American Ornithologists' Union. Washington, D.C.

Austin, K.K. 1993. Habitat use and home range size of breeding northern goshawks in the southern Cascades. Master's Thesis, Oregon State University, Corvallis.

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7: 564-571.

Bright-Smith, D.J. and R.W. Mannan. 1994. Habitat use by breeding male northern goshawks in northern Arizona. Studies in Avian Biology no. 16: 58-65.

Bull, E.L. and J.H. Hohman. 1994. Breeding biology of northern goshawks in northeastern Oregon. Studies in Avian Biology no. 16: 103-105.

Crocker-Bedford, D.C. 1990. Goshawk reproduction and forest management. Wildlife Society Bulletin 18: 262-269.

Doyle, F.I. and J.M.N. Smith 1994. Population responses of northern goshawks to 10-year cycle in numbers of snowshoe hares. Studies in Avian Biology no. 16: 122-129.

Hargis, C.D., C. McCarthy, and R.D. Perloff. 1994. Home ranges and habitats of northern goshawks in eastern California. Studies in Avian Biology no. 16: 66-74.

Haward, G.D. and R.E. Escano. 1989. Goshawk nest-site characteristics in western Montana and northern Idaho. Condor 91: 476-479.

Johnson, D.R. 1989. Body size of northern goshawks on coastal islands of British Columbia. Wilson Bulletin 101: 637-639.

Kennedy, P.L. 1991. Reproductive strategies of northern goshawks and Cooper's hawks in north-central New Mexico. Ph.D. dissertation, Utah State University, Logan.

Kennedy, P.L., J.M. Ward, G.A. Rinker, and J.A. Gessaman. 1994. Post-fledgling areas in northern goshawk home ranges. Studies in Avian Biology no. 16: 75-82.

Kennedy, P.L. 1997. The northern goshawk (Accipiter gentilis atricapillus): Is there evidence of a population decline? Journal of Raptor Research 31(2): 95-106.

Kenward, R.E. 1978. Hawks and doves: factors affecting success and selection in goshawk attacks on woodpigeons. Journal of Animal Ecology 47: 449-460.

Kenward, R.E. 1982. Goshawk hunting behaviour and range size as a function of food and habitat availability. Journal of Animal Ecology 150: 69-80.

Knight, D.H. 1994. Mountains and Plains. The Ecology of Wyoming Landscapes. Yale University Press, New Haven and London.

Oakleaf, B., H. Downing, B. Raynes, M. Raynes, O. Scott. 1982. Wyoming Avian Atlas. Wyoming Game and Fish Department.

Ratti, J.T. and E.O. Garton. 1996. Research and experimental design. Pages 1-23 in T.A. Bookhout, ed. Research and Management Techniques for Wildlife and Habitats, (T.A. Bookhout ed.). Fifth ed., rev. The Wildlife Society, Bethesda, Md.

Reynolds, R.T., R.T. Grahm, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. U.S.D.A. Forest Service General technical Report RM-217. Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado.

Reynolds, R.T., S.M. Joy, and D.G. Leslie. 1994. Nest productivity, fidelity, and spacing of northern goshawks in Arizona. Studies in Avian Biology no. 16: 106-113.

Reynolds, R.T., E.C. Meslow, and H.M. Wight. 1982. Nesting habitat of coexisting accipiter in Oregon. Journal of Wildlife Management 46(1): 124-138.

Samuel, M.D., D.J. Pierce and E.O. Garton. 1985. Identifying areas of concentrated use within the homerange. Journal of Animal Ecology 54: 711-719.

Speiser, R. and T. Bosakowski. 1987. Nest site selection by northern goshawks in northern New Jersey and southeastern New York. Condor 89: 387-394.

Siders, M.S., and P.L. Kennedy 1994. Nesting of Accipiter hawks: is body size a consistent predictor of nest habitat characteristics? Studies in Avian Biology no. 16: 92-96.

Squires, J.R. 1998. Food habits of northern goshawks in southcentral Wyoming. In prep.

Squires, J.R. and R.T. Reynolds. 1997. Northern Goshawk (Accipiter gentilis). In The Birds of North America, No. 298. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Squires, J.R. and L.F. Ruggerio. 1995. Winter movements of adult northern goshawks that nested in southcentral Wyoming.

Widén, P. 1984. Activity patterns and time-budget in the goshawk Accipiter gentilis in a boreal forest area in Sweden. Ornis Fennica 61: 109-112.

Widen, P. 1989. The hunting habitats of goshawks Accipiter gentilis in boreal forests of Central Sweden. Ibis 131: 205-231.

Wiens, J.A., J. Addicott, T. Case and J. Diamond 1986. The importance of spatial and temporal scale in ecological investigations. In: Diamond, J. and Case, T.J. (eds), Community Ecology, Harper & Row, New York, pp. 145-153.

Younk, J.V., and M.J. Bechard. 1992. Effects of gold mining activity on northern goshawks beeding in Nevada's Independence and Bull Run Mountains. Annual Report Raptor research enter, Boise State University, Boise, Idaho.

Chapter 2- Prey abundance and habitat characteristics in northern goshawk core use areas

Introduction:

The northern goshawk (Accipiter gentilis) is listed as a sensitive species by the U.S. Forest Service in the Rocky Mountain Region, and a petition to list the goshawk as endangered is currently being reviewed by the U.S. Fish and Wildlife Service. Goshawks nest in mature forests, which causes concern for their populations. While nesting habitat is well studied (see Squires and Reynolds 1997 for a summary), goshawk foraging preferences are poorly understood in North America. Foraging area choice could be especially important for breeding male goshawks, which provide the majority of the food to the nestlings and female until the young disperse (Squires and Reynolds 1997). Widén (1997) suggests that degradation of foraging areas due to intensive forest management is one reason goshawk populations are declining in Fennoscandia. Although strong evidence of population declines in North America is lacking (Kennedy 1997), forest management could have a similar effect in North America.

Only Beier and Drennan (1997) attempted to identify the relative importance of habitat structure and prey abundance in goshawk foraging areas compared to random areas. The authors found that goshawks used foraging areas based upon habitat structure rather than prey abundance in northern Arizona. Wakeley (1978) and Bechard (1982) found similar results in ferruginous (Buteo regalis) and Swainson's (Buteo swainsoni) hawks.

Goshawks may hunt over large areas, but core areas within home ranges receive concentrated use. Core areas are described by Samuel et al. (1985) as areas within an animal's home range which receive concentrated use, and may contain reliable food sources. Despite the importance of core areas, few authors examine characteristics of core areas used by raptors. In northcentral New Mexico, Kennedy et al. (1994) show that core areas comprise 32% of breeding goshawks' home ranges (male and female), and that male core areas are smaller than females. Additionally, the authors show that male core areas away from nests are preferred hunting areas. Raptors often return to areas where prey are captured (Wakeley 1978, Toland 1986).

Goshawk foraging habits are very hard to study. Most authors use radio-telemetry to monitor movements of adults goshawks during the breeding season (Beier and Drennan 1997, Hargis et al. 1994, Bight-Smith and Mannan 1994). Male goshawks move large distances, making tracking difficult. The average size of male home ranges during the breeding season ranges from 1758 ha in Arizona (Bright-Smith and Mannan 1994) to 2425 ha in northern California (Austin 1993). Goshawks make kills up to 5400 m from nests in southcentral Wyoming (See Chapter 3). Additionally, goshawks often use forests for hunting during the breeding season (Beier and Drennan 1997, Hargis et al. 1994, Bright-Smith and Mannan 1994), making visual observations very difficult.

Authors have tracked goshawks movements using hand held or truck mounted antennas (Beier and Drennan 1997, Hargis et al. 1994, Bright-Smith and Mannan 1994). Because goshawks move large distances over forested and rugged terrain, tracking movements requires much effort. Beier and Drennan (1997) averaged 10 hours of effort to obtain one precise foraging location (average error = 22 m) during the breeding season.

My objective was to determine how prey abundance and habitat characteristics affected the use of kill sites by breeding male goshawks in the lodgepole forests of southcentral Wyoming. Specifically, I investigated if prey abundance or habitat characteristics were correlated with how often a bird was found in an area where it had made a kill. A field crew and

I tracked northern goshawks for 561 hours during 1996 and 1997 using a three tower system in which towers were placed on hill tops. We were able to track male movements almost continuously and identify areas where goshawks made kills.

Methods:

Goshawks are short duration sit-and-wait predators, flying short distances from perch to perch, pausing briefly at each perch to search for prey (Kenward 1982). A goshawk's foraging path through the landscape can be traced by taking locations at two minute intervals.

I found active goshawk nests during the summers of 1996 and 1997. I followed the foraging movements of male goshawks and identified kill areas. Prey abundance and habitat characteristics were measured in kill areas. The number of times goshawks returned to kill areas was used as a measure of relative importance or core use. Prey abundance and habitat characteristics were correlated with core use to determine important factors.

Nest Searches. Historic goshawk territories were searched. Territories were defined as a cluster of known nests originally found by falconers, forest service technicians conducting goshawk surveys, reports from the general public, and walking randomly placed transects during 1991 and 1992 (Squires and Ruggerio 1996). When a territory was visited, the nests were checked for goshawk presence with field glasses. If goshawks were not present, an attempt to search every tree for goshawk nests within 200 m of the most recently occupied nest was made. Within one km of the former nest broadcast surveys (Kennedy and Stahleckler 1983) were conducted on as many territories as possible where 200 m searches revealed no goshawks.

Radio Telemetry. Adult goshawks were trapped approximately five days after their eggs hatched (mid to late June) using a dho-gaza set (Bloom 1987) with a live great-horned owl (Bubo virginianus) as a lure. Transmitters with one year lifespans and tip switches were attached to goshawks using a backpack harness (total weight = 25.5 g). Tip switches increased the signal rate when birds were horizontal. The foraging movements of male goshawks were monitored using a three tower system. Towers with null-peak antennas were placed on tall knobs surrounding the nest and/or foraging areas. Eight male goshawks were monitored during the summers 1996 and 1997, four were monitored each summer. The goshawks monitored in 1996 included Marten, Simpson's Creek, Glass Creek, and Divide Creek. The goshawks monitored in 1997 included Boundary, Angel Creek, Elk Creek, and Grande Creek. Male foraging movements were monitored from the time goshawk nestlings were 10-20 days old to 50-60 days old.

Each male goshawk was tracked during tracking sessions lasting from noon until noon the following day during the daylight period. Goshawk pairs were monitored at 14 day intervals. A total of 32 tracking sessions were conducted on eight birds during the summers of 1996 and 1997. Telemetry testing using correctable global positioning systems (GPS) indicated our average error was approximately 100 m.

Locations were taken on male goshawks during tracking sessions at two minute intervals until the male returned to the nest with prey (Squires1995). One to three foraging bouts were followed per session. Foraging bouts were recorded in the mornings and late afternoon. Locations were taken at ten minute intervals when foraging bouts were not being recorded. Prey deliveries at the end of foraging bouts were confirmed by observers in ground blinds placed near nests. Nest observers were in radio contact with telemetry personnel to confirm the presence of adult males in nest stands. Prey type was noted when possible.

Male goshawks usually returned directly to the nest to deliver prey after making a kill during the breeding season in Sweden (R. Kenward, pers. comm.). Goshawk kill areas can be identified by closely monitoring male movements and noting when males begin direct paths toward nests (see Fig. 1). Widén (1982) suggested that during the winter, predation could be monitored in telemetered goshawks by recording activity on an automated chart roll and noting periods of intense activity followed by long periods of inactivity with poor signal strength. The periods of intense activity were frequent changes in signal strength associated with the capture of prey. The long periods of inactivity and poor signal strength were the result of goshawks perching on prey on the ground. I observed similar patterns in signal strength and activity of radio signals at the point of return, except the period of inactivity and poor signal strength was relatively short (10 s to 10 min). Prey and habitat sampling occurred at the points of return from successful foraging bouts (confirmed by observers at the nest). Points of return were referred to as kill sites. I assumed: 1) a period of intense activity, defined as changing signal strength and bearing every one to 10 min, followed by a short period (10 s to 10 min) of low signal strength and then 2) a rapid return to the nest (one to five min) and 3) a prey delivery to the nest or fledglings were areas in which male goshawks had made kills.

Kill sites were located through orienteering and a GPS unit. At each kill site, 300 m by 300 m grids were oriented toward the bird's location just prior to the kill. Each grid was composed of three 300 m transects spaced 150 m apart. Point counts were spaced at 150 m and placed at the ends and the middle of each transect for a total of nine point counts per grid (see Fig. 2). Sherman live traps (23 x 13 x 13 cm) were placed at 10 m intervals along each transect, for a total of 93 traps per grid.

Prey Abundance. I sampled prey as soon as possible after the kill location was obtained (n=18, mean= 4.8 days, median=3, mode=1, range=1 to 9). Point counts were begun at 6:00 and

8:00 on two consecutive mornings, and all point counts were finished by 10:30. The distances to all birds and red squirrels (Tamiasciurus hudsonicus) were estimated for six minutes at each point count. The distances to all birds and red squirrels not observed at point counts but observed along transects were recorded.

Small mammal trapping was conducted for approximately 40 hours. Traps were baited with whole oats and checked and re-set three times during the 40 hours. Traps were opened by 20:00 (mean = 18:06) and checked the following morning by 10:00 (mean = 8:52). Each species trapped was recorded and sprung traps were checked and re-set. Traps were checked again the same evening by 20:00 (mean = 17:52), and re-set. Traps were checked a final time the following morning by 10:00 (mean = 8:40).

Habitat. Habitat structure was measured at nine 0.04 ha plots in each grid. One plot was placed at the center of the grid, and eight random plots were placed in a stratified random manner. No more than two plots were placed in each quarter of the grid.

Methods used to measure habitat variables followed James and Shugart (1970) and Noon (1980) with some modifications. Most habitat characteristics were measured along two 22.6 m transects, each placed in the cardinal directions and bisected a 0.04 ha circular plot (11.3 m radius). The species and d.b.h. were recorded for all trees and shrubs whose main stem was at least breast height. Trees and shrubs below breast height was recorded as shrubs. The distance from the center of the plot and d.b.h. of the nearest tree in each quarter was measured. The number of live and dead stems intersecting the observer's outstretched hands along both transects was used to calculate shrub density. Dominant shrub species (those > 0.5 m tall and below breast height) were recorded in order of prevalence. Five Daubenmire quadrangles were used to estimate ground coverage (Daubenmire 1959). One was placed at the center and one randomly placed along each half transect for a total of five per plot. The percent coverage of each plant species, woody and herbaceous litter, and rock covering the Daubenmire quadrat was recorded. The presence of live canopy at 20 stations along each transect was recorded and used to calculate canopy coverage. A clinometer was used to measure height of live canopy at the center of the plot and at points where transects intersected the edge of the plot. Understory structure was measured with a density board 2 m tall and 0.3 m wide, divided in to three sections (0-0.3 m, 0.3-1 m, and 1-2 m). The number of squares on the density board obscured by trees, shrubs, and rock were recorded for each section. Four readings were taken from the plot center to the points where transects intersected the plot edge.

The distance to the nearest down dead piece of wood in each quarter was also recorded. Wood smaller than 2 cm dbh and less than 0.5 m in length were not recorded. The diameter (at the point closest to the plot center) and woody debris length were recorded. The log class, distance, diameter, and woody debris length for the largest and nearest downed log were recorded during 1997. Log classes were defined as: 1) freshly fallen with fresh leaves or needles; 2) solid wood with or without bark and branches; 3) wood decayed and soft; 4) wood in advanced stages of decay and very soft; and 5) wood very decayed and almost indistinguishable from the ground.

In addition to measuring structural variables, the dominant vegetation of the plot, distance to the nearest edge, and edge type were recorded. Edges were defined as a major change in habitat, which included streams, forest types, natural openings and clearcuts. The distance to water was recorded for sites sampled in 1997. The topographic position of the plot was noted, such as drainage, ridgeline, and gentle slope as well as slope and aspect using a clinometer and compass.

Locations taken at ten minute and two minute intervals, sub-sampled at ten minute intervals, were overlaid on kill areas to determine the number of times a bird was located in a kill area. The number of times a bird returned to a kill site was used to measure relative use, herein referred to as core use. The locations of sites sampled for prey and habitat were recorded and differentially corrected with a G.P.S. Six of seven sites sampled in 1996 averaged 50 m (range 32 m to 81 m) from locations calculated from tower bearings. The location of the seventh site was not recorded. G.P.S. locations were also taken on sites sampled in 1997; however, due to a system error G.P.S. locations were unreliable. Idrisi version 1.01.004 for Windows was used to construct 300 m (radius) circles centered on the 1996 G.P.S. locations and the 1997 locations calculated from tower bearings. The number of times males visited 20 random areas located within 99 % minimum convex polygons were also measured to determine if kill areas received greater use. The 99 % minimum convex polygons were generated from male locations spaced at 10 minute intervals using the program Calhome (Kie et al. 1994).

Data Analysis:

All statistical analyses were conducted with Minitab version 11.21, ®1996. I used paired t-tests between the core use of random areas and kill areas to determine if kill areas received more use. Pearson's correlation values between core use and prey and habitat variables were generated for each bird. Bootstrapping was conducted on each set of correlations to determine if the correlation means were normally distributed. One sample t-tests were conducted on the correlation values from each bird to determine if correlations were significantly different from, greater, or less than zero. Wilcoxon signed rank tests were used when correlations were not normally distributed. A correlation matrix was constructed and used to discard correlated structural habitat measurements ($r < 0.800$). Mann-Whitney tests were used to determine if prey abundance at a kill site was related to the prey type delivered to the nest.

Detections of prey (excluding flyovers) of 50 m or less from the point count were used to calculate bird and red squirrel abundance. Hairy woodpecker and northern flicker abundances were calculated using unlimited distances because they occurred in low densities. Each sampling day the abundance of each prey species was calculated at each point count. Abundances of prey were calculated separately for all species at each point count and each day. The abundance data from the nine point counts were summed for the day to calculate the total number of each species. Each species maximum abundance from two days of surveys were used in correlation analyses. Bird abundance data were grouped in three size categories: small (6-27 g), medium (28-46 g), and large birds (47-141 g). Birds included: small birds such as the mountain chickadee (Parus gambeli), ruby-crowned kinglet (Regulus calendula), and brown creeper (Certhia americana), medium birds such as the green-tailed towhee (Pipilo chlorurus), hermit thrush (Catharus guttatus), and Townsend's solitaire (Myadestes townsendi), and large birds such as the American robin (Turdus migratorius), hairy woodpecker (Picoides villosus), and northern flicker (Colaptes auratus). Avian abundance was analyzed using size groups as variables. Potentially important prey species (American robin, northern flicker, hairy woodpecker and red squirrel) were analyzed separately.

Each trapping session I used catch per unit effort (number trapped / hour) as indices of small mammal abundance. I adjusted for sprung traps by using the equation described by Nelson and Clark (1973) which subtracts one half a trap from the trapping units for every sprung trap. For each species, the maximum catch effort value from the three sessions was used as the abundance of the species for that site. Species included in the analyses were deer mice (Peromyscus maniculatus), least chipmunk (Eutamias minimus), and red-backed vole (Clethrionomys gapperi). The combined catch effort values of deer mice, least chipmunks, and red-backed voles were also analyzed. The combined or total catch effort value for two sites from Glass Creek included uinta chipmunks (Eutamias umbrinus).

Structural habitat measurements were divided in two groups: forested and open plots. Averages were calculated separately for variables collected at forest and open plots to produce a value for each kill site. Tree d.b.h. data were assigned to size classes as described by Noon (1980) to calculate tree densities (see Table 5). Tree density was calculated for all trees (live and dead) greater than 3 cm in diameter.

Averages of non-structural variables, such as percent slope, distance to nearest edge and distance to water were calculated using all plots regardless of forest or opening designation. The most common edge type, topographic position, and dominant habitat from random plots were used as the values of categorical variables for each site.

Results:

Kill Sites. Goshawk movements were monitored for a total of 561 hours during the summers of 1996 and 1997. In 1996, male goshawks made 25 deliveries during 18 tracking sessions, from which 15 (60%) kill sites were confirmed. In 1997, male goshawks made 19 deliveries during 16 tracking sessions, from which 15 (79%) kill sites were confirmed. In 1996 and 1997, males delivered an average of 0.14 items per hour (see Tables 1-2). Goshawks returned an average of 4.12 times more to kill sites than random sites within home ranges ($p = 0.02$).

Twenty-one kill sites from seven male goshawks were sampled during 1996 and 1997. Five, four, three, three, three, two and one kill sites were sampled from the seven goshawks. Five additional kill sites from four birds were not sampled because they were located on private land to which I did not have access. Goshawks with three or more kill sites were used in analyses.

Core Use. Each bird had at least one kill area which appeared to be most important. Two to three areas were returned to the same number of times, and one area was used approximately twice as much as the other areas (see Fig. 5).

Prey Abundance. On average, goshawks did not return more often to kill sites with higher prey abundances. However, two birds returned most often to kill sites with very high abundances of prey (See Fig. 6-8). Glass Creek male returned most often to sites with more least chipmunks ($r = 0.824$) and medium sized birds ($r = 0.999$). Grande Creek male returned most often to sites with more red squirrels ($r = 0.938$), American robins (0.994), and least chipmunks ($r = 0.755$).

The Glass Creek male returned to one site 13 times versus a total of two returns to the other three sites. In that kill site the maximum catch effort of least chipmunks was 12.8 / 12 hrs versus average of 5.5 / 12 hrs (s.e. = 1.0) for all kill sites. Medium avian prey abundance was 10 in the 300 m sampling grid versus an average of 2.1 (s.e. = 0.63) for all kill sites. The Grande Creek male returned to one site 12 times, and returned to the other two sites six times each. In that kill site the American robin abundance was 20, versus an average of 4.9 (s.e. = 1.2) for all sites, red squirrel abundance was 24, versus an average of 8.9 (s.e. = 1.3) for all sites, and least chipmunk catch per unit effort was 15 / 12 hrs, versus an average of 5.5 / 12 hrs (s.e. = 1.0) for all sites. The results for the Grande Creek male may be confounded by the presence of more trees in larger size classes (23 cm to 37.5 cm d.b.h.) on the most used kill site. However, Glass Creek male was the only bird whose core use was negatively related to trees 23 to 37.5 cm in d.b.h.

During 1996 goshawks delivered one red squirrel, one lagomorph, one small mammal (vole or mouse sized), and four unknown prey items from sampled kill sites. During 1997 goshawks delivered three red squirrels, one least chipmunk, two unidentified birds, one unidentified mammal (not a red squirrel), and five unidentified prey items were delivered from sampled kill sites. Red squirrels were the only prey item delivered enough times to determine if prey abundance was related to prey types delivered to nests. Only kill sites from 1997 were used in the analysis to eliminate potential inter-year differences in red squirrel abundance. A Mann-Whitney test was used to determine if red squirrel abundances in sites from which red squirrels were captured ($n = 3$) were greater than in sites where red squirrels were not killed ($n = 4$). Red squirrel abundance was greater in sites where red squirrels were killed compared to sites where other prey types were killed (median difference = 4.5 red squirrels, $p = 0.0494$, adjusted for ties). The mean abundance of red squirrels in red squirrel kill sites was 12.7, s.e. = 5.7 versus a mean of 4.3, s.e. = 1.1 in non-red squirrel kill sites.

Red squirrels, American Robins, least chipmunks and deer mice were the most common species detected or captured at kill sites (see Tables 3 and 4). Golden-mantled ground squirrels (6 detected at 18 kill sites), northern flickers (14 detected at 18 kill sites), and hairy woodpeckers (13 detected at 18 kill sites) were absent from many sites.

Habitat. Goshawks returned most often to sites with gentler slopes (mean $r = -0.630$, $p = 0.011$, $n = 5$) and fewer shrubs covering the ground (mean $r = -0.444$, $p = 0.023$, $n = 5$) (See Fig. 9-10). Slopes ranged from 6 % to 60 %, with an average of 24 % in kill sites ($n = 18$). The percent coverage of woody plants in Daubenmire quadrats ranged from 2 % to 38 %, with an average of 17 % in kill sites ($n = 18$). Percent slope was not correlated with densities of trees 23 cm $\leq$ d.b.h. $<$ 38 ($r = -0.124$) or coverages of shrubs ($r = -0.102$). Percent slope was highly correlated with distance to the nest (mean $r = 0.620$, $p = 0.034$, $n = 5$).

The birds returned most often to sites with greater densities of trees 23 cm $\leq$ d.b.h. $<$ 38 (median $r = 0.517$, $p = 0.089$, $n = 5$), and greater densities of conifers 23 cm $\leq$ d.b.h. $<$ 38 (median r

$= 0.624$, $n = 5$, $p = 0.14$) (See Fig. 11-12). All birds but Glass Creek returned most often to sites dominated by lodgepole pine. Trees 23 cm ≤ d.b.h. < 38 are large for lodgepole pine in southcentral Wyoming (see Fig. 13). The kill site which received the most use for Glass Creek was dominated by aspen. Additionally, the large numbers of least chipmunks in that kill site may have influenced its use. Dropping Glass Creek from the analysis, goshawks returned more often to sites with greater densities of conifers 23 cm ≤ d.b.h. < 38 (median $r = 0.800$, $p = 0.05$, $n = 4$). The percent coverage of shrubs was not correlated with the density of conifers 23 cm ≤ d.b.h. < 38 ($r = -0.063$).

Two goshawks returned most often to sites with open areas which had fewer shrubs. The two goshawks were the only birds with three or more kill sites containing random plots in open areas (Divide Creek $n = 3$ and Angel Creek $n = 5$). Both birds exhibited similar correlations for five variables. They were negatively correlated with dominant shrub stem density, density board coverage at 0 - 0.3 m, and woody plant coverage on Daubenmire quadrats. Core use of both sites was positively related with density board coverage at 1 - 2 m, and Daubenmire coverage of bare ground and dead litter.

Four goshawks returned most often to sites in which natural meadows were the most common edge type. The edge type most commonly associated with one bird's heavily used kill site was lodgepole.

Goshawks made kills in areas with a wide range habitat structure (see Tables 5 - 8). Goshawks did not return most often to sites with greater canopy coverages or differing distances to edge. However, canopy coverage of forested random plots in all kill sites averaged 53 % (s.e. = 3 %). The average distance to nearest edge in all plots was 40 m (s.e. = 3 m) and the average distance to natural openings was 46 m (s.e. = 6 m).

Discussion:

Our data indicate that, on average, goshawks return more often to kill areas based upon habitat characteristics rather than prey abundance. However, prey abundances can differ between home ranges, e.g. red squirrels may be more abundant in one home range, while least chipmunks may be abundant in another home range. I found that analyzing kill sites by the abundance of a single species or prey group across goshawks may lead to the erroneous conclusion that goshawks do not return to kill sites based upon prey numbers. I show that goshawks may return to areas more often when very large numbers of prey are present. Beier and Drennan (1997) suggest that goshawks have difficulty assessing the relative abundance of prey above a certain threshold at fine spatial scales. I suggest goshawks may be able to assess relative abundance when prey numbers are high.

Additionally, goshawks may have better chances of killing a prey species when the prey species is abundant. Red squirrel abundance in sites from which a red squirrel was delivered (mean = 12.7, s.e 5.7) was greater than red squirrel abundance in sites where other prey types were killed (mean = 4.3, s.e. 1.1). However, our results must be interpreted with caution, because the number of kill sites from which red squirrels were delivered was three.

Habitat characteristic and core areas. Goshawks hunt in a wide diversity of habitats (see Tables 5-8). Forests in kill areas have high canopy closure (mean = 52.8%, s.e. 2.8%). Goshawks return most often to kill sites with greater densities of conifers 23 cm to 37.5 cm in d.b.h. (range = 0 to 11 stems / 0.04 ha), lower ground coverages of woody plants (range = 1 % to 30 %), and more gentle slopes (range = 6 % to 60 %).

In southcentral Wyoming goshawks return most often to kill sites with habitats which resemble their foraging areas in northern Arizona (Beier and Drennan 1997). Foraging areas in ponderosa pine forests in Arizona have wide ranges of structure (Beier and Drennan 1997). Beier and Drennan (1997) show goshawks use foraging areas with greater densities of larger trees (> 40.6 cm d.b.h.) and greater canopy coverage (mean of foraging areas = 48%) than random areas. Beier and Drennan (1997) suggest greater densities of trees and greater canopy coverages are more important for the capture of prey than open understories in northern Arizona. Widén (1989) and Beier and Drennan (1997) also suggest mature forests allow goshawks to reach perches undetected by goshawk prey while allowing room for maneuverability.

I suggest that greater densities of larger trees in southcentral Wyoming also allow goshawks to approach prey unseen, while more open understories permit goshawks to more easily detect prey. Foraging areas in Arizona have open understories (mean = 6.3 %), but open understories are present throughout goshawk home ranges. I have no data on random sites, however, the density of conifers 23 to 37.5 cm in d.b.h. is not correlated with ground coverages of woody plants ($r = -0.063$) in kill areas.

Goshawks returned most often to sites with gentler slopes. Goshawks nest in relatively flat areas (Reynolds et al. 1982, Hayward and Escano 1989, Squires and Ruggerio 1996). Iverson et al. (1996) reported the majority of goshawk locations occurred in areas with gentle slopes (0 - 35 %) in southeast Alaska. The authors suggested that most of the old-growth forests in southeast Alaska occurred on gentle slopes. In our study percent slope was not correlated with the density of larger trees ($r = -0.124$) or Daubenmire coverages of woody plants ($r = -0.102$). Slope was positively correlated with distance to the nest (mean $r = 0.620$, $p = 0.034$, $n = 5$). By foraging more often in close proximity to nests male goshawks probably expended less energy delivering prey (See Chapter 3).

Male goshawks did not use areas which varied in distance to nearest edge. However, the average distance to nearest natural opening for random plots on all sites was 46.4 m, s.e. 5.7 m. Additionally, the maximum distance to the nearest edge for all sites was 200 m. Kenward (1982) reported goshawks in Sweden to make most of their kills within 200 m of a woodland-opening edge in predominately agricultural landscapes. Most goshawk prey in Swedish agricultural areas occurred near woodland-opening edges. I could not determine if goshawks actually used forest-natural opening edges due to telemetry error of approximately 100 m. However, golden-mantled ground squirrels, red squirrels, and least chipmunks were often associated with natural openings (see Chapter 4).

Few authors examine goshawk foraging area use, probably due to the difficulty of distinguishing foraging from other activities. Because I continuously monitored bird movements and observed nests, I am confident my data represent foraging areas. Additionally, the points of direct return from foraging paths represent areas in which goshawks make kills. Although our sample size is low, our data are valuable because they represent areas in which prey were captured and the relative importance of those areas.

A 300 m scale around kill sites was chosen to determine the number of times a male goshawk returned to an area. This area was chosen because it was the smallest circle in which inferences about prey abundance could be made. By only including detections up to 50 m from point counts my sampling grid included prey detections up to 283 m at each corner of the sampling grid, excluding northern flickers and hairy woodpeckers. Locations from tower bearings had an average error of 100 m, while sampling grids were located an average of 50 m from the actual kill site locations. Thus, on average, the actual kill site was located 150 m from the grid center. The average distance from an attacking goshawk to its prey was 54 m in forests and 103 m in open areas in

Sweden (Kenward 1982). Additionally, goshawks are considered short duration sit-and-wait predators, and interperch flight distances were 100 m in forests and 200 m in the open (Kenward 1982). Considering the hunting style of goshawks, our sampling grid largely represented prey abundances and habitat characteristics present within the average perch to kill distance and fully represented a sample of characteristics goshawks encountered during successful foraging bouts.

Summary and management recommendations. Goshawks in southcentral Wyoming made kills in areas with moderately high canopy coverage and within an average of 46 m of natural openings. Goshawks returned more often to kill areas with gentler slopes, fewer woody plants in the understory and more conifers 23 cm to 37.5 cm in diameter. Percent slope was correlated with distance to the nest. Goshawks may have had a better of chance of capturing red squirrels in areas of greater red squirrel abundance. Two goshawks returned most often to kill sites where prey numbers were high, but three did not return more frequently to areas with higher prey abundances.

No management guidelines exist for goshawk habitat in the Central and Northern Rocky Mountains. Reynolds et al. (1992) recommend the majority of foraging areas be maintained as mature forest with interlocking crowns in the southwest. Reynolds et al.'s (1992) recommendations are based on the habitat needs of 14 species of goshawk prey. Our results indicate Reynolds et al.'s (1992) recommendations would benefit goshawks in southcentral Wyoming in two ways. Goshawks returned most often to sites with mature forests, and two goshawks returned most often to areas with high prey abundances.

Squires and Ruggiero (1996) suggested old-growth scoring procedures in lodgepole pine forests be changed so that mature stands with little structural complexity be given higher scores in order to protect nesting habitat. Important foraging areas would also be identified by changing old-growth scoring procedures.

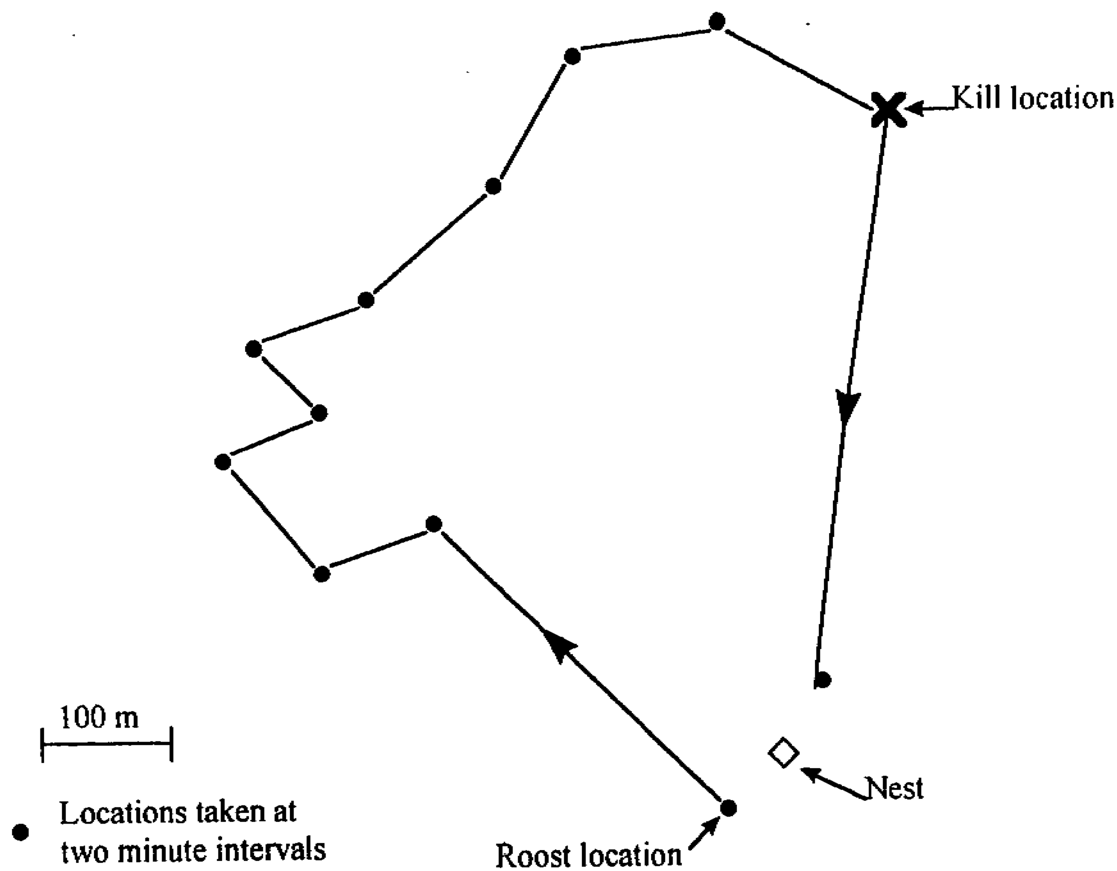

Figure 1. An example of a male goshawk foraging bout during the breeding season in southcentral Wyoming.

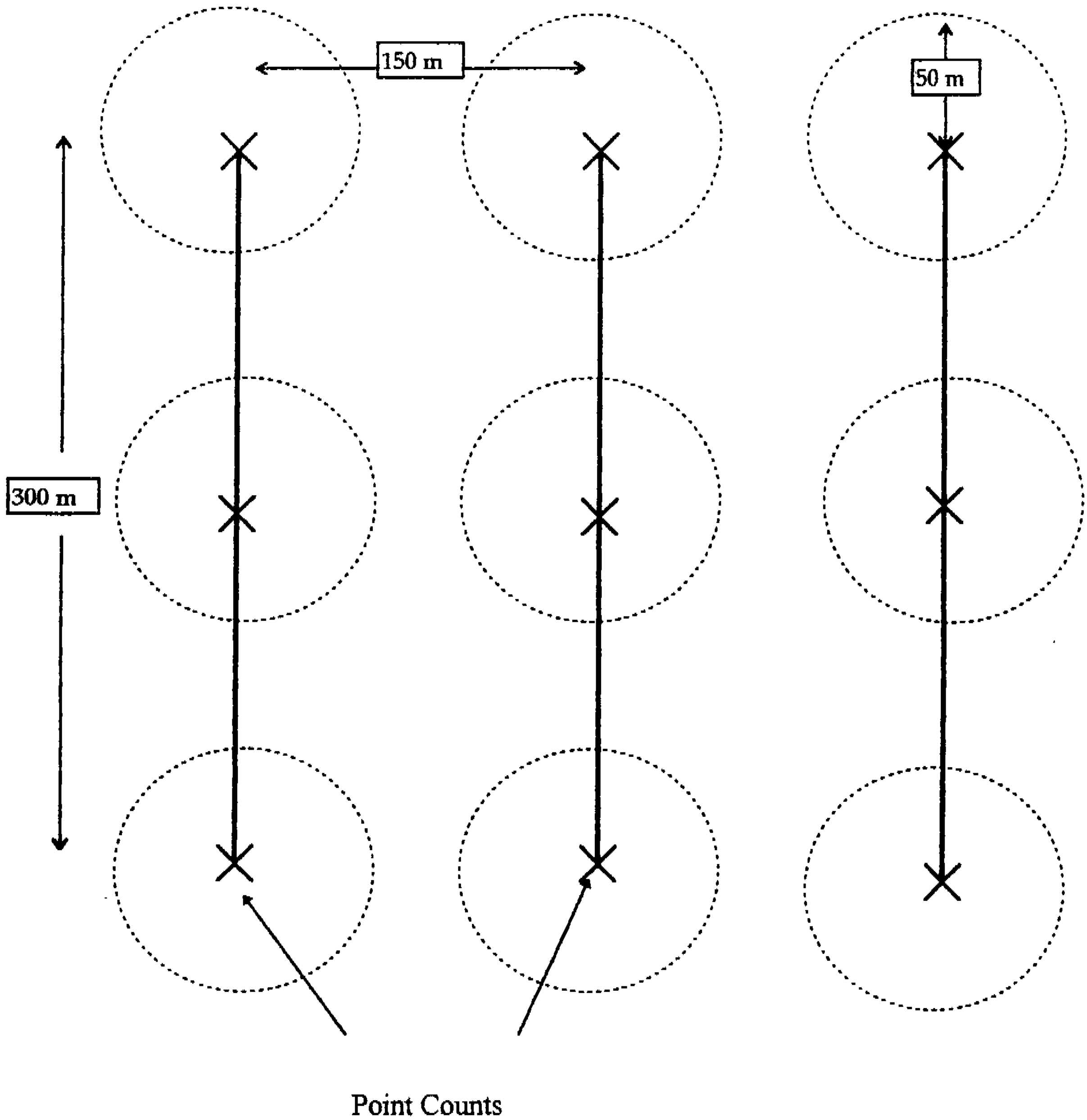

Figure 2. Pictorial of sampling grid used to sample prey abundance at northern goshawk kill sites in southcentral Wyoming.

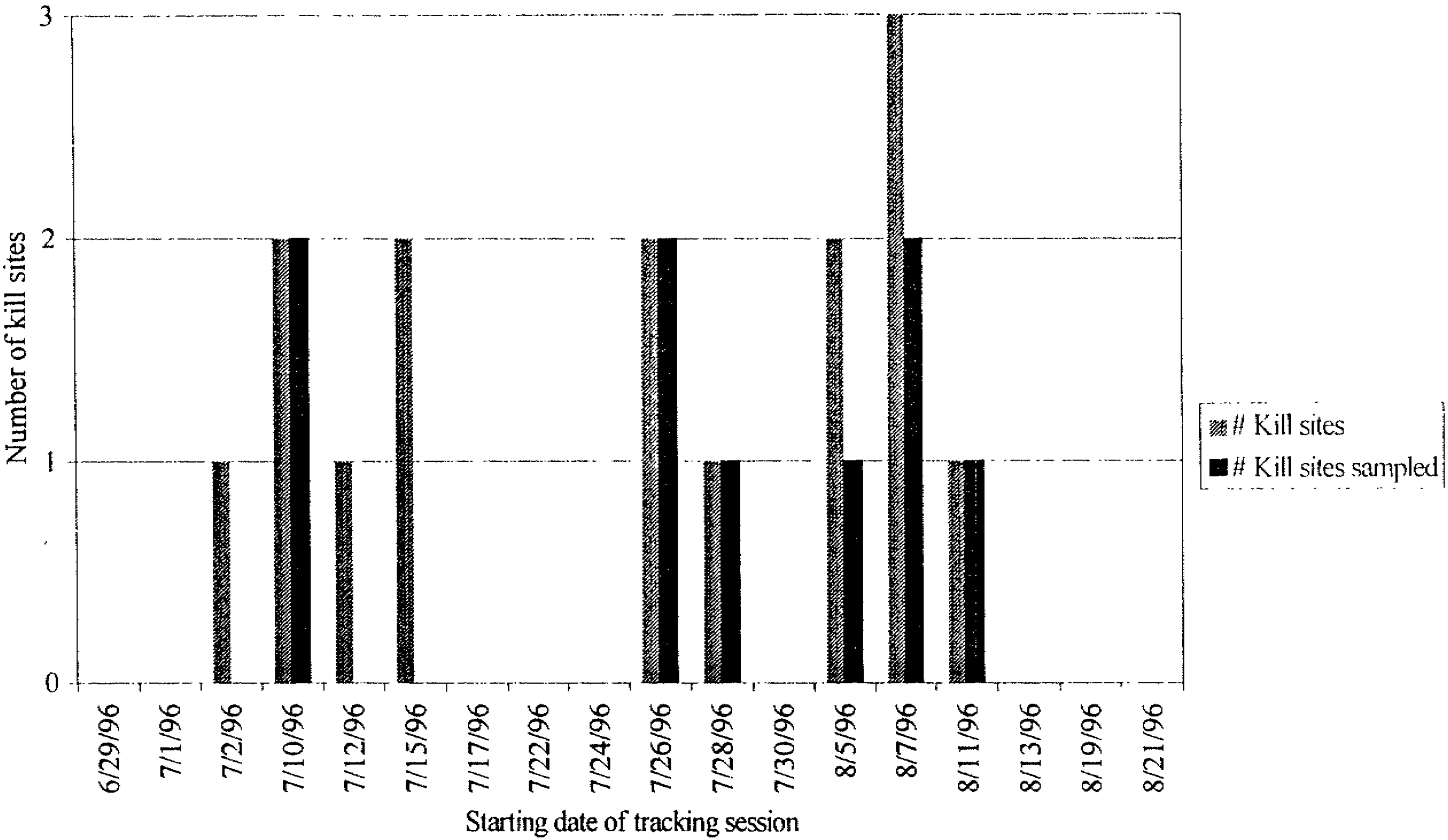

Figure 3. Distribution of northern goshawk kill sites by date during 1996 in southcentral Wyoming.

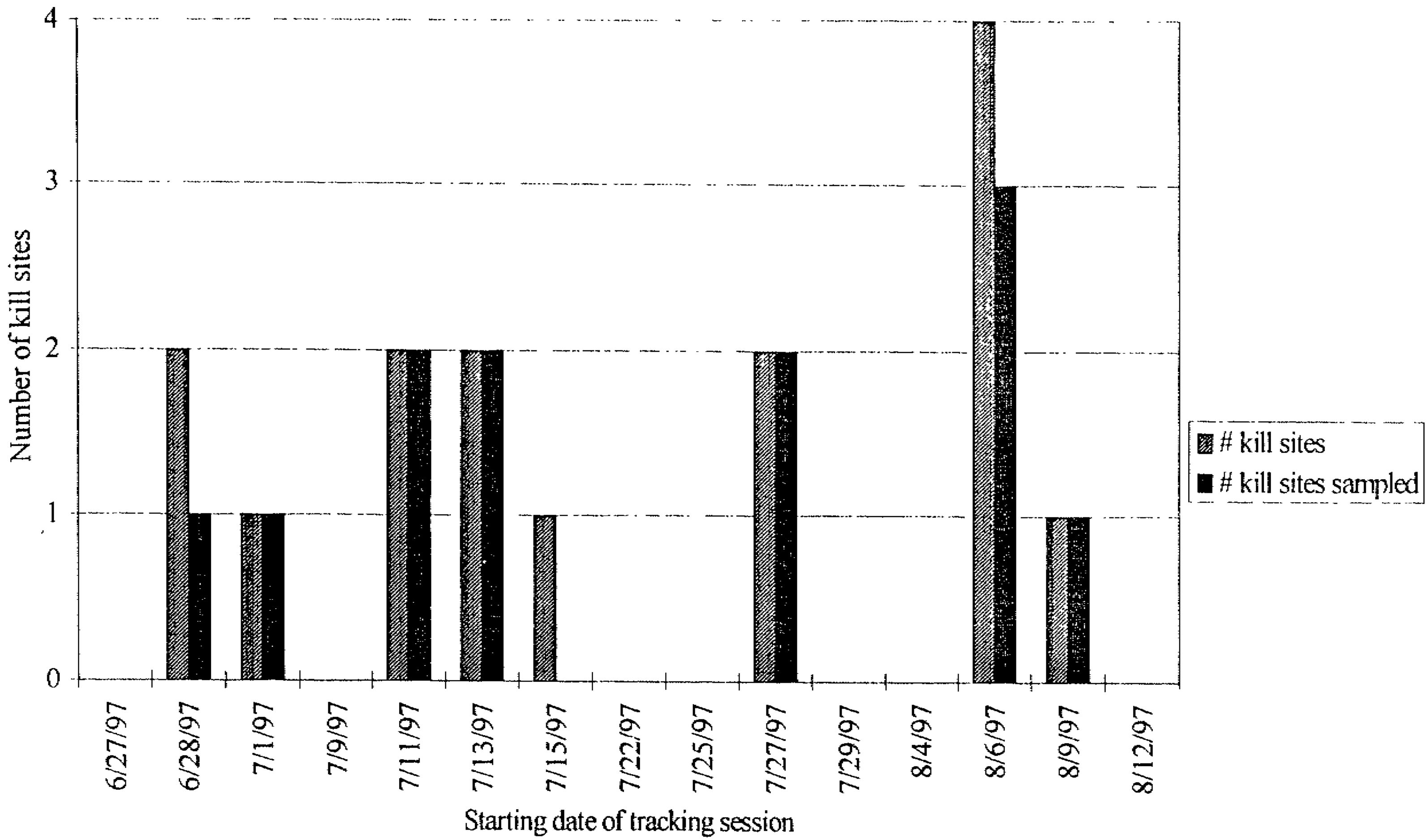

Figure 4. Distribution of goshawk kill sites by date during 1997 in southcentral Wyoming.

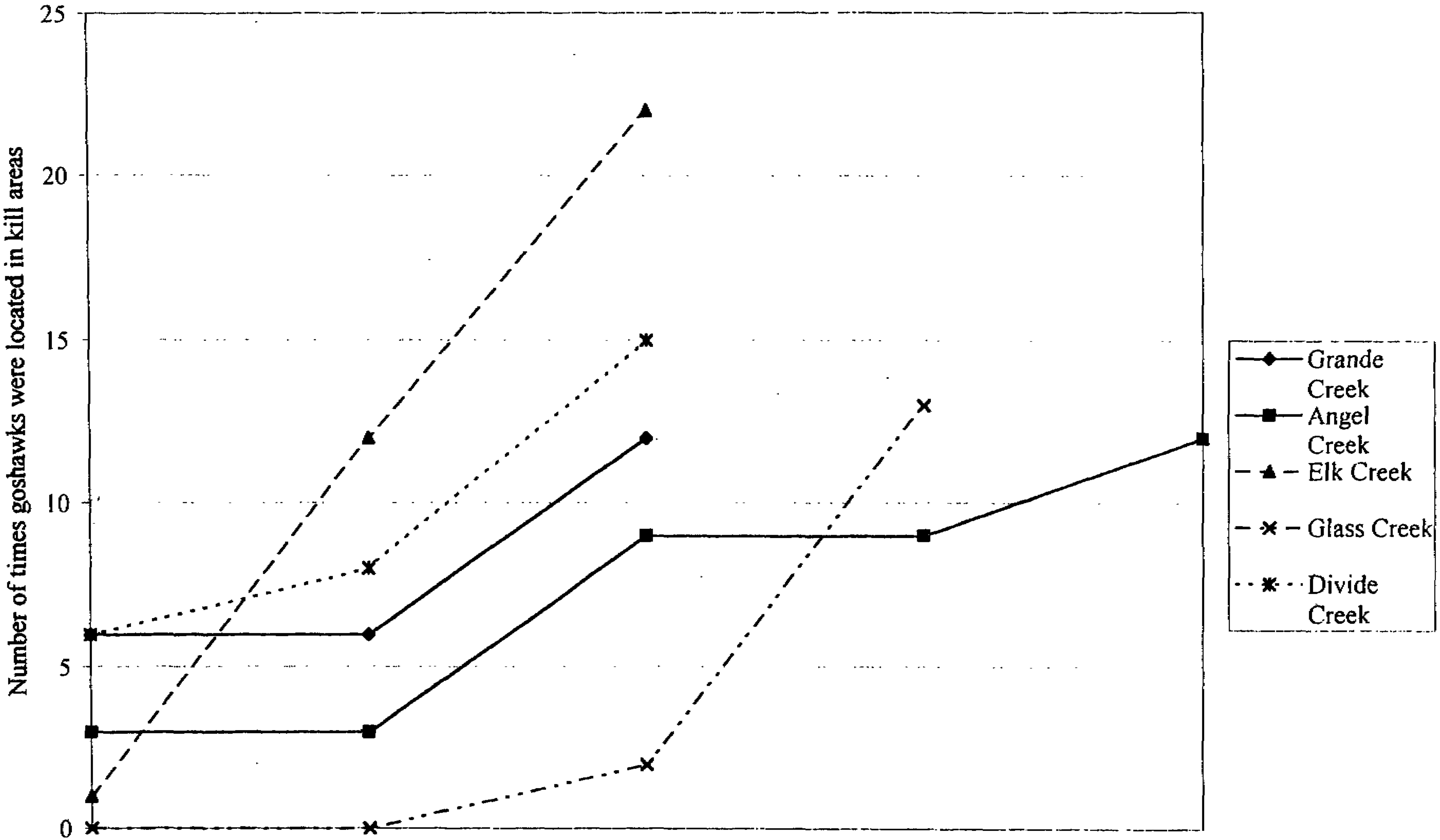

Figure 5. Core use at the 300 m scale of northern goshawk kill sites sampled for prey during 1996 and 1997 in southcentral Wyoming.

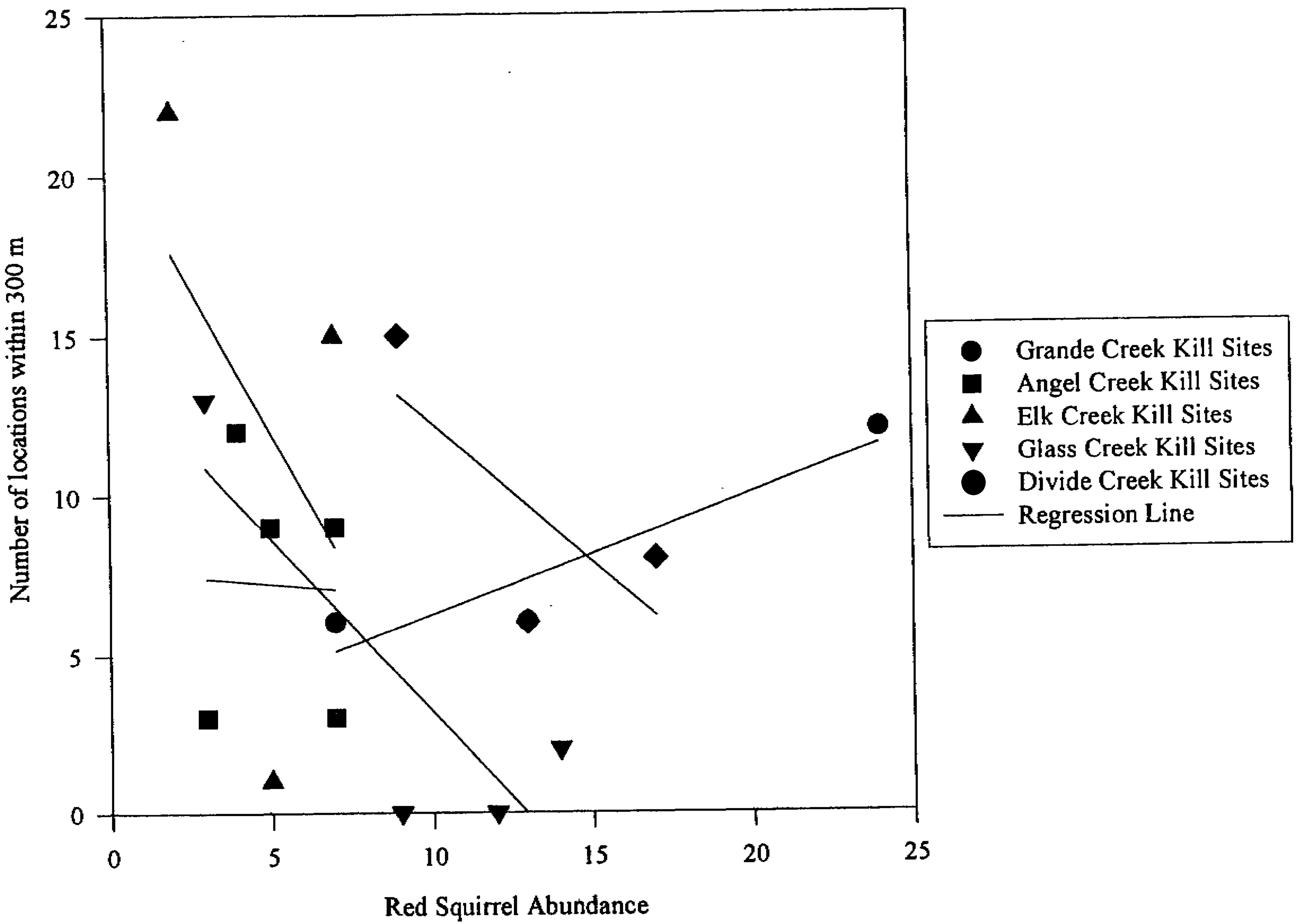

Figure 6. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and red squirrel abundance in southcentral Wyoming during the breeding seasons of 1996 and 1997.

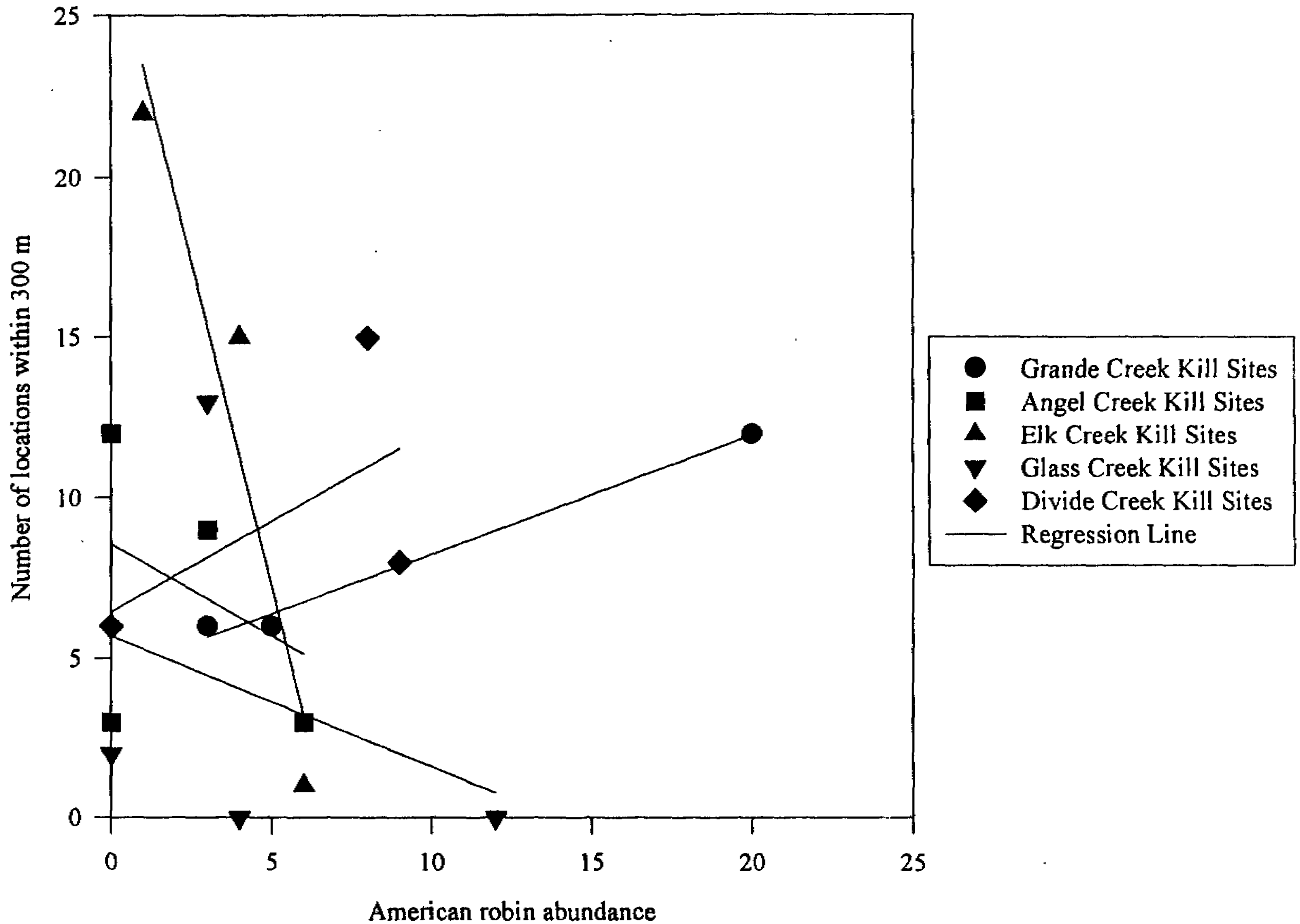

Figure 7. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and American robin abundance in southcentral Wyoming during the breeding seasons of 1996 and 1997.

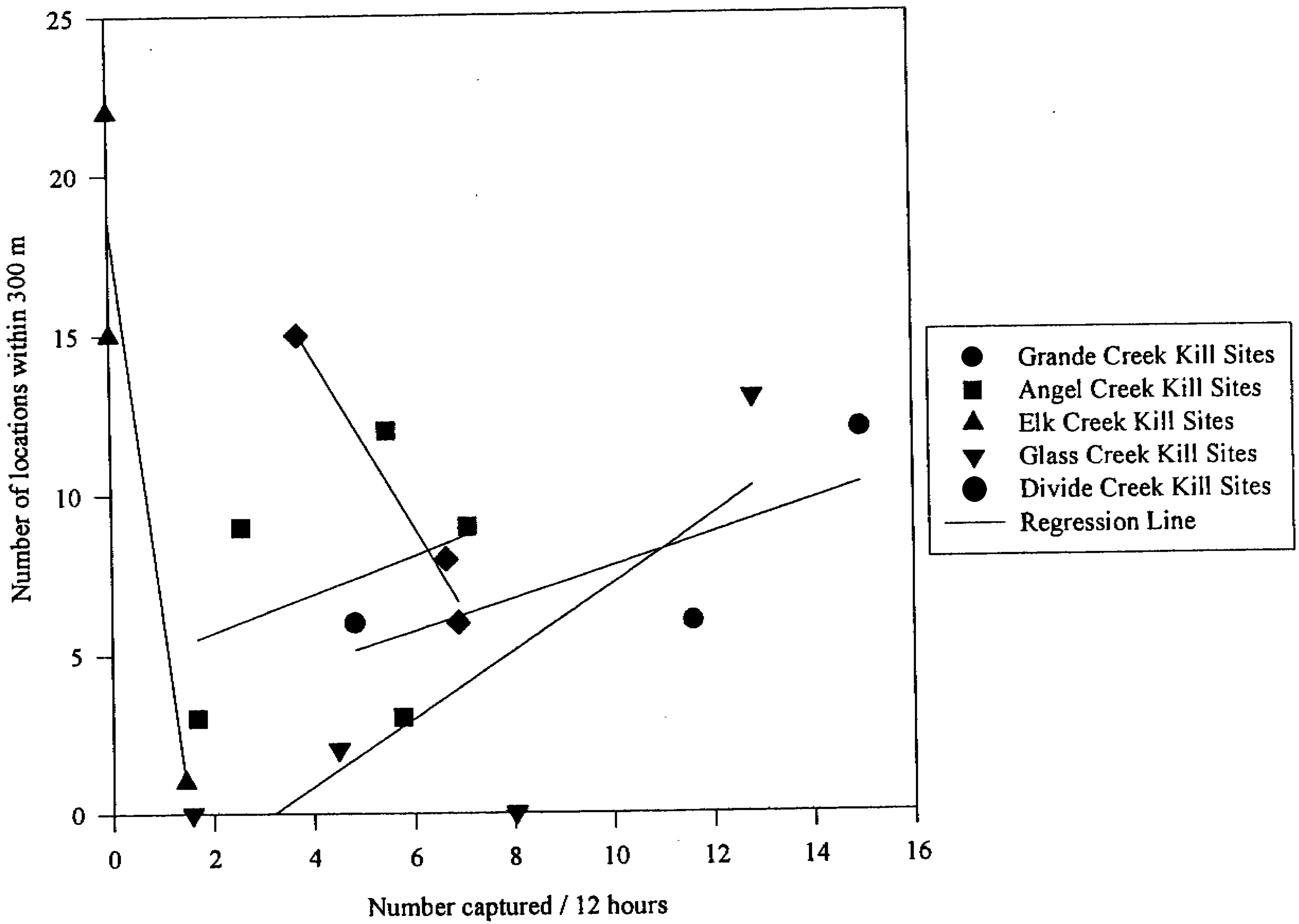

Figure 8. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and least chipmunk catch per unit effort in southcentral Wyoming during the breeding seasons of 1996 and 1997.

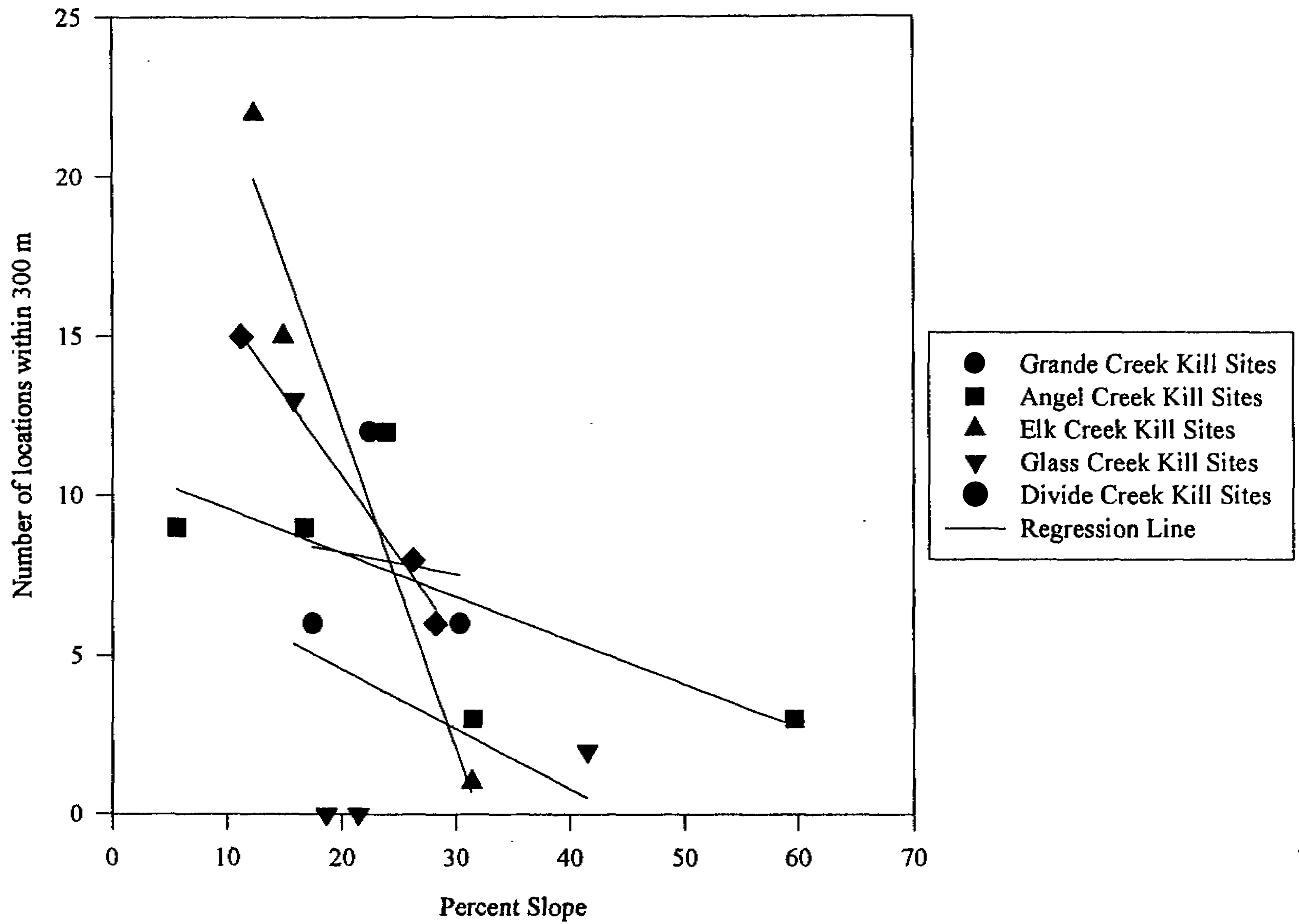

Figure 9. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and percent slope in southcentral Wyoming during the breeding seasons of 1996 and 1997.

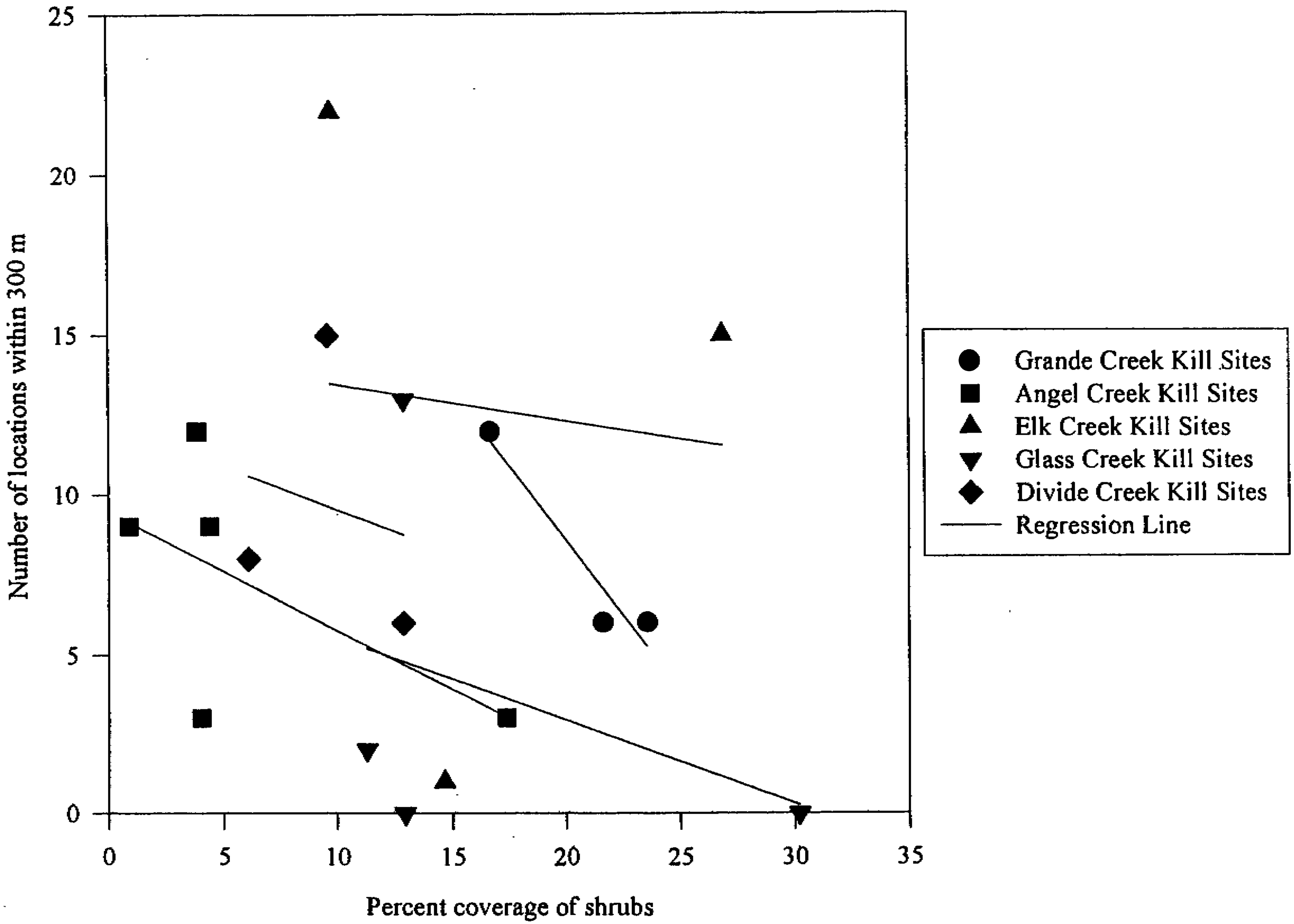

Figure 10. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and percent coverage of shrubs in southcentral Wyoming during the breeding seasons of 1996 and 1997.

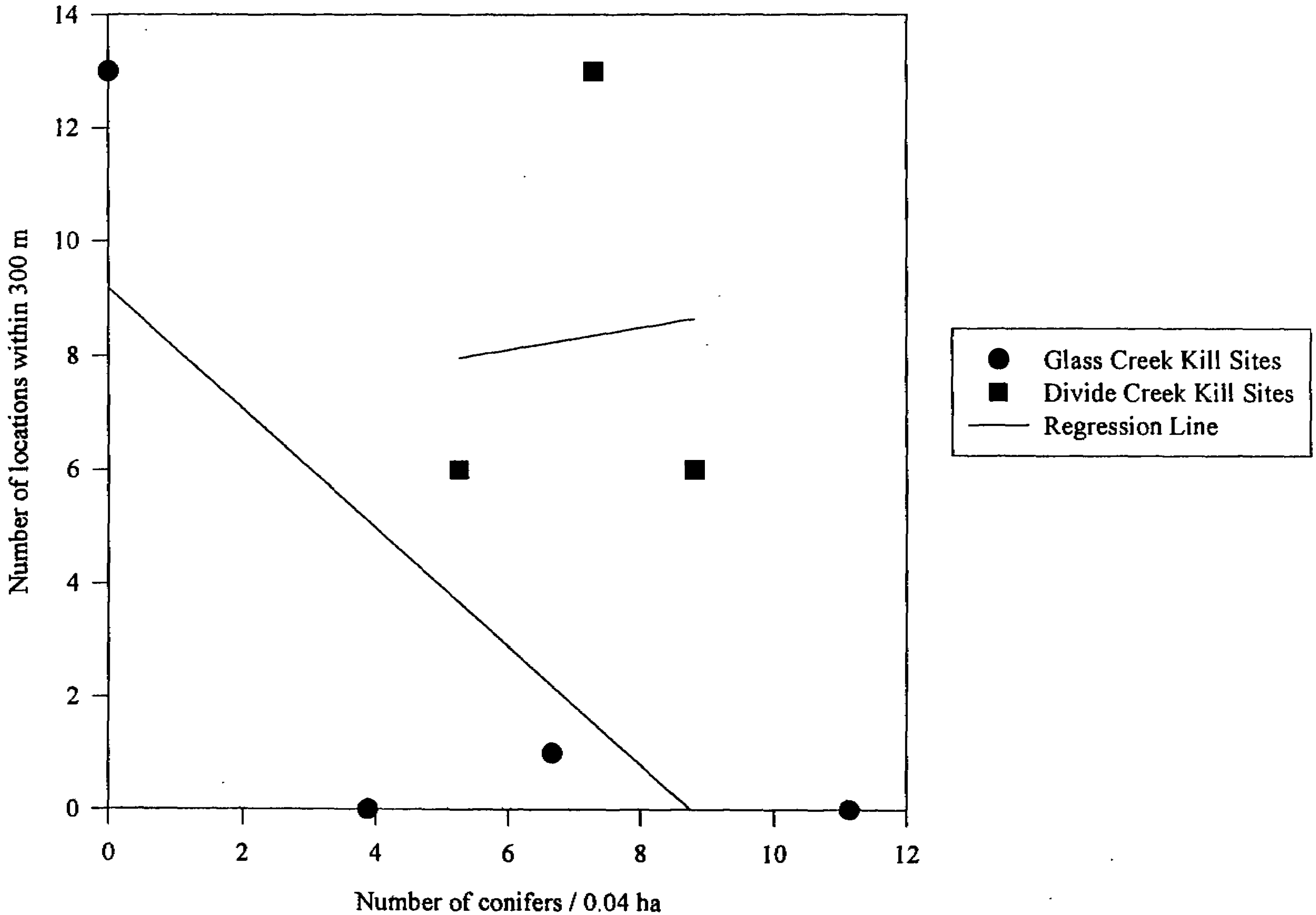

Figure 11. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and densities of conifers 23 to 37.5 cm dbh in southcentral Wyoming during the 1996 breeding season.

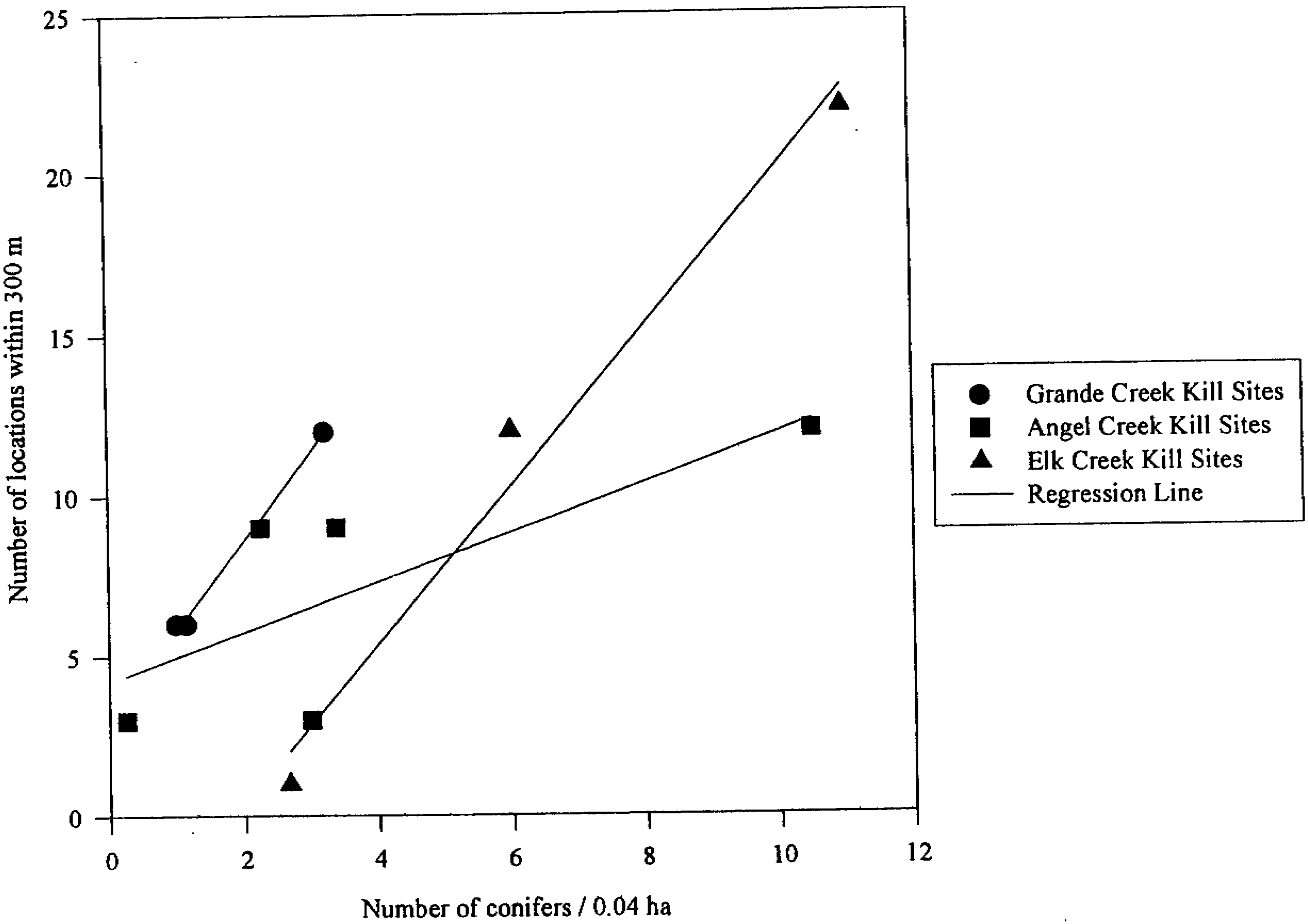

Figure 12. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and densities of conifers 23 to 37.5 cm dbh in southcentral Wyoming during the 1997 breeding season.

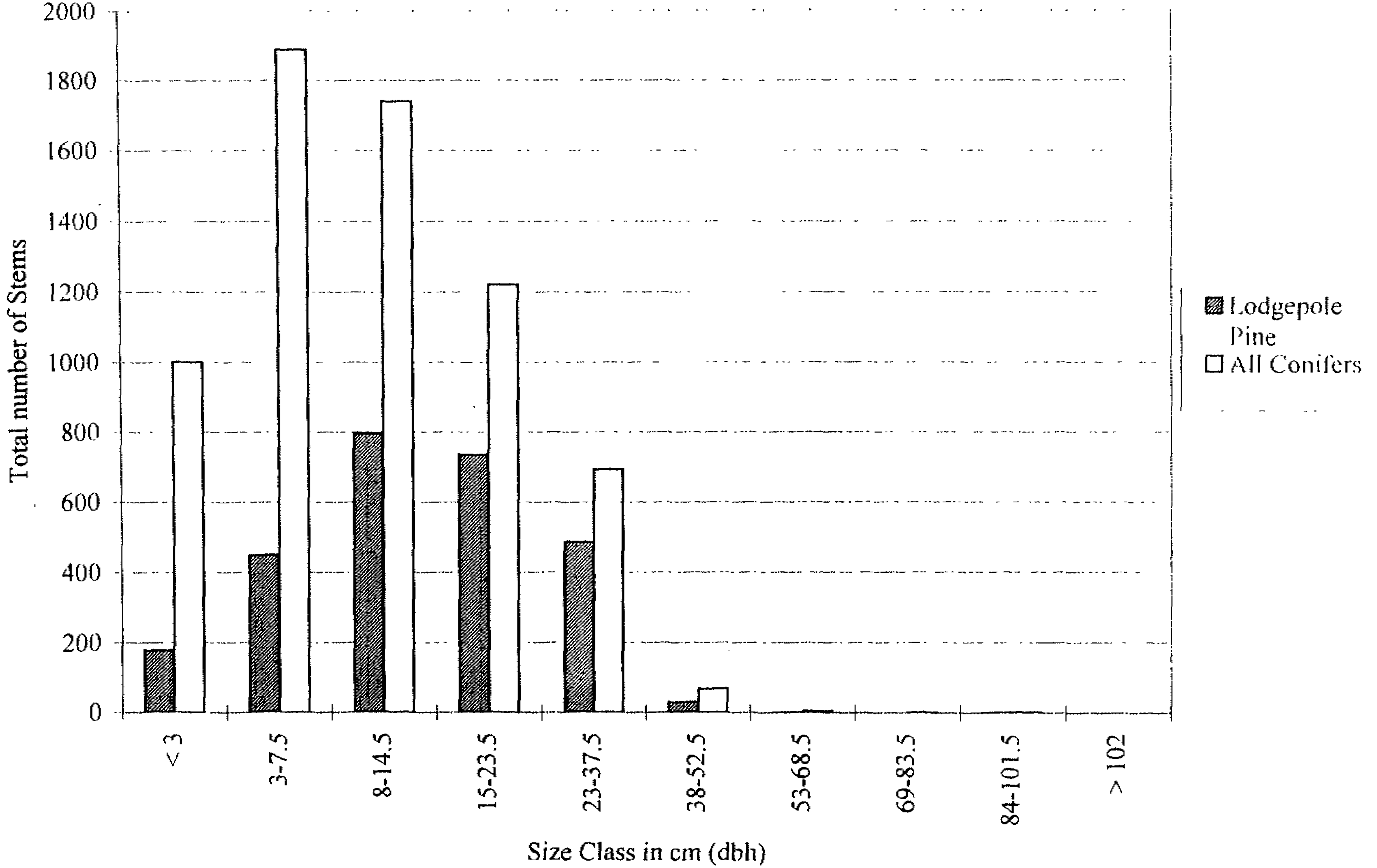

Figure 13. Distribution of lodgepole pine and total conifer tree densities by size classes in 144 vegetation plots in 21 goshawk kill sites from seven male goshawks in southcentral Wyoming during the breeding season.

Table 1. Northern goshawk tracking session summaries for 1996 in southcentral Wyoming.

Nest	Session #	Start Date	End Date	# Male deliveries	# Kill sites	# Kill sites sampled
Divide Creek	1	7/2/96	7/2/96	2	1	0
Divide Creek	2	7/15/96	7/16/96	1	1	0
Divide Creek	3	7/28/96	7/29/96	2	1	1
Divide Creek	4	8/7/96	8/8/96	4	3	2
Divide Creek	5	8/13/96	8/14/96	3	0	0
Divide Creek	6	8/21/96	8/22/96	0	0	0
Glass Creek	1	7/12/96	7/14/96	1	2	0
Glass Creek	2	7/26/96	7/27/96	3	2	2
Glass Creek	3	8/5/96	8/6/96	2	2	1
Glass Creek	4	8/11/96	8/12/96	2	1	1
Glass Creek	5	8/19/96	8/20/96	0	0	0
Marten	1	7/10/96	7/11/96	3	2	2
Marten	2	7/24/96	7/25/96	0	0	0
Simpson's Creek	1	7/1/97	7/2/97	2	0	0
Simpson's Creek	2	6/29/96	6/30/96	0	0	0
Simpson's Creek	3	7/17/96	7/17/96	0	0	0
Simpson's Creek	4	7/22/96	7/23/96	0	0	0
Simpson's Creek	5	7/30/96	7/31/96	0	0	0
Total	18			25	15	9

Table 2. Northern goshawk tracking session summaries for 1997 in southcentral Wyoming.

Site	Session #	Start Date	End Date	# of Male deliveries	# kill sites	# kill sites sampled
Angel Creek	1	6/27/97	6/27/97	1	0	0
Angel Creek	2	7/11/97	7/12/97	2	2	2
Angel Creek	3	7/27/97	7/28/97	2	2	2
Angel Creek	4	8/9/97	8/10/97	1	1	1
Boundary	1	7/1/97	7/2/97	2	1	1
Boundary	2	7/15/97	7/16/97	1	1	0
Boundary	3	7/22/97	7/24/97	0	0	0
Boundary	4	8/4/97	8/5/97	0	0	0
Elk Creek	1	6/28/97	6/29/97	2	2	1
Elk Creek	2	7/13/97	7/14/97	2	2	2
Elk Creek	3	7/29/97	7/30/97	0	0	0
Elk Creek	4	8/12/97	8/13/97	0	0	0
Grande Creek	1	7/9/97	7/10/97	1	0	0
Grande Creek	2	7/25/97	7/26/97	0	0	0
Grande Creek	3	8/6/97	8/8/97	5	4	3
Total	16			19	15	12

Table 3. Summary statistics for the number of detections for prey species (maximum number in 300 m sampling grid) in 18 northern goshawk kill areas during 1996 and 1997 in southcentral Wyoming.

Species	Mean	Confidence Level (95.0%)	Standard Error	Median	Minimum	Maximum	Sum
American Robin	4.83	2.51	1.19	3.5	0	20	87
Hairy Woodpecker	0.72	0.66	0.311	0	0	5	13
Northern Flicker	0.78	0.55	0.26	0	0	4	14
Golden-mantled Ground Squirrel	0.33	0.34	0.16	0	0	2	6
Red Squirrel	8.94	2.83	1.34	7	2	24	161
Small Avian Prey	30.33	5.56	2.63	30.5	11	54	546
Medium Avian Prey	2.11	1.34	0.64	1	0	10	38
Large Avian Prey	10.94	3.23	1.53	9.5	3	25	197

Table 4. Summary statistics for maximum small mammal catch per unit effort (# caught / 12 hours) in northern goshawk kill areas during 1996 and 1997 in southcentral Wyoming.

Species	Mean	Confidence Level (95.0%)	Standard Error	Median	Minimum	Maximum
Deer Mouse	5.64	2.80	1.33	3.21	0	19.69
Least Chipmunk	5.54	2.13	1.01	5.16	0	14.95
Red-backed Vole	1.70	1.01	0.48	0.96	0	7.78
Uinta Chipmunk	0.41	0.74	0.35	0	0	6.29
Golden-mantled Ground Squirrel	0.07	0.16	0.07	0	0	1.34
Total of Above Species	12.24	4.13	1.96	11.35	1.0	28.32
Masked Shrew	0.20	0.32	0.15	0	0	2.58
Unknown Shrew	0.51	0.41	0.20	0	0	2.50
Red Squirrel	0.10	0.14	0.07	0	0	0.86
Meadow Vole	0.22	0.22	0.10	0	0	1.08
Short-tailed Weasel	0.11	0.15	0.07	0	0	1.04
Mountain Cottontail	0.05	0.10	0.05	0	0	0.87
Unknown Mouse	0.05	0.10	0.05	0	0	0.87
Juvenile Deer Mouse	0.05	0.10	0.05	0	0	0.83

Table 5. Tree density summary statistics (# trees / 0.04 ha) for forested random plots from 21 kill sites by seven male northern goshawks in northern goshawk kill sites sampled during 1996 and 1997 in southcentral Wyoming.

Tree Density	Mean	Confidence Level (95.0%)	Standard Error	Median	Standard Deviation	Minimum	Maximum
Conifer Density (> 3 cm d.b.h.)	43.75	15.22	7.21	51.41	30.60	3.63	105.25
Conifers <3 cm d.b.h.	7.67	4.46	2.12	3.13	8.98	0.25	29
Conifers 3-7.5 cm d.b.h.	13.95	6.31	2.99	11.21	12.69	0.63	45.25
Conifers 8-14.5 cm d.b.h.	14.34	5.63	2.67	15.10	11.33	1	37.11
Conifers 15-23.5 cm d.b.h.	10.10	3.33	1.57	9.36	6.69	0.75	20
Conifers 24-37.5 cm d.b.h.	4.85	1.83	0.87	3.64	3.68	0	11.14
Conifers 38-52.5 cm d.b.h.	0.46	0.28	0.13	0.25	0.55	0	2
Conifers 53-68.5 cm d.b.h.	0.04	0.06	0.03	0	0.12	0	0.5
All Tree Density (> 3 cm d.b.h.)	81.09	16.39	7.77	76.60	32.95	23	157
All Trees <3 cm d.b.h. cm d.b.h.	15.29	4.61	2.19	14.36	9.28	2.5	31.83
All Trees 3-7.5 cm d.b.h.	28.66	7.65	3.63	26.35	15.38	5.89	62
All Trees 8-14.5 cm d.b.h.	28.93	7.39	3.50	26.23	14.85	5	66.33
All Trees 15-23.5 cm d.b.h.	17.13	3.43	1.62	18.31	6.89	5.5	26.5
All Trees 23-37.5 cm d.b.h.	5.86	1.76	0.83	4.75	3.54	1	11.4
All Trees 38-52.5 cm d.b.h.	0.47	0.27	0.13	0.29	0.55	0	2
All Trees 53-68.5 cm d.b.h.	0.04	0.06	0.03	0	0.12	0	0.5

Table 6. Summary statistics for forested random vegetation plots in 21 kill sites from seven male northern goshawks sampled during 1996 and 1997 in southcentral Wyoming. (W.D. = Woody Debris, D.B. = Density Board).

Vegetation Parameter	Mean	Confidence Level (95.0%)	Standard Error	Median	Standard Deviation	Minimum	Maximum
Dominant Shrub Stem Total	100.53	57.12	27.07	43.88	114.87	4	413.67
Distance to Nearest Tree (m)	2.2	0.28	0.13	2.22	0.57	1.17	3.4
Nearest Tree Width (cm)	7.85	2.1	1	6.02	4.23	2.88	17
Distance to Nearest W.D. (m)	1.43	0.32	0.15	1.47	0.65	0.44	3.09
Nearest W.D. Width (cm)	7.59	1.04	0.49	7.82	2.1	4.02	12.36
Nearest W.D. Length (m)	5.34	1.19	0.57	5.35	2.4	1.47	11.79
Distance to Largest W.D. (m)	5.01	0.57	0.27	5.15	1.15	2.15	6.89
Largest W.D. Width (cm)	15.93	2.82	1.34	15.31	5.67	5.33	26.9
Largest W.D. Length (m)	11.23	2.15	1.02	11.73	4.31	2.57	18.56
% Canopy Coverage	52.79	5.96	2.83	52.35	11.99	30	76.25
% Coverage of D.B. 0-.3m	67.8	7.29	3.45	68.38	14.65	40	87.5
% Coverage of D.B. .3-1 m	47.03	6.67	3.16	46.61	13.41	28.81	76.31
% Coverage of D.B. 1-2 m	38.4	7.55	3.58	35.97	15.19	19.44	70.42
% Coverage of D.B. 0-2 m	40.43	6.33	3	36.89	12.72	21.56	74.83
Height to Live Canopy (m)	9.10	1.10	0.51	9.26	2.17	4.79	12.76
% Coverage Grass	13.13	5.62	2.66	9.03	11.29	0.57	35.07
% Coverage Bare Ground	13.56	6.44	3.05	9.75	12.95	0	35.83
% Coverage Herbaceous Litter	74.3	7.33	3.47	77.55	14.74	35.50	92.11
% Coverage Woody Litter	8.91	2.51	1.19	9.21	5.05	0	18.44
% Coverage Rock	3.43	2.49	1.18	0.25	5.02	0	17.06
% Coverage of Woody Stems	13.3	4.12	1.95	12.88	8.28	0.9	30.21
% Coverage Forbes	7.32	2.25	1.07	7.04	4.53	0.13	18
% Coverage Logs	8.19	2.27	1.08	7.81	4.57	0.5	18.2

Table 7. Summary Statistics of open random plots sampled during 1996 and 1997 in 13 northern goshawk kill sites in southcentral Wyoming which contained non-forested plots.

Vegetation Parameters	Mean	Confidence Level (95.0%)	Standard Error	Median	Standard Deviation	Minimum	Maximum
Dominant Shrub Stem Total	294.78	131.25	60.24	242.75	217.2	0	809
% Coverage of D.B. 0-.3 m	65.18	15.59	7.16	65.83	25.8	20	100
% Coverage of D.B. .3-1 m	27.91	12.29	5.64	25	20.33	0.71	68.57
% Coverage of D.B. 1-2 m	9.65	6.64	3.05	5.20	10.98	0	30
% Coverage of D.B. 0-2 m	30.44	7.57	3.48	30.25	12.53	9.15	50.25
% Coverage of Grass	29.93	8.14	3.73	34.44	13.46	7.67	49.3
% Coverage of Bare Ground	19.04	5.08	2.33	20.50	8.4	3	35.75
% Coverage of Herbaceous Litter	18.94	12.38	5.68	9.25	20.48	0	65
% Coverage of Woody Litter	6.67	5.95	2.7	2.63	9.36	0	29.33
% Coverage of Rock	16.90	7.44	3.38	14.75	11.71	0	34.50
% Coverage of Woody Stems	16.84	7.26	3.33	15.2	12.01	2.13	37.70
% Coverage of Forbes	9.23	5.83	2.67	6	9.64	1.20	37.75
% Coverage of Buckwheat	9.30	5.28	2.42	8.75	8.73	0	26.75
% Coverage of Woody Debris	3.10	2.47	1.13	0	4.08	0	11
% Coverage of Other	1.66	1.75	0.81	0.25	2.9	0	9.85

W.D. = Woody Debris

Literature Cited

Austin, K.K. 1993. Habitat use and home range size of breeding northern goshawks in the southern Cascades. M.S. thesis, Oregon State University, Corvallis.

Bechard, M.J. 1982. Effect of vegetative cover on foraging site selection by Swainson's hawks. Condor 84: 153-159.

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7: 564-571.

Bloom, P.H. 1987. Capturing and handling raptors. In Pendleton, B.A., B.A. Millsap, K.W. Cline and D.M. Bird (eds.) Raptor Management Techniques Manual. National Wildlife Federation Scientific and Technical series no. 10.

Bright-Smith, D.J. and R.W. Mannan. 1994. Habitat use by breeding male northern goshawks in northern Arizona. Studies in Avian Biology no. 16: 58-65.

Daubenmire, R. 1959. A canopy-cover method of vegetation analysis. Northwest Science 33: 43-64.

Hargis, C.D., C. McCarthy, and R.D. Perloff. 1994. Home ranges and habitats of northern goshawks in eastern California. Studies in Avian Biology no. 16: 66-74.

Haward, G.D. and R.E. Escano. 1989. Goshawk nest-site characteristics in Western Montana and Northern Idaho. Condor 91: 476-479.

Iverson, G.C., G.D. Hayward, K. Titus, E. Degayner, R.E. Lowell, D.C. Crocker-Bedford, P.F. Schempf, and J. Lindell. 1996. Conservation assessment for the northern goshawk in southeast Alaska. General Technical Report PNW-GTR-387. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 101 p.

James, F.C., and H.H. Shugart. 1970. A quantitative method of habitat description. Audubon Field Notes 24(6): 727-736.

Kennedy, P.L. 1997. The northern goshawk (Accipiter gentilis atricapillus): Is there evidence of a population decline? Journal of Raptor Research 31(2): 95-106.

Kennedy, P.L. and D.W. Stahlecker. 1993. Responsiveness of nesting northern goshawks to taped broadcasts of three conspecific calls. Journal of Wildlife Management 57: 249- 257.

Kennedy, P.L., J.M. Ward, G.A. Rinker, and J.A. Gessaman. 1994. Post-fledgling areas in northern goshawk home ranges. Studies in Avian Biology no. 16: 75-82.

Table 8. Summary Statistics for non-structural measurements of random plots in northern goshawk kill sites sampled during 1996 and 1997 in southcentral Wyoming.

Parameters	Mean	Confidence Level (95.0%)	Standard Error	Median	Standard Deviation	Minimum	Maximum
Percent Slope	23.84	6.24	2.96	21.94	12.54	5.56	59.67
Distance to Nearest Edge (m)	39.88	6.58	3.33	30	42.30	0	200
Distance to Natural Opening (m)	46.40	11.24	5.64	30	49.52	0	200
Distance to Water (m)	239.32	130.14	58.41	160.63	193.71	50.67	672.22

Kenward, R.E. 1982. Goshawk hunting behaviour and range size as a function of food and habitat availability. Journal of Animal Ecology 150: 69-80.

Kie, J.G., J.A. Baldwin, and C.J. Evans. 1994. Calhome: Home Range Analysis Program, Electronic User's Manual. U.S. Forest Service Pacific Southwest Research Station, Fresno, California.

Nelson L Jr. and F.W. Clark. 1973. Correction for sprung traps in catch/effort calculations of trapping results. Journal of Mammalogy 54(1): 295-298.

Noon, B.R. 1980. Techniques for sampling avian habitats. Forest Service General Technical Report RM-82: 42-52.

Reynolds, R.T., R.T. Grahm, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. U.S.D.A. Forest Service General technical Report RM-217. Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado.

Reynolds, R.T., E.C. Meslow, and H.M. Wight. 1982. Nesting habitat of coexisting accipiter in Oregon. Journal of Wildlife Management 46(1): 124-138.

Samuel, M.D., D.J. Pierce and E.O. Garton. 1985. Identifying areas of concentrated use within the homerange. Journal of Animal Ecology 54: 711-719.

Squires, J.R. and R.T. Reynolds. 1997. Northern Goshawk. (Accipiter gentilis). In The Birds of North America, No. 298. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Squires, J. and L. Ruggiero. 1996. Nest site preference of northern goshawks in southcentral Wyoming. Journal of Wildlife Management: 60(1): 170-177.

Toland, B. 1986. Hunting success of some Missouri raptors. Wilson Bulletin 98(1): 116-125.

Wakely, J.S. 1978. Factors affecting the use of hunting sites by ferruginous hawks. Condor 80: 316-326.

Widén, P. 1982. Radio monitoring the activity of goshawks. Symposia of the Zoological Society of London no. 49: 153-160.

Widén, P. 1989. The hunting habitats of goshawks Accipiter gentilis in boreal forests of central Sweden. Ibis 131: 205-231.

Widén, P. 1997. How, and why is the goshawk (Accipiter gentilis) affected by modern forest management in Fennoscandia? Journal of Raptor Research 31(2):107-113.

Chapter 3 - Landscape characteristics associated with goshawk kill areas.

Introduction:

Shrub-steppe birds generally use different habitat characteristics depending upon the scale at which habitat use is examined (Wiens et al. 1987). Raptors also use habitats differently at different scales, especially at larger scales. Because raptors have such large home ranges (e.g. goshawk home ranges can be as large as 3010 ha (Hargis et al. 1994)), they may be sensitive to landscape change (Thiollay and Meyburg 1988).

Widén (1989) found goshawks in older, larger patches in Swedish boreal forests greater than available. Goshawks also made the majority of their kills in older, larger patches. Kenward and Widén (1989) reported that goshawks in Swedish agricultural areas made all of their kills within 200 m of edges. Patterns of goshawk habitat use were explained by prey availability. In the boreal forest matrix, one of the goshawk's main prey (black grouse) was found in greater densities in larger patches during the spring (Angelstam 1983 cited in Widén 1988). Additionally, squirrels were probably abundant and evenly distributed in mature patches (Lemnell, pers. comm. cited in Kenward and Widén 1989). Widén (1989) suggested larger patches were advantageous for goshawks with respect to energetic costs because they had a greater chance of encountering prey without having to move to another patch. In Swedish agricultural areas the goshawk's main prey, pheasants and brown hares, were common along forest edges (Kenward and Widén 1989). They found goshawk habitat use was affected by prey availability rather than landscape features.

Goshawk habitat use in North America is also related to prey availability (Reynolds et al. 1992). Beier and Drennan (1997) show goshawk foraging areas to have large trees with open understories rather than higher prey abundances. The authors suggest that prey availability, defined as favorable habitat structure with prey present above a certain threshold, may be more important than prey abundance.

Goshawks use habitats at the landscape scale (Bright-Smith and Mannan 1994, Hargis et al. 1994). Hargis et al. (1994) found that during the nestling phase perched goshawks were located in mature timber surrounded by a variety of patches in a variety of seral stages. Bright-Smith and Mannan (1994) found one of 13 male goshawks used areas with a higher patch diversity than expected, and four of 13 goshawks used areas greater than 200 m from edges than expected at random.

Although the authors could not determine if goshawks were foraging or day roosting, their results suggest that non-nesting activities of goshawks are affected by landscape characteristics. Studies such as those by Hargis et al. (1994) and Bright-Smith and Mannan (1994) could provide more detailed information (foraging v/s roosting activity) by closely monitoring bird movements to determine a bird's activity.

I continuously followed the movements of male goshawks during the breeding season in southcentral Wyoming and identified areas where male goshawks had made kills. The objectives of my study were to:

1) Determine if landscape characteristics affected the relative use of kill areas.
2) Determine if landscape characteristics around kill sites differed from random sites.
3) Determine if the type of prey captured varied with landscape characteristics.

I tested several hypotheses regarding goshawk hunting. I predicted goshawks would return most often to kill sites with: 1) greater coverages of forest and conifer, 2) larger patch sizes of forest, conifer, and greater overall patch sizes, 3) areas dominated by a few patch types (greater patch dominance values), 4) greater distances between conifer and natural opening patches, 5) lower coverages and smaller patch sizes of natural openings and clearcuts, 6) lower overall patch densities, as well as lower patch densities of forest, conifer, natural openings and clearcuts, 7) lower patch diversity, and 8) closer to nests. Goshawks made the majority of their kills in large, mature patches of boreal forest in Sweden (Widén 1989). The author suggested mature forests allow goshawks to approach prey unseen while allowing room for maneuverability. Large patches allowed goshawks to spend more time hunting and less time switching patches.

I also tested for differences for patch types and characteristics for which no specific hypotheses were generated. Characteristics measured included: 9) patch shape, 10) percent cover, patch size, and density of all other patch types, 11) average elevation.

I also tested hypotheses regarding habitat characteristics used to capture red squirrels versus other types of prey. I predicted goshawks would kill red squirrels in areas with: 12) greater coverages and larger patch sizes of conifer, conifer-aspen, and total patch size, 13) greater distances between conifer and natural opening patches, 14) areas dominated by a few patch types, 15) lower overall patch densities, as well as patch densities of conifer and conifer-aspen, and 16) lower patch diversity. Patch shape was also analyzed but no specific hypotheses were tested. Goshawks preferred mature forests for hunting in Sweden (Kenward and Widén 1989). The authors suggested more squirrels could be found by goshawks in large patches without flying to another patch. Red squirrels are found in coniferous forests in southcentral Wyoming (See Chapter 4).

Methods:

Nest Searches and Radio Telemetry. Historic goshawk nest sites were searched. I tried to select nests that: 1) had not been previously tracked and; 2) were located where topography allowed efficient radio tracking. The foraging movements of male goshawks were continuously monitored and points of direct return from foraging bouts were identified (see Chapter 2). Points of return from foraging bouts in which prey were delivered to the nest (confirmed and identified by observers in blinds) were considered areas where male goshawks had made kills. Eight male goshawks were monitored during the summers of 1996 and 1997 during the nestling through late fledgling stages (see Chapter 2).

Landscape characteristics. Major patch types were digitized extending 1 km beyond male 99 % minimum convex polygon home ranges. Home ranges of 99 % were chosen because it was the smallest home range which included all kill sites. Home ranges were generated from telemetry locations taken at 10 minute intervals using the program Calhome (Kie et al. 1994). Patch types for four home ranges were digitized from scanned 1:24,000 color arial photographs, and one home range was digitized from scanned 1:40,000 infrared arial photographs. Patch types were defined by the dominant overstory species (or the lack of) when possible (see Table 1). No ground truthing was conducted; however, all digitizing was conducted by a single person who was familiar with the area.

Landscape characteristics were measured using the program r.le version 2.1 (Baker 1994). Digitized patch layers were analyzed at 2 m resolution. Patch measurements are explained in Table two. Landscape characteristics were measured at two scales and two levels of patch classification. Landscape characteristics were measured in 300 m and 1 km radius circles drawn around each kill and random point. They were quantified using digitized maps of two levels of patch classification:

1) a map with patches defined to species where possible; and 2) a coarser map with patches defined as forest and varying types of non-forested patches (see Table 1). The two patch classifications were used to determine if goshawks used habitats at a course or fine level. Forest patches in the coarse classification were grouped, as were old and young clearcuts, while natural openings, major roads, and river-willow areas were held constant.

The number of times a bird was located within 300 m and 1 km of each kill and random site was measured using Idrisi for Windows version 1.01.004. Locations taken at 10 minute intervals, as well as those taken at two minute intervals but sub-sampled at 10 minute intervals, were overlaid on the 300 m and 1 km circles around each kill and random site to calculate relative use.

Data Analysis:

All data analyses were conducted using Minitab for windows version 11.21. Analyses were conducted only on birds from which at least four kill sites were obtained. Most landscape characteristics were analyzed at both the 1 km and 300 m scales and both coarse and fine patch classifications. Paired t-tests were conducted on the relative use of kill and random sites to determine if kill sites received more use than random sites.

Objective one. Pearson's correlation values were generated between landscape variables and the relative use of kill sites for each bird. Boot strapping techniques were used to determine if correlation values were normally distributed. If correlation values were normally distributed, one sample t-tests were conducted to determine if correlations from all birds differed significantly from zero. If correlation values were not normally distributed one sample Wilcoxon tests were used.

Objective two. Fifty random sites were generated for each bird within 99 % minimum convex polygons. Paired t-tests were used to determine if landscape characteristics of kill sites differed significantly from random sites. Bootstrapping techniques were used to determine if the differences were normally distributed and one sample Wilcoxon tests were used when data were not normally distributed

Objective three. I used Mann-Whitney tests to determine if landscape characteristics differed with the type of prey captured at kill sites. Analyses were conducted at both the 300 m and 1 km scales with only the finest patch classification. Sample sizes were sufficient to compare red squirrel kill sites with kill sites from which red squirrels were known to not be captured.

Results:

I identified 26 kill sites from five male goshawks during 1996 and 1997. Glass Creek male made seven kills (1996), Divide Creek male six (1996), Angel Creek male five (1997), Grande Creek male four (1997), and Elk Creek male four (1997). Grande Creek made four kills within a three day period (the late fledgling period). The other four goshawks made kills throughout the nestling and fledgling phases. Goshawks used kill sites more than random sites at the 300 m (mean difference = 4.12 locations, p = 0.02) and 1 km scales (median difference = 8.675 locations, p = 0.053).

Goshawks captured prey in habitats with a wide variety of landscape pattern. Goshawks made kills in narrow patches of aspen in drainages surrounded by sagebrush and grassland, to areas dominated by coniferous forests (See Tables 3-13). At 1 km natural openings covered the most area (42 %), while conifer covered the most area at 300 m (40 %). Aspen comprised an average of 14 %

and 21 % of goshawk kill areas at 1 km and 300 m. Clearcuts only covered an average of 2 % and 3 % of kill areas at 1 km and 300 m. However, coverage of clearcuts did range as high as 27 % and 15 % at 1 km and 300 m.

1. Percent coverage of forest and conifer. Goshawks returned most often to sites with greater coverages of conifer at the 300 m (mean r = 0.398, p = 0.076, n = 5) and 1 km scales (mean r = 0.517, p = 0.043, n = 5) (See Fig. 1-2). Goshawks returned most often to sites with greater coverages of forest at the 1 km scale (mean r = 0.384, p = 0.11, n = 5) and 300 m scale (mean r = 0.172, p = 0.28, n = 5). Goshawk kill areas did not have greater coverage of conifer at the 300 m (mean r = -0.0343, p = 0.64, n = 5) or 1 km scales (mean difference = 0.0119, p = 0.31, n = 5), or forest at the 300 m (mean r = 0.0417, p = 0.25, n = 5) or 1 km (mean difference = 0.0052, p = 0.47, n = 5) than random sites.

2. Patch size of forest, conifer and the patch size for all patches. Goshawks returned more often to sites with larger patch sizes of conifer (mean r at 300 m = 0.199, p = 0.18, n = 5 and mean r at 1 km = 0.334, p = 0.099, n = 5) and forest (mean r at 300 m = 0.108, p = 0.30, n = 5 and median r at 1 km = 0.3970, p = 0.295, n = 5). Goshawks returned less often to sites with greater total average patch sizes at the fine (mean r at 300 m = -0.398, p = 0.95, n = 5 and mean r at 1 km = 0.640, p = 1.0, n = 5) and coarse patch classifications (mean r at 300 m = - 0.056, p = 0.44, n = 4 and mean r at 1 km = -0.589, p = 1.00, n = 5).

Kill sites did not have greater patch sizes of conifer at the 300 m or 1 km scales. Kill sites at the 1km scale had smaller conifer patch sizes (mean difference = - 148152 m^2, std. = 158496 m^2). Forest patch sizes were greater in kill areas at the 300 m and 1 km scales (mean difference = 26348 m^2, p = 0.15, n = 5 and median difference = 53612 m^2, p = 0.14, n = 5 respectively). Total patch size was less on kill sites than random sites at both scales and both patch classifications, with the exception of patch size at 300 m and the finest patch classification (median difference = 1604 m^2, p = 0.295, n =5). In a post-hoc, one tailed t-test, total patch size was less on kill sites than random sites at the 1 km scale, finest patch classification (mean difference = -18368 m^2, p = 0.058, n = 5).

3. Patch Dominance. Goshawks returned most often to sites dominated by fewer patches at the 300 m scale (mean r = 0.391, p = 0.054, N = 5), and kill sites were dominated by fewer patch types than random sites (mean difference = 0.0568, p = 0.080, N = 5) at the 300 m. However, dominance values were considered unreliable at the 300 m scale. Shannon diversity measures were artificially low because the number of patch types and coverage of that patch type were underestimated by one at each site (see Appendix one). At the 300 m scale many kill areas had Shannon diversity values of zero, resulting in dominance values of zero. Although Shannon diversity values of zero may have indicated areas were dominated by one patch type, areas with values of zero may also have had two patch types present. No relationships existed at the 1 km scale.

4. Average distance from conifers to natural openings. Most goshawk kill sites had patches of forests adjacent to natural openings using the coarse patch classification. Distances were only examined at the finest patch classification. Goshawks did not return more often to areas with greater distances between conifer and natural opening patches. Goshawks made kills in areas in which conifer and natural opening patches were closer than in random sites (mean difference = -15.11 m, p = 0.037, n = 5) at the 1 km scale.

5. Percent coverage and patch size of natural openings and clearcuts. The percent coverage of natural openings was constant between the two patch classifications (see Table 1). Goshawks returned less often to sites with greater coverages of natural openings (mean r = -0.420, p = 0.098, N = 5 and mean r = -0.271, p = 0.43, N = 5). Goshawks returned most often to sites with greater coverages of clearcuts at both scales and both patch classifications. The percent coverage of clearcuts at the 1 km scale and the finest patch classification was significantly and positively related to relative use with a post-hoc, one-tailed t-test (mean r = 0.519, p = 0.051, N = 3). The percent coverage of natural openings (mean difference at 300 m = -0.0295, p = 0.32, n = 5, mean difference at 1 km = 0.031, p = 0.61, n = 5) and clearcuts (mean difference at 300 m = 0.0071, p = 0.64, n = 5, mean difference at 1 km = 0.00031, p = 0.51, n = 5) was not less on kill sites than random sites at the 300 m and 1 km scales using the finest patch classifications. No relationships existed using the coarse patch classification.

Goshawks returned more often to sites with smaller patch sizes of natural openings at the 1 km scale (mean r = -0.541, p = 0.019, N = 5) (See Fig. 3). No relationship existed at 300 m (mean r = 0.271, p = 0.43, n = 5). Goshawks also returned most often to sites with larger patch sizes of clearcuts at 300 m (mean r = 0.449, p = 0.87, n = 3) and 1km (mean r = 0.445, p = 0.05, n = 3) with the finest and coarse (mean r at 300 m = 0.33, p = 0.85, n = 3, and mean r at 1 km = 0.327, p = 0.82, n = 3) patch classification. Goshawks made kills at sites with smaller patch sizes of natural openings than random sites at 300 m (mean difference = - 17044 m^2, p = 0.20, n = 5) and 1 km (mean difference = - 43132 m^2, p = 0.39, n = 5). Goshawks also made kills at sites with smaller patch sizes of clearcuts than random sites at 1 km (mean difference = - 2324 m^2, p = 0.29, n = 5) with the finest patch classification.

6. Patch density of forest, conifer, natural openings, clearcuts and the density of all patches. Goshawks returned most often to sites with greater densities of conifer (See Fig. 4) and natural opening patches (See Fig. 5) at 1 km in post-hoc, one-tailed Wilcoxon tests (median r = 0.477, p = 0.053, N = 5 and median r = 0.581, p = 0.053, N = 5). Goshawks also returned most often to sites with greater total patch densities at 300 m (mean r = 0.449, p = 0.96, n = 5) and 1 km (mean r = 0.580, p = 1.00, n = 5) using the finest patch classification (See Fig. 6-7). Patch density of forest was analyzed at only the 1 km scale due to a lack of variation in forest patch density at the 300 m scale.

Goshawk kill areas had fewer natural opening patches than random sites at 1 km (mean difference = -2.21 patches, p = 0.062, and n = 5). Total patch density was less on kill sites than random sites at 300 m fine patch classification (mean difference = -2.03 patches, p = 0.10, n = 5) and 1 km coarse patch classification (mean difference = -3.29 patches, p = 0.061, n = 5).

7. **Patch diversity measures.** Goshawks returned most often to kill sites with higher patch diversity. Patch diversity was measured using only the fine patch classification. Patch richness was positively related to relative use at 300 m (mean r = 0.482, p = 0.036, N = 5) using a post-hoc, one tailed t-test. Richness was lower on kill sites than random sites (300 m scale), although the relationship was weak (mean difference = -0.092, p = 0.34, N = 5).

8. **Distance to the nest.** Goshawks returned more often to kill sites closer to nests (median r = -0.5545, p = 0.09, N = 5) (See Fig. 7). Distance to the nest was measured from the estimated location of each kill site and was analyzed using only relative use. Most kills were made within 2500 m of nests (see Fig. 8), but distances ranged from 162 m to 5456 m. Kill sites from Grande Creek ranged only from 1188 m to 2270 m from the nest. Excluding Grande Creek from the analysis, the relationship became stronger (mean r = -0.685, p = 0.0047, n = 4).

9. **Patch shape of all types by group and all patch shapes.** Goshawks returned more often to kill sites with clearcuts which had greater perimeter to area ratios at 300 m (mean r = 0.558, p = 0.037, n = 3, coarse classification), and aspen patch shapes with lower perimeter to area ratios at 300 m (mean r = -0.331, p = 0.12, n = 5) and 1 km (mean r = -0.392, p = 0.073, n =5). However, goshawks made kills in areas with aspen patches which had greater perimeter to area ratios at 1 km than random sites (mean difference = 0.1748, p = 0.056, n = 5).

10. Percent cover, patch size, and density of types other than forest, conifer, natural openings, and clearcuts. Goshawks returned more often to areas with lowers coverages of agricultural areas at 1 km (mean $r = -0.727$, $p = 0.013$, $n = 4$, fine patch classification), smaller patch sizes of aspen at 300 m (mean $r = -0.500$, $p = 0.010$, $N = 5$). Goshawk kill areas had lower coverages of major roads than random sites at 1 km (median difference = -0.00129, $p = 0.091$, $n = 5$).

11. Average elevation. Goshawks returned more often to areas higher in elevation (mean = 0.351, $p = 0.23$, $N = 5$). Average elevation was analyzed at only the 300 m scale. The average elevation of kill sites ranged from only 2347 m to 2862 m. Average elevation did not differ between random and kill areas.

12. Percent coverage and patch size of conifer, conifer-aspen and the size of all patches. Goshawks delivered red squirrels from five kill sites and prey known not to be red squirrel from seven kill sites. The prey delivered from the remaining 14 sites either could not be identified or were classified as an unknown mammal. Of the seven non-red squirrel deliveries, two were identified as small prey, one small mammal, one lagomorph, one mammal with white fur, one least chipmunk, and one unknown bird. The five red squirrel kill sites were obtained from four different male goshawks. The seven non-red squirrel kill sites were also obtained from four male goshawks. Red squirrel and non-red squirrel kill sites had three male goshawks in common.

Goshawks killed red squirrels in areas with greater coverages of conifer at 300 m (median difference = 0.5055, $p = 0.0047$) and 1 km (median difference = 0.2318, $p = 0.1278$) and conifer-aspen at 300 m (median difference = 0.0113, $p = 0.0881$) and 1 km (median difference = 0.04, $p = 0.0217$) than non-red squirrel kill sites. Patch sizes of conifer at 1 km in red squirrel kill sites were greater than in non-red squirrel kill sites (median difference = 80564 m^2, $p = 0.1649$). However, at 300 m the relation ship was reversed (median difference = -23428 m^2). Patch size of conifer-aspen in red squirrel kill sites was larger at both scales, with the relationship being strongest 1 km scale (median difference = 62540 m^2, p = 0.0047). The total patch size did not differ between red squirrel and non-red squirrel kill sites.

13. Distance of conifer edges to natural opening edges. Goshawks killed red squirrels in areas where conifer patches were farther from natural openings at 1 km (median difference = 25.65 m, p = 0.0174). Distances were also greater in red squirrel kill sites at 300 m; however, Mann-Whitney tests were not performed because all the non-red squirrel site distances were 0 m. The average distance from conifer to natural opening edges was 32.7 m and the median distance was 43 m in red squirrel kill areas.

14. Patch dominance. Goshawks did not kill red squirrels in areas with greater patch dominance values at 300 m or 1 km and both patch classification.

15. Patch density of conifer, conifer-aspen and total. Patch density of conifer, conifer-aspen, and total patch density did not differ between red squirrel and non-red squirrel kill sites.

16. Patch diversity measures. Goshawks killed red squirrels in areas of greater patch diversity. Using post-hoc, two tailed Mann-Whitney tests, Shannon-Wiener (median difference = 0.5650, p = 0.0149) and inverse Simpson's diversity (median difference = 1.159, p = 0.0149) measures were greater on red squirrel kill sites at 1 km.

Patch shape by type and total. Conifer patch shapes did not differ between red squirrel and non-red squirrel kill sites. Conifer-aspen patch shapes were not analyzed due to a lack of conifer-aspen patches in non-red squirrel kill sites.

Discussion:

Goshawks made kills in areas with greater patch sizes of forest, but lower overall patch sizes than random areas. Their kill areas had lower total patch densities, and smaller and fewer natural opening patches. Conifer and natural opening patches were closer in kill areas. Aspen patches in kill areas had greater perimeter to edge ratios.

Goshawks killed red squirrels at sites with greater coverages of conifer and conifer-aspen than non-red squirrel kill sites. Conifer patches were farther from natural openings in red squirrel kill sites. Patch diversity was greater in red squirrel kill sites.

The birds returned most often to kill sites closer to nests with greater coverages and larger patch sizes of forest and conifer. However, overall patch sizes were lower and densities of conifer patches greater on the most used sites. Percent coverage of natural openings was lower on the most heavily used kill sites. They returned most often to sites with smaller aspen patches, greater densities of small natural openings, and smaller distances between conifer and natural opening patches. Patch diversity and total patch density were higher in the most heavily used kill sites. Three goshawks returned most often to sites with greater coverages and larger patch sizes of clearcuts.

When examining my results, several factors must be kept in mind. Due to my relatively low sample size (n = 5 male goshawks) and the non-random choice of nests, my results may not be representative of goshawk populations. Also the activity of goshawks during locations used in calculating relative use can not determined, thus relative use may represent activities other than foraging. However, goshawk foraging habits are difficult to study because goshawks often move quickly through rugged, forested terrain. Additionally, male goshawks hunt over large areas. Goshawks in southcentral Wyoming made kills up to 5456 m from nests during the breeding season.

Beier and Drennan (1997) averaged 10 hours of effort to obtain precise foraging locations in northern Arizona during the breeding season. We confidently identified 26 kill sites by male goshawks during approximately 561 hours of effort over two years, an average of 22 hours of effort per kill site.

Goshawk declines in Fennoscandia (Finland, Sweden and Norway) are the result of fragmentation of boreal forest landscapes, making prey less available to breeding goshawks (Widén 1997). Widén (1997) suggests that to conserve goshawk populations, more research is needed to determine what factors are important to goshawks, including the location of goshawk kill sites in relation to habitat characteristics. My study is the first in North America to examine landscape characteristics around goshawk kill sites during the breeding season. Additionally, my study is the first to determine how relative use of kill areas varies with landscape pattern.

My results are similar to those reported by Hargis et al. (1994). Goshawks perch in areas of high vegetative diversity in California (Hargis et al. 1994). Hargis et al. (1994) suggested preserving edges of mature timber and natural openings in goshawk foraging areas. Goshawks in southcentral Wyoming make kills in areas with shorter distances between natural opening and conifer patches than random sites. Goshawks also returned most often to kill sites with greater patch diversity and higher densities of small natural openings. It is difficult to determine if goshawks actually use edges for hunting from telemetry data. However, golden-mantled ground squirrels and northern flickers appear frequently in goshawk pellets collected during the breeding season in southcentral Wyoming. Both species of prey occur frequently in natural meadows and rocky openings (see Chapter 4). Goshawks could hunt from the edges of small natural openings, allowing them to approach prey unseen.

I found aspen patches in goshawk kill areas to have higher perimeter to area ratios. Although I could not determine if higher ratios were a result of patches being narrow or simply having convoluted perimeters, higher ratios may have indicated increased aspen edge. Aspen in southcentral Wyoming supported the highest densities of breeding woodpeckers compared to any other habitat type (Loose 1996). Least chipmunks also used aspen habitat greater than expected at random (see Chapter 4). Goshawks hunted along edges in Sweden when prey were present (Kenward and Widén 1989). Perhaps goshawks increased their opportunities of encountering more and different types of prey by incorporating aspen patches with greater amounts of perimeter or edge in foraging areas.

Other authors have found goshawks to prefer large, mature patches of forest. Widén (1989) suggested goshawks hunting in large patches could spend more time hunting squirrels and less time switching patches in Sweden. Goshawks in southcentral Wyoming made kills in areas with greater forest patch sizes and fewer and smaller natural openings than random areas. Percent coverage of conifer was greater in red squirrel kill areas than non-red squirrel kill areas, however, patch sizes of conifer in red squirrel kill sites were smaller at 300 m than in sites where other prey types were killed.

Forest management has been proposed to have negative affects on goshawk populations Fennoscandia (Widén 1997). Goshawks in southcentral Wyoming returned most often to sites with greater coverages and patch sizes of clearcuts. I attributed increased goshawk use to the presence of mature forest adjacent to clearcuts. Goshawks returned most often to kill areas with mature forest (see Chapter 2).

Goshawks made kills which were delivered 162 m to 5456 m from nests. However, goshawks returned most often to sites closer to nests. No authors of goshawk studies have examined the relationship of foraging with distance to the nest. The male goshawk provided the bulk of the food to the female and young (See Chapter 5). Goshawks which hunted close to nests probably expended less energy delivering prey. Wakeley (1978) found feruginous hawks intensively hunted the closest suitable areas to nests.

Management and future research recommendations:

Goshawks capture prey in a variety of habitats, from aspen stringers surrounded by sagebrush to areas dominated by conifer forests. Vegetation diversity should be maintained throughout the home range. Goshawks intensively use large areas of conifer forests interspersed with small natural openings in close proximity to nests. Timber harvest could cause male goshawks to expend more energy to capture and deliver prey by decreasing the amount conifer forests near nests.

In the Medicine Bow National Forest, buffers of varying sizes are placed around goshawk nests, but large amounts of nearby conifer forests are removed. More study is needed to determine how much forest in close proximity to nests is required to provide suitable foraging habitat. Since, suitable goshawk habitat can be lost by managing for goshawks only in areas of known goshawk activity (Widén 1997), managers should identify areas of potential nesting habitat and foraging areas should be managed as if goshawks were present.

Future studies of foraging goshawks should not only examine habitat characteristics of foraging versus random points, but also determine the relative use of foraging areas. Additionally, more works on the impact of forest fragmentation on goshawk prey are needed before the effects of forest management on foraging areas can be properly evaluated (Squires and Reynolds 1997, Garton et al. 1989).

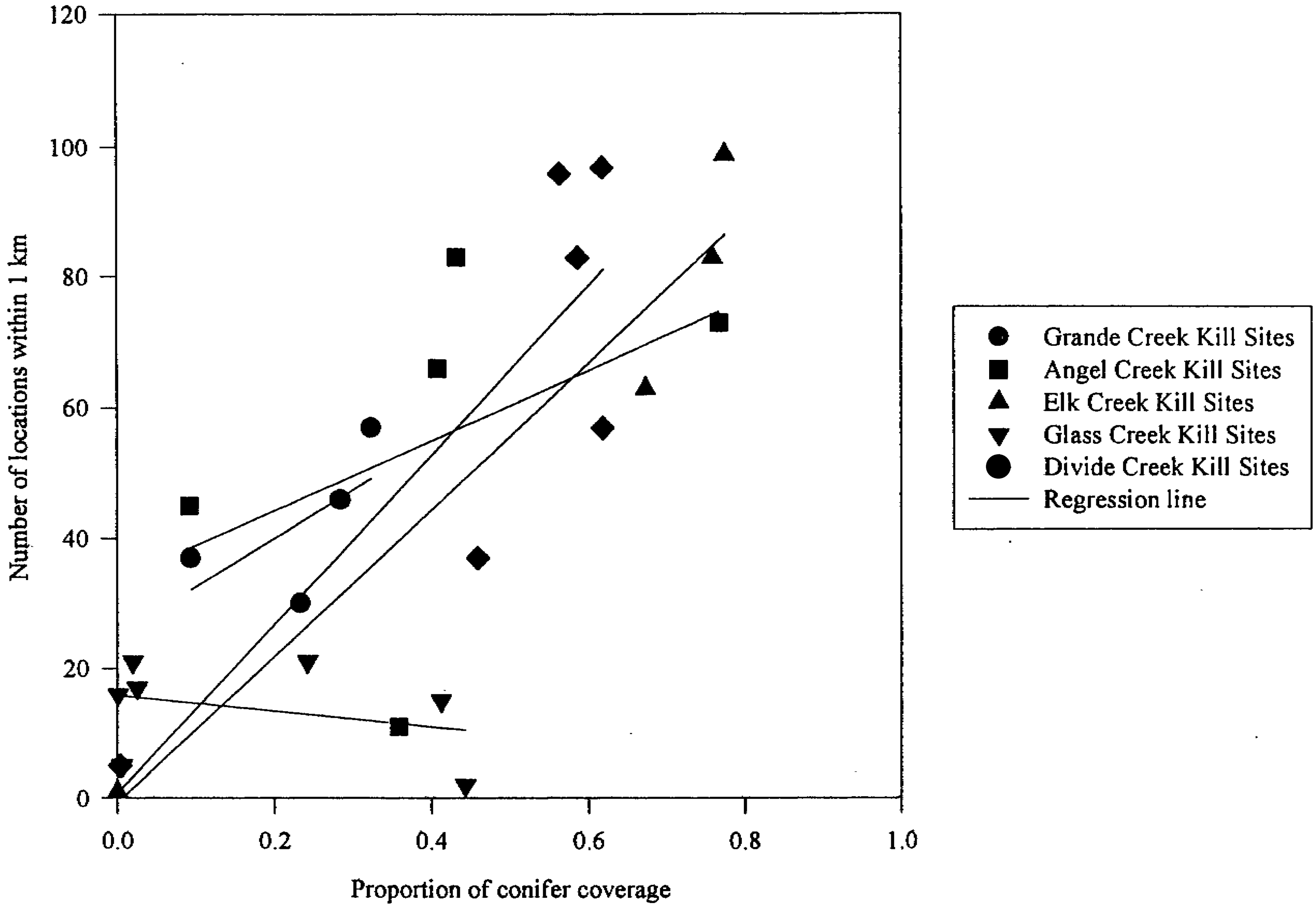

Figure 1. Scatterplot showing the relationship between proportion of conifer coverage and relative use in 1 km radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

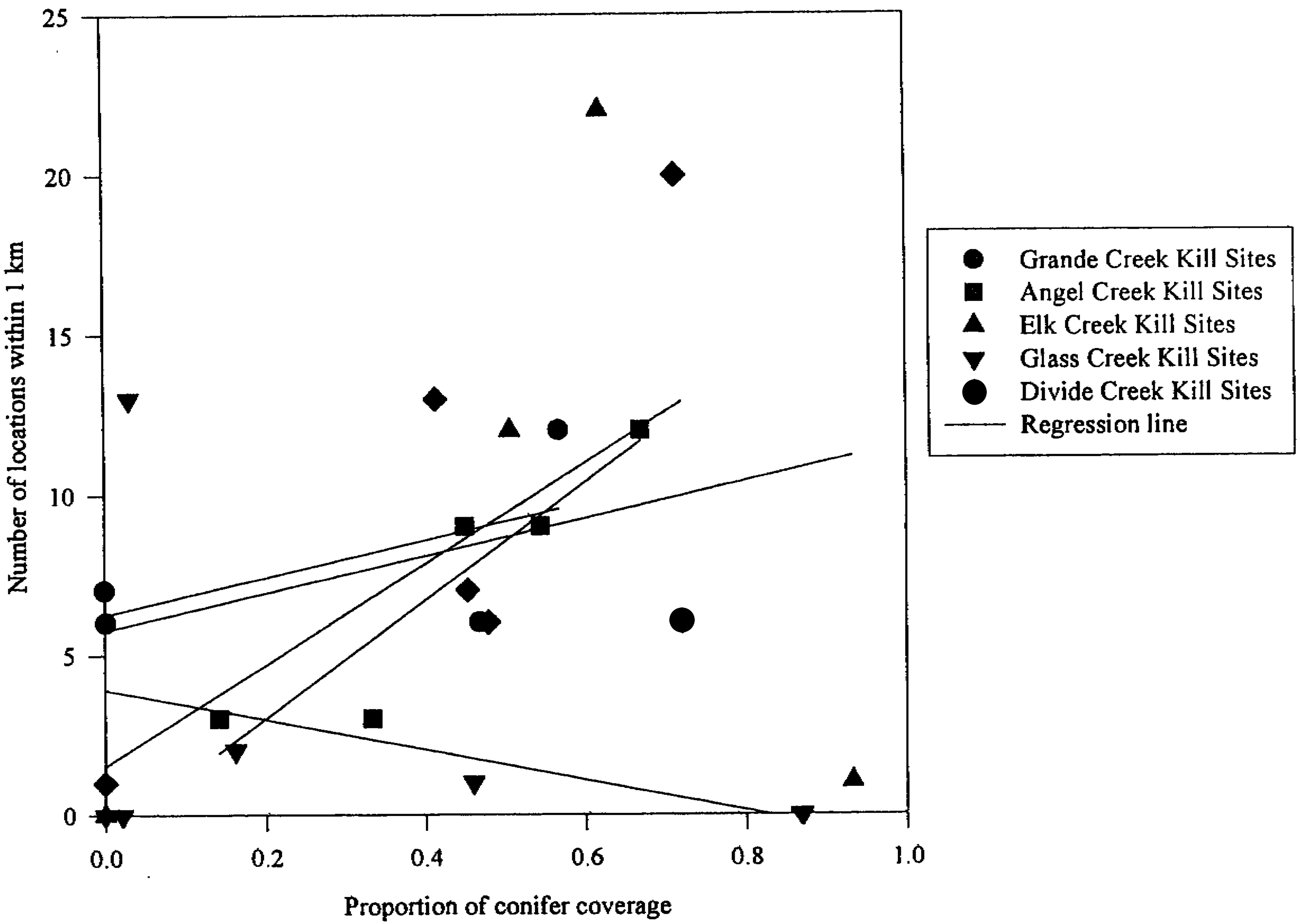

Figure 2. Scatterplot showing the relationship between proportion of conifer forest and relative use in 300 m radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

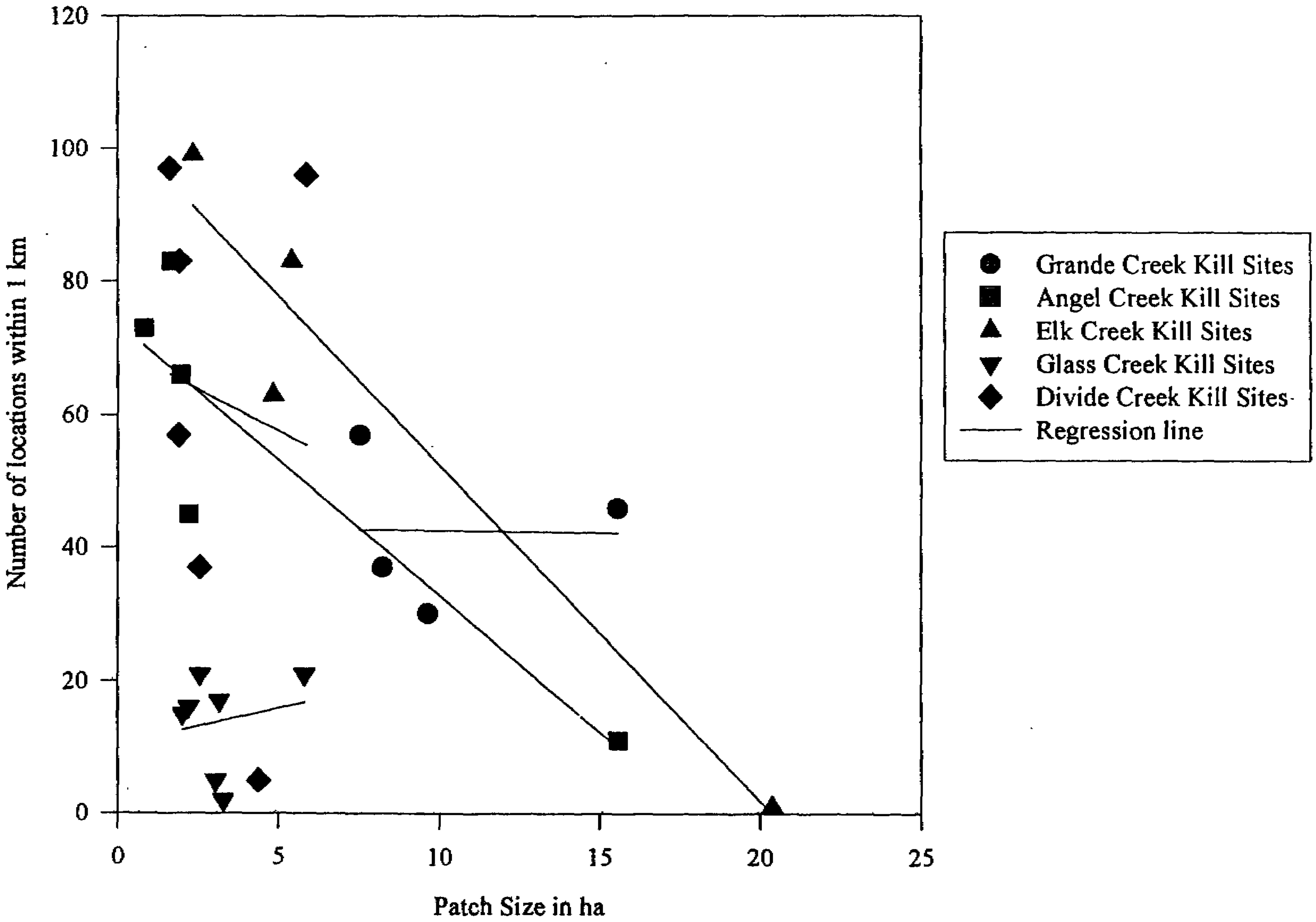

Figure 3. Scatterplot showing the relationship between natural opening patch size and relative use in 1 km radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

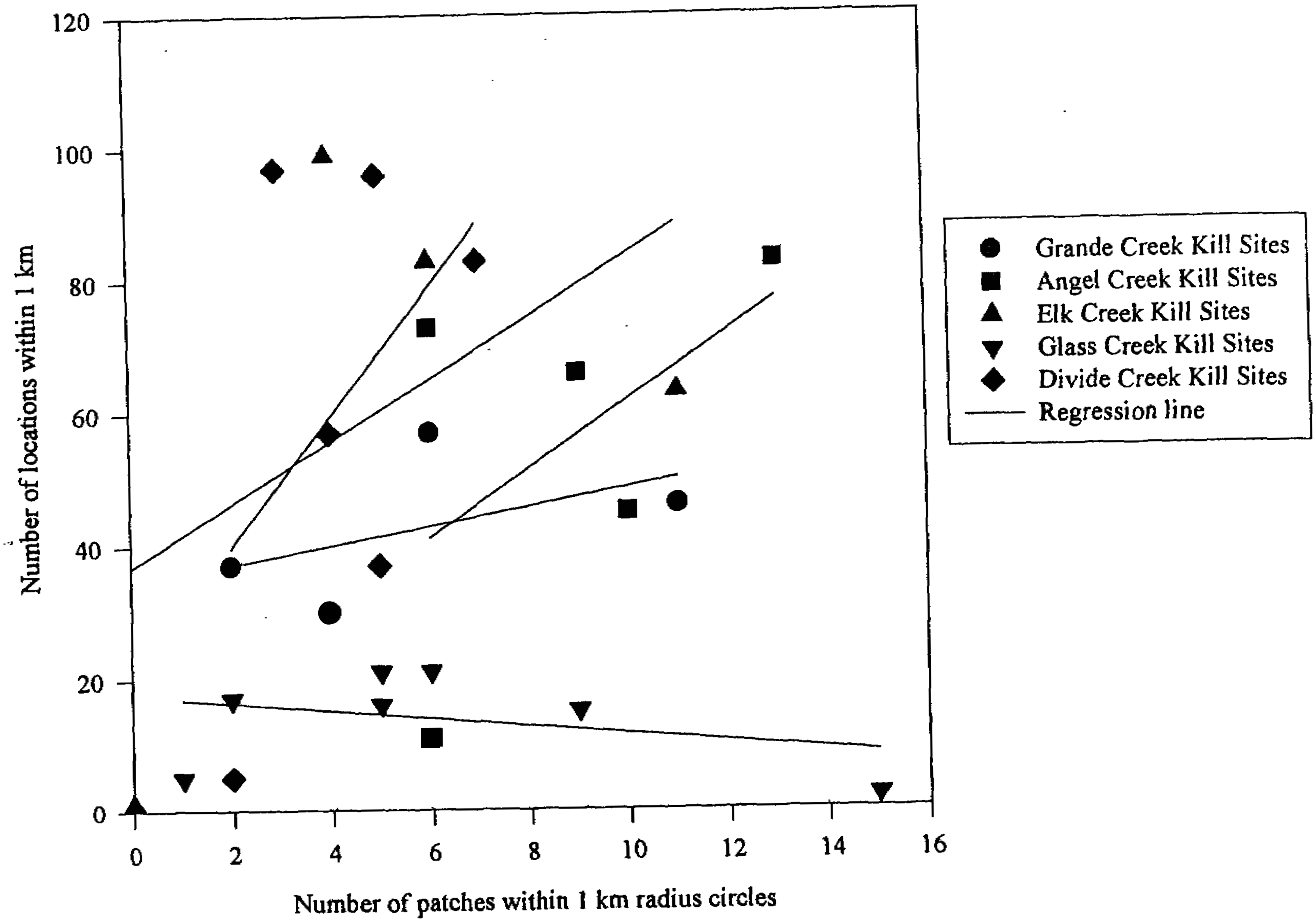

Figure 4. Scatterplot showing the relationship between conifer patch density and relative use in 1 km radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

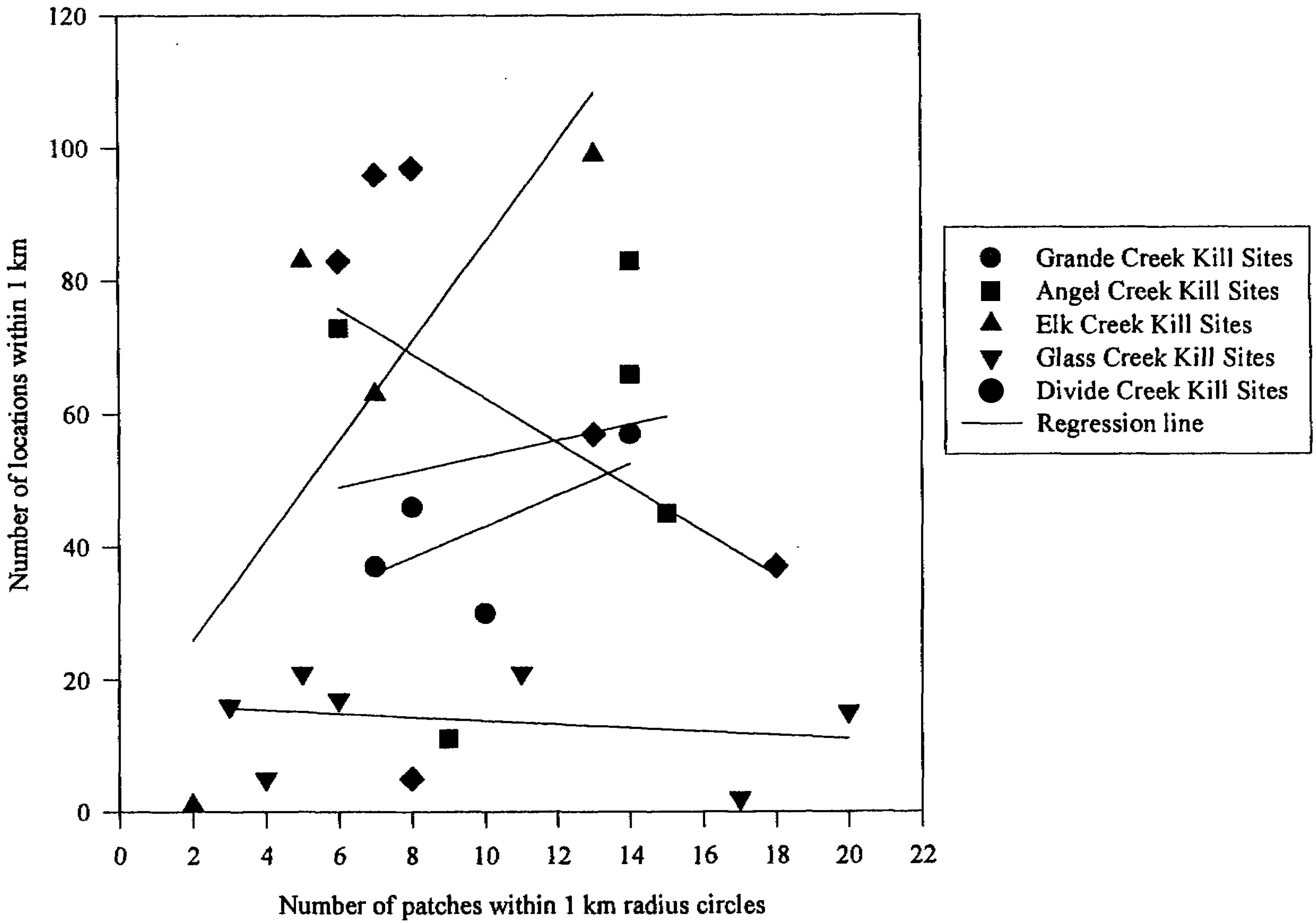

Figure 5. Scatterplot showing the relationship between natural opening patch density and relative use in 1 km radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

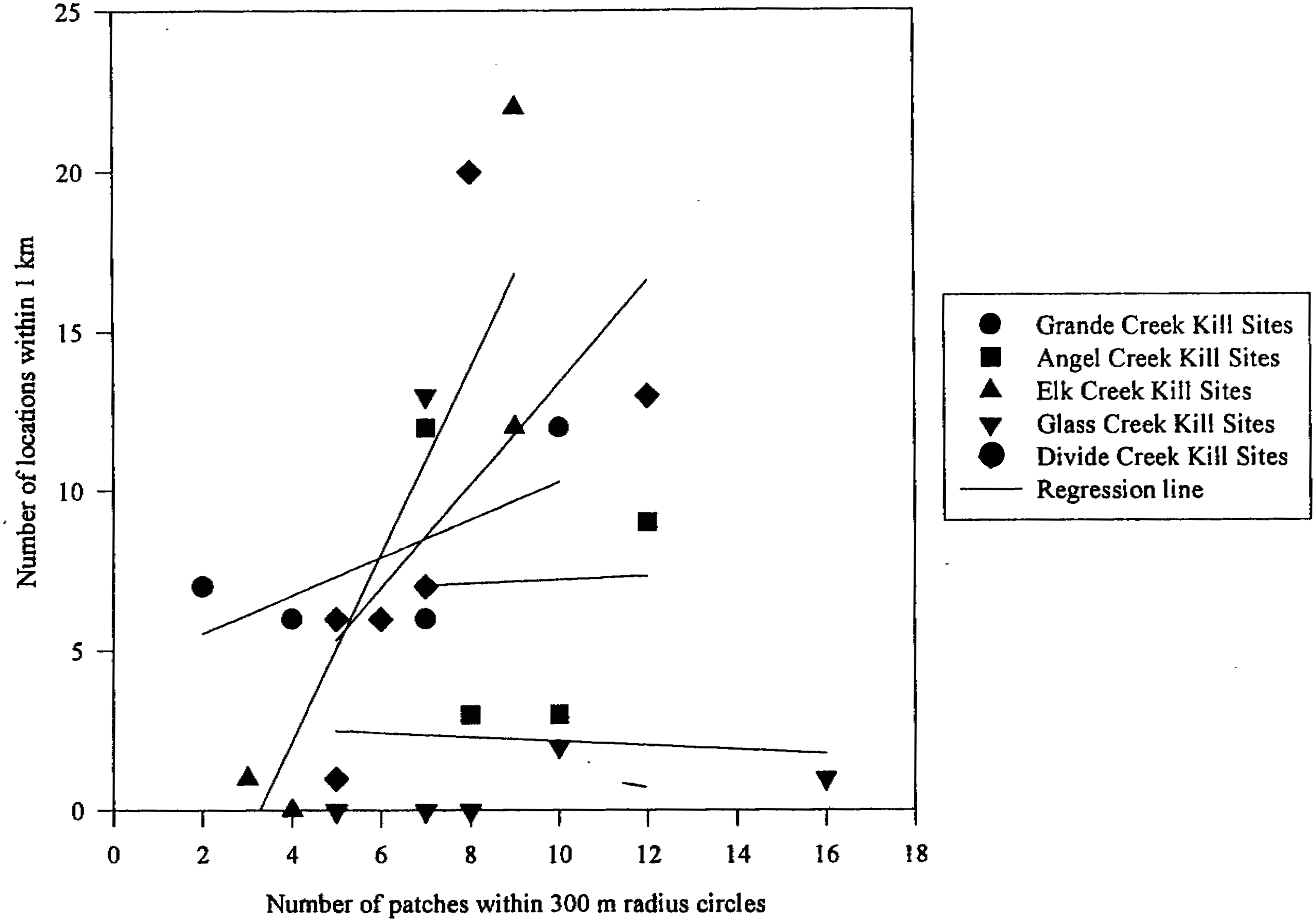

Figure 6. Scatterplot showing the relationship between total patch density and relative use in 300 m radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

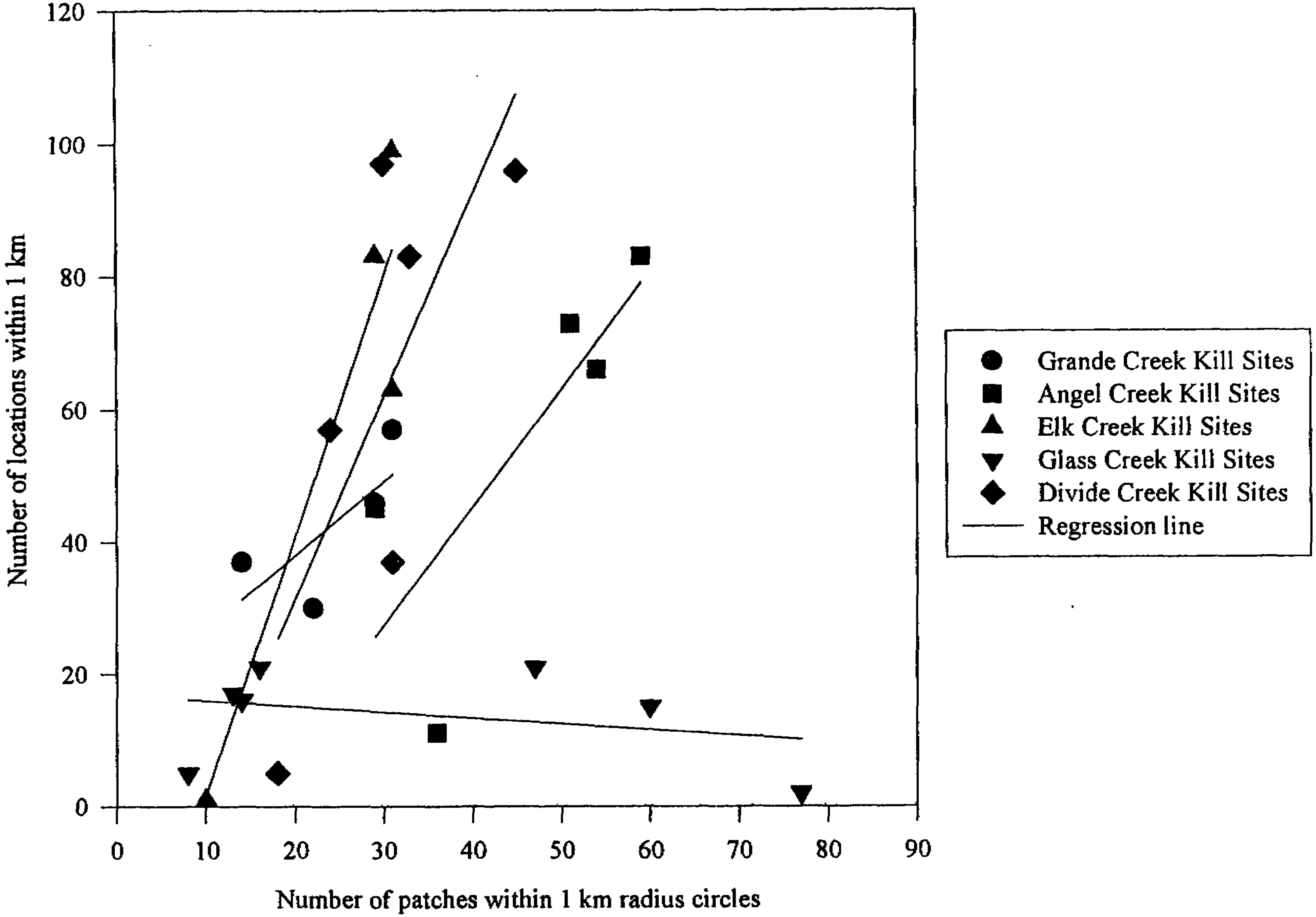

Figure 7. Scatterplot showing the relationship between total patch density and relative use in 1 km radius circles around goshawks kill sites in southcentral Wyoming during the breeding seasons of 1996 and 1997.

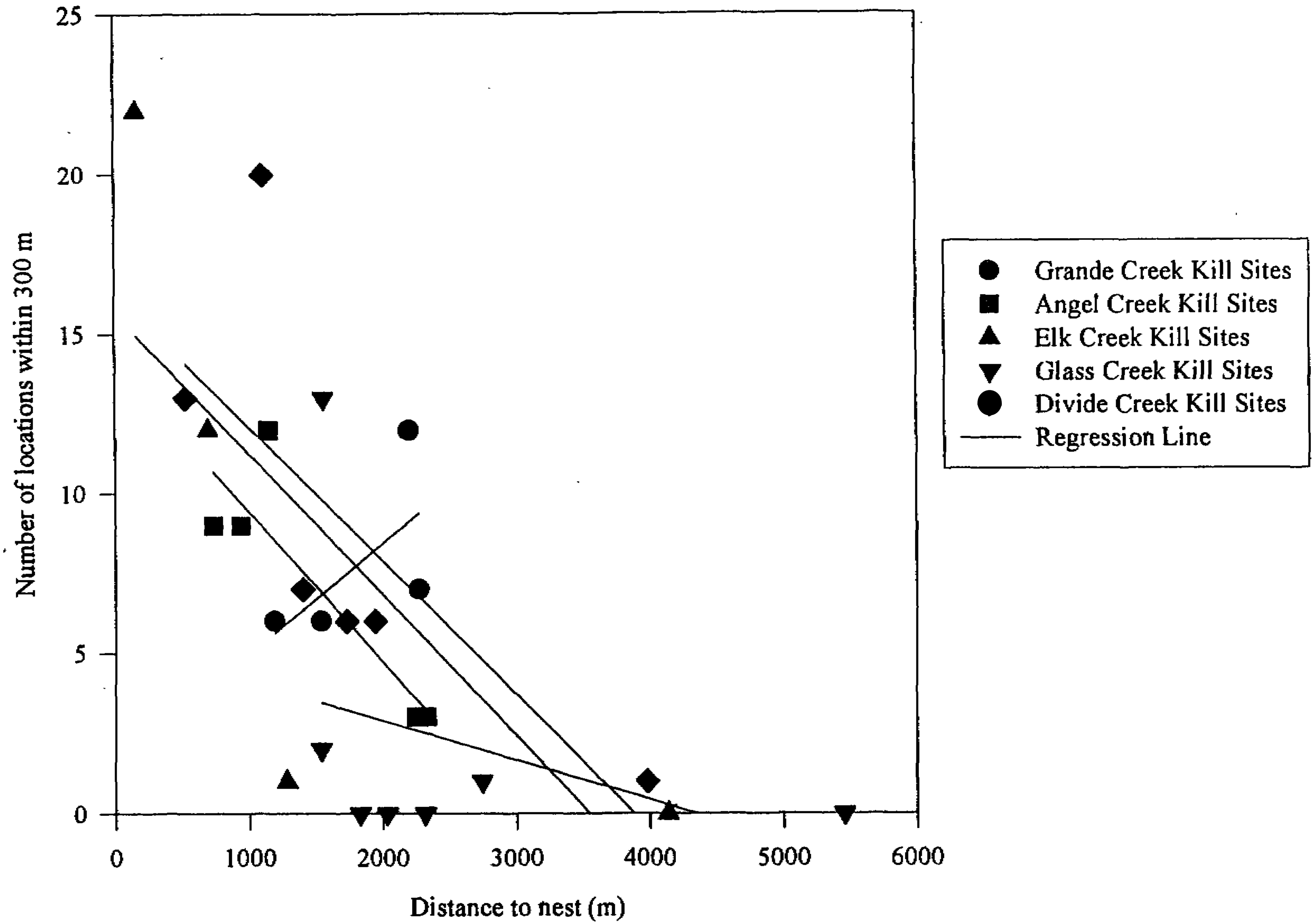

Figure 8. Scatterplot of male northern goshawk kill sites showing the relationship between relative use and distance to the nest in southcentral Wyoming during the breeding seasons of 1996 and 1997.

Table 1. Patch classifications used on digitized maps of goshawk home ranges in southcentral Wyoming.

Coarse Patch Classification	Fine Patch Classification	Explanation
Forest	Conifer	All coniferous patches. Includes lodgepole, sub-alpine fir, douglas fir and ponderosa pine.
Forest	Aspen	All aspen patches
Forest	Conifer-Aspen	Even conifer and aspen mixtures
Forest	Thinned Conifer	Conifer patches mechanically thinned
Natural Opening	Natural Opening	Includes shrub, grass and rocky openings
Clearcut	Clearcut	Clearcuts in which trees could not be seen on areal photos
Clearcut	Old Clearcut	Clearcuts in which trees were visible on areal photos
Agricultural	Agricultural	Mostly hay fields and a few stock ponds
Major Roads	Major Roads	Two lane dirt roads and highways
River-Willow	River-Willow Corridor	Areas including willow and/or water cover

Table 2. Explanations of landscape variables measured using r.le version 2.1 (Baker 1994).

Variable	Explanation	Formula	Formula explanation	Citation
Patch Density	Number of patches	N/A	N/A	Baker 1994
Patch Richness	Number of patch types	N/A	N/A	Baker 1994
Shannon Index (H')	Diversity index which combines richness and eveness	$= -\sum_{I=1}^{m} p_i * \ln(p_i)$	p_i = fraction of area occupied by I m = number of patches	Baker 1994
Dominance (D)	Stresses deviation from eveness	= ln(n)-H'	n = number of patches H' = Shannon Index	Baker 1994, O'neill et al. 1988
Inverse Simpson's Index (1/S)	Diversity index which combines richness and eveness	$= 1/\sum_{I=1}^{m} p_i^2$	p_i = fraction of area occupied by i m = number of patches	Baker 1994
Distance from conifer to natural opening patches	Measured as the average distance from the edge of each conifer or natural opening to another conifer or natural opening patch	N/A	N/A	Baker 1994
Percent Cover	The amount of land area covered by each patch type	N/A	N/A	Baker 1994
Patch Size	The average patch size	N/A	N/A	Baker 1994
Patch Shape (corrected perimeter/area)	A circle has a value of zero, while an infinitely long and narrow patch can increase to infinity. A square has a value of 1.12	$= (0.282*\text{perimeter}) / (\text{area})^{1/2}$	N/A	Baker 1994

Table 3. Summary statistics for landscape variables measured in 1 km circles surrounding 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Patch Density	Patch Richness*	Shannon-Wiener Patch Diversity*	Patch Dominance*	Inverse Simpson's Patch Diversity *	Patch Shape	Distance from Conifer to Natural Opening Patches	Patch Size (m^2)
Mean	32.38	3.65	0.83	0.4	2.1	2.18	20.13	133166.4
Confidence Level (95.0%)	7	0.59	0.14	0.11	0.3	0.08	11.15	348764.8
Standard Deviation	17.33	1.47	0.35	0.28	0.75	0.21	27.59	86070.8
Standard Error	3.4	0.29	0.07	0.05	0.15	0.04	5.41	16879.8
Median	30.5	3	0.84	0.34	1.93	2.19	8.12	103032
Mode	31	3	#N/A	#N/A	#N/A	2.23	0	101343
Minimum	8	2	0.22	0	1.11	1.85	0	40800.4
Maximum	77	8	1.52	0.88	3.63	2.99	123.03	392704
Count	26	26	26	26	26	26	26	26

* r.le version 2.1 underestimated the patch richness and percent coverage by one patch type, lowering patch diversity measures.

Table 4. Summary statistics for landscape variables measured in 300 m circles surrounding 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Patch Density	Patch Richness*	Shannon-Wiener Patch Diversity*	Patch Dominance*	Inverse Simpson's Patch Diversity*	Patch Shape	Distance from Conifer to Natural Opening Patches	Patch Size (m^2)
Mean	7.62	2.27	0.48	0.25	1.58	1.92	8.46	45936.4
Confidence Level (95.0%)	1.3	0.37	0.14	0.09	0.22	0.08	7.23	10615.5
Standard Deviation	3.23	0.92	0.35	0.22	0.55	0.19	17.89	26282
Standard Error	0.63	0.18	0.07	0.04	0.11	0.04	3.51	5154.32
Median	7	2	0.49	0.22	1.46	1.9	0	40393.2
Mode	7	2	0	0	1	#N/A	0	40393.2
Minimum	2	1	0	0	1	1.48	0	17672
Maximum	16	4	1.16	0.86	3.01	2.32	59.01	141376
Count	26	26	26	26	26	26	26	26

* r.le version 2.1 underestimated the patch richness and percent coverage by one patch type, lowering patch diversity measures.

Table 5. Summary statistics for 26 goshawk kill sites in southcentral Wyoming. Distance to the nest is measured from the kill site and elevation is the average pixel value within 300 m radius circles of goshawk kill sites.

	Distance (m)	Elevation (m)
Mean	1885	2570
Confidence Level (95.0%)	476.9	48.2
Standard Deviation	1181	119.3
Standard Error	231.6	23.4
Median	1640	2549
Mode	#N/A	#N/A
Minimum	162	2347
Maximum	5456	2862

Table 6. Summary statistics for proportion of coverage of habitat types in 1 km circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum
Conifer	0.353	0.107	0.266	0.052	0.383	#N/A	0	0.774
Aspen	0.138	0.046	0.115	0.022	0.107	#N/A	0.015	0.446
Conifer-Aspen	0.021	0.01	0.026	0.005	0.008	0	0	0.077
Natural Openings	0.42	0.117	0.289	0.057	0.382	#N/A	0.053	0.932
Clearcut	0.023	0.016	0.038	0.008	0	0	0	0.148
Old Clearcut	0.014	0.015	0.038	0.007	0	0	0	0.158
Agricultural	0.027	0.037	0.091	0.018	0	0	0	0.451
Major Road	0.002	0.002	0.006	0.001	0	0	0	0.027
Thinned Conifer	0.002	0.002	0.006	0.001	0	0	0	0.023
River-Willow Corridor	0*	0	0	0	0	0	0	0*

* Actual value is < 0.001 but > 0.

Table 7. Summary statistics for the proportion of coverage of habitat types in 300 m circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum
Conifer	0.401	0.123	0.305	0.06	0.456	0	0	0.933
Aspen	0.205	0.085	0.211	0.041	0.14	0	0	0.709
Conifer-Aspen	0.023	0.031	0.077	0.015	0	0	0	0.347
Natural Openings	0.309	0.116	0.288	0.057	0.194	#N/A	0	0.855
Clearcut	0.033	0.032	0.078	0.015	0	0	0	0.269
Old Clearcut	0.024	0.037	0.091	0.018	0	0	0	0.437
Agricultural	0	0	0	0	0	0	0	0
Major Road	0.001	0.003	0.006	0.001	0	0	0	0.033
Thinned Conifer	0.004	0.007	0.017	0.003	0	0	0	0.084
River-Willow Corridor	0	0	0	0	0	0	0	0

Table 8. Summary statistics for patch density of habitat types in 1 km circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification. Units are the number of patches.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum
Conifer	6.038	1.509	3.736	0.733	5.5	6	0	15
Aspen	9.615	1.959	4.85	0.951	8	14	2	20
Conifer-Aspen	1.423	0.678	1.677	0.329	1	0	0	5
Natural Openings	11.192	3.11	7.699	1.51	8	4	2	27
Clearcut	2.538	1.433	3.547	0.696	0	0	0	10
Old Clearcut	0.654	0.625	1.548	0.304	0	0	0	6
Agricultural	0.423	0.327	0.809	0.159	0	0	0	3
Major Road	0.308	0.357	0.884	0.173	0	0	0	3
Thinned Conifer	0.154	0.187	0.464	0.091	0	0	0	2
River-Willow Corridor	0*	#N/A	#N/A	#N/A	0	0	0	0*

* Actual value is < 0.001 but > 0.

Table 9. Summary statistics for patch density of habitat types in 300 m circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Min	Max
Conifer	1.846	0.601	1.488	0.292	1.5	1	0	5
Aspen	2	0.666	1.649	0.323	2	1	0	5
Conifer-Aspen	0.269	0.293	0.724	0.142	0	0	0	3
Natural Openings	2.577	0.759	1.88	0.369	2	1	0	7
Clearcut	0.615	0.499	1.235	0.242	0	0	0	4
Old Clearcut	0.154	0.187	0.464	0.091	0	0	0	2
Agricultural	0	0	0	0	0	0	0	0
Major Road	0.077	0.11	0.272	0.053	0	0	0	1
Thinned Conifer	0.077	0.11	0.272	0.053	0	0	0	1
River-Willow Corridor	0	0	0	0	0	0	0	0

Table 10. Summary statistics for patch shape (corrected perimeter/area) of habitat types in 1 km circles around goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum	Count *
Conifer	2.331	0.177	0.428	0.086	2.319	#N/A	1.508	3.168	25
Aspen	2.389	0.144	0.358	0.07	2.35	#N/A	1.938	3.202	26
Conifer-Aspen	2.052	0.194	0.351	0.091	2.021	1.649	1.532	2.826	15
Natural Openings	2.048	0.094	0.232	0.046	2.032	#N/A	1.659	2.782	26
Clearcut	1.778	0.08	0.112	0.035	1.755	#N/A	1.646	1.946	10
Old Clearcut	1.757	0.169	0.136	0.061	1.742	#N/A	1.586	1.898	5
Agricultural	2.016	0.427	0.461	0.174	1.982	#N/A	1.563	2.925	7
Major Road	5.41	6.838	2.753	1.589	5.999	#N/A	2.411	7.821	3
Thinned Conifer	1.926	1.654	0.666	0.384	1.559	#N/A	1.525	2.695	3
River-Willow Corridor	2.09	#N/A	#N/A	0	2.09	#N/A	2.09	2.09	1

* Count = Number of kill sites containing patches.

Table 11. Summary statistics for patch shape (corrected perimeter/area) of habitat types in 300 m circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Min	Max	Count *
Conifer	2.155	0.235	0.53	0.113	1.935	#N/A	1.433	3.027	22
Aspen	2.125	0.267	0.571	0.128	1.975	#N/A	1.495	3.994	20
Conifer-Aspen	1.607	0.325	0.204	0.102	1.527	#N/A	1.464	1.91	4
Natural Openings	1.851	0.108	0.262	0.052	1.854	#N/A	1.451	2.522	25
Clearcut	1.745	0.099	0.108	0.041	1.721	#N/A	1.584	1.914	7
Old Clearcut	1.798	0.49	0.197	0.114	1.863	#N/A	1.576	1.954	3
Agricultural	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0
Major Road	3.598	8.094	0.901	0.637	3.598	#N/A	2.961	4.235	2
Thinned Conifer	1.733	3.227	0.359	0.254	1.733	#N/A	1.479	1.987	2
River-Willow Corridor	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0

* Count = Number of kill sites containing patches

Table 12. Summary statistics for patch sizes (m^2) of habitat types in 1km circles around 26 goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum	Count
Conifer	205580	75888.5	183847	36769.5	151498	#N/A	317.6	645913	25
Aspen	52435.7	20141.6	49866.8	9779.69	31015.7	#N/A	8002	203896	26
Conifer-Aspen	53971.7	23070.7	41660.3	10756.6	48182.4	#N/A	1588	112728	15
Natural Openings	263168	138783	343601	67385.7	92958.1	#N/A	10534.2	1391334	26
Clearcut	27674.6	10218.8	14284.9	4517.29	26451.7	#N/A	7222.4	47554.8	10
Old Clearcut	70681.9	53391.2	42999.7	19230	56772	#N/A	24794	124341	5
Agricultural	141675	157106	169872	64205.6	85364	#N/A	444	471843	7
Major Road	20339.3	50521.9	20337.8	11742	15972	#N/A	2540	42506	3
Thinned Conifer	46785.3	62722.8	25249.3	14577.7	44964	#N/A	22496	72896	3
River-Willow Corridor	14480	#N/A	#N/A	0	14480	#N/A	14480	14480	1

* Count = Number of kill sites containing patches

Table 13. Summary statistics for patch sizes (m^2) of habitat types in 300 m circles around goshawk kill sites in southcentral Wyoming using the fine patch classification.

	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Minimum	Maximum	Count
Conifer	96403.6	37416.5	84390.1	17992	64508	#N/A	114.68	263700	22
Aspen	38434.2	19269.7	41173.3	9206.63	21430	#N/A	136	158972	20
Conifer-Aspen	19918.7	32423.7	20376.6	10188.3	13733.3	#N/A	3208	49000	4
Natural Openings	49134.3	27058	65550.7	13110.1	24370.7	#N/A	1874	241708	25
Clearcut	18779.3	24329.6	26306.7	9942.98	9456	#N/A	440	75924	7
Old Clearcut	51284	157600	63442.7	36628.6	25968	#N/A	4408	123476	3
Agricultural	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0
Major Road	4892	55297.2	6154.66	4352	4892	#N/A	540	9244	2
Thinned Conifer	16524	91636.8	10199.3	7212	16524	#N/A	9312	23736	2
River-Willow Corridor	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	0	0

* Count = Number of kill sites containing patches

Literature Cited

Angelstam, P. 1983. Population dynamics of tetraonids, especially the black grouse Tetra tetrix L., in boreal forests. Ph.D. dissertation, Uppsala University. Cited in Widén 1989.

Baker, W.L. 1994. The r.le Programs: a set of GRASS programs for the quantitative analysis of landscape structure version 2.1.

Bechard, M.J. 1982. Effect of vegetative cover on foraging site selection by Swainson's hawks. Condor 84: 153-159.

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7: 564-571.

Bright-Smith, D.J. and R.W. Mannan. 1994. Habitat use by breeding male northern goshawks in northern Arizona. Studies in Avian Biology no. 16: 58-65.

Garton, E.O., P.H. Hayward and G.D. Hayward. 1989. Management of prey habitats and populations. National Wildlife Federation Scientific and Technical Series no. 12: 298-304.

Hargis, C.D., C. McCarthy, and R.D. Perloff. 1994. Home ranges and habitats of northern goshawks in eastern California. Studies in Avian Biology no. 16: 66-74.

Kenward, R. and P. Widén. 1989. Do goshawks Accipiter gentilis need forests? Some conservation lessons from radio tracking. In Raptors in the Modern World. eds. B.U. Meyburg and R.D. Chancellor. WWGBP: Berlin, London and Paris. pp 561 - 567.

Kie, J.G., J.A. Baldwin, and C.J. Evans. 1994. Calhome: Home Range Analysis Program, Electronic User's Manual. U.S. Forest Service Pacific Southwest Research Station, Fresno, California.

Loose, S.S. 1993. Woodpecker habitat use in the forests of southeast Wyoming. Master's Thesis, University of Wyoming, Laramie.

O'Neill, R.V., J.R. Krummel, R.H. Gardner, G. Sugihara, B. Jackson, D.L. Angeles, B.T. Milne, M.G. Turner, B. Zygmunt, S.W. Christensen, V.H. Dale, and R.L. Grahm. 1988. Indices of landscape pattern. Landscape Ecology 1: 153-162.

Reynolds, R.T., R.T. Grahm, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, Jr., G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management Recommendations for the Northern Goshawk in the Southwestern United States. USDA Forest Service, Gen. Tech. Rep. RM-217, Ft. Collins, CO.

Squires, J.R. and R.T. Reynolds. 1997. Northern Goshawk (Accipiter gentilis). In The Birds of North America, No. 298. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Thiollay, J., and B.U. Meyburg. 1988. Forest fragmentation and the conservation of raptors: a survey on the island of Java. Biological Conservation 44: 229-250.

Wakeley, J.S. 1978. Factors affecting the use of hunting sites by feruginous hawks. Condor 80: 316:326.

Widén, P. 1989. The hunting habitats of goshawks Accipiter gentilis in boreal forests of central Sweden. Ibis 131: 205-231.

Widén, P. 1997. How, and why is the goshawk (Accipiter gentilis) affected by modern forest management in Fennoscandia? Journal of Raptor Research 31(2): 107-113.

Wiens, J.A., J.T. Rotenberry and B. Van Horne. 1987. Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. Oikos 48: 132-147.

Chapter 4 - Habitat use by selected goshawk prey.

Introduction:

Several authors have found raptor populations to be limited by prey populations (see Garton et al. 1989 for a summary). Ward and Kennedy (1996) found that goshawk nests in New Mexico which were experimentally supplemented with food had higher nestling survival than control nests during one year of the study. Doyle and Smith (1994) found goshawk nest success to fluctuate with the snowshoe hare cycle in the Yukon Territory. Lindén and Wikman (1983) found the number of nesting pairs of goshawks in Finland to decrease as grouse populations declined.

Because the status of goshawk populations are of increasing concern, a potential method to increase or maintain goshawk populations is to increase prey. While the habitat preferences of goshawk prey in other areas are relatively well known, few researchers study goshawk prey in forests dominated by lodgepole pine, particularly in Wyoming.

Clark et al. (1980) identified seven studies of goshawk prey in a review of Wyoming mammal literature including red squirrels (Tamiasciurus hudsonicus), golden-mantled ground squirrels (Spermophilus lateralis), least chipmunks (Tamias minimus), uinta chipmunks (Tamias umbrinus) and mountain cottontail (Sylvilagus nuttalli). None of the authors investigated habitat use. I know of one study conducted in Wyoming on the habitat use of a mammalian prey species, the red squirrel (Rothwell 1977). Garton et al. (1989) suggested that without knowledge of habitat preferences, the effects of forest management on prey populations can not be properly evaluated.

Our objective was to determine what habitat characteristics existed at kill sites and to compare these characteristics to where prey were found. Red squirrels, ground squirrels and chipmunks, and small mammals made up 41%, 34%, and 17% of identified deliveries to nests during the breeding season (see Chapter 5). Birds comprised only 20% of identified deliveries to nests. Goshawks generally remove fur and feathers from prey at plucking posts before delivering the item to the nest (Boal and Mannan 1994). Goshawks in our study may have plucked birds more often, and removed fur from mammals less often (see Chapter 5), resulting in an artificially high identification of mammals delivered to nests compared to birds. Northern flicker and American robin feathers appeared frequently in goshawk pellets in southcentral Wyoming (Squires in prep.).

Methods:

Goshawk kill areas were located by continuously monitoring the foraging paths of telemetered male goshawks during the breeding season (see Chapter 2). The points along foraging paths where goshawks began direct paths toward nests were kill sites. Observers at nests confirmed prey deliveries while telemetry personnel tracked using radio telemetry. Eight birds were monitored during the summers of 1996 and 1997. The goshawks monitored in 1996 included Marten, Simpson's Creek, Glass Creek, and Divide Creek. Goshawks monitored in 1997 included Boundary, Angel Creek, Elk Creek, and Grande Creek.

At kill sites prey surveys were conducted using a series of point counts and Sherman live traps along three 300 m transects (see Chapter 2, Fig. 1). Transects were spaced 150 m apart and oriented back toward the goshawk's location just prior to the kill. Point counts were spaced 150 m apart, and three points counts were placed on each transect. Sherman live traps were spaced at 10 m intervals along transects, for a total of 93 traps per grid. Point counts were conducted on two consecutive mornings and finished by 10:30. Small mammal trapping was conducted during two nights and one day. The locations of prey species were marked with flagging while walking transects, conducting point counts and checking small mammal traps. Habitat characteristics were measured using 0.04 h.a. circular plots centered on prey locations as described by James and Shugart (1970) and Noon (1980) with some modifications (see Chapter 2). The location of prey whose behavior had been affected by the observer were not marked. Additionally, of prey locations from point counts and transects, only those which were observed visually were measured. When possible, all prey locations were measured at a site. Nine random plots placed in a systematic random fashion in each sampling grid were also measured. Random plots were placed so that no more than two were located in each quarter of the grid. The dominant habitat, distance to nearest edge, and edge type were recorded for all small mammal captures.

Data Analysis:

Analyses were used to identify trends regarding prey habitat use in goshawk foraging areas. Two sets of analyses were conducted for each species. Prey use plots were compared with random plots, and prey abundance was correlated with habitat structure.

Goodness of fit chi-square tests were used to determine if categorical variables differed between used and random locations. Categorical data from random plots in kill sites where prey were located were pooled and used to calculate expected frequencies. Categorical data from prey centered plots were pooled in the same manner to determine the observed percent frequencies.

Shrew and deer mice use was analyzed using data collected during each small mammal capture (major habitat, distance to nearest edge, edge type). For shrews and deer mice, expected values were calculated from all random plots in all sites.

Non-categorical data were analyzed using paired t-tests or Wilcoxon signed rank tests when necessary. Used and random data for each site were averaged. The difference between used and random locations for each kill site was evaluated using paired t-tests (H_o: Difference between used and random = 0). Forest and non-forested habitats were separated for red squirrels, least chipmunks, gray jays, and deer mice. Red Squirrel and least chipmunk use versus random patterns were also analyzed using logistic regression.

Pearson's correlation coefficients were generated between non-categorical data of use plots and the abundance of prey species at each site to determine if prey abundance varied with habitat characteristics. Correlations with values greater than 0.60 were evaluated using simple linear regression.

Results:

Results for individual species are presented. Dominant vegetation and topography are described first, followed by use versus random patterns. Finally, habitat and abundance relationships are described.

Prey surveys were conducted at 21 kill sites from seven male goshawks during the summers of 1996 and 1997. A total of 140 vegetation plots (0.04 h.a.) centered on prey locations were conducted on 25 bird and mammal species: least chipmunk (40), red squirrel (36), uinta chipmunk (8), American robin (Turdus migratorius) (7), northern flicker (Colaptes auratus) (7), deer mouse

(Peromyscus maniculatus) (6), gray jay (Perisoreus canadensis)(6), golden-mantled ground squirrel (4), hairy woodpecker (Picoides villosus) (4), Sorex spp. (4), green-tailed towhee (Pipilo chlorurus) (3), hermit thrush (Catharus guttatus) (2), blue grouse (Dendragapus obscurus) (1), mountain cottontail (1), dark-eyed junco (Junco hyemalis) (1), downey woodpecker (Picoides pubescens) (1), Empidonax species (1), Lincoln's sparrow (Melospiza lincolnii) (1), red-breasted nuthatch (Sitta canadensis) (1), red crossbill (Loxia curvirostra) (1), song sparrow (Melospiza melodia) (1), Swainson's thrush (Catharus ustulatus) (1), warbling vireo (Vireo gilvus) (1), western tanager (Piranga ludoviciana) (1), and western wood-peewee (Contopus borealis) (1). Prey habitat use plots were measured at 15 of the 21 kill sites. Most prey habitat use plots were located during 1996 surveys (122 out of 140). Prey use plots (0.04 ha) included in analyses were located in kill sites from three birds. Data from small mammal capture locations were collected from five birds.

A total of 390 small mammals in 11 species were captured over two years (see Table 1). Dominant habitat, distance to nearest edge, and edge type were recorded for each capture. Deer mice, least chipmunks and red-backed voles comprised 90 % of all captures. Deer mice were the most-often captured species during evening trapping sessions (runs one and three), while least chipmunks dominated the day trapping sessions (run two).

Red Squirrels. Red squirrels used conifer forests with a wide range of structure (see Tables 2-3). Used sites had high canopy closure (mean = 60%, s.e. = 3.2), high canopy heights (mean = 8.4 m, s.e. = 0.4), and large densities of trees 23 to 37.5 cm dbh (mean = 9.4 stems / 0.04 ha, s.e. = 1.3). Trees 23 to 37.5 cm dbh are large for lodgepole pine in southcentral Wyoming (see Chapter 2, Fig. 13).

Red squirrels did not use topographic position, dominant shrubs, shrub and ground cover dispersion, and edge type in proportion to their availability ($p < 0.0001$). Percent frequency of red squirrel categorical data was calculated from 30 plots in six sites, and expected values from 54 random plots in six sites. Red Squirrels used ridges or hilltops greater than expected (17% used, 5% expected). Shrubs (69% used, 44% expected) and groundcover (69% used versus 48% expected) in understories were clumped in dispersion. Juniper (Juniperus communis) (20% used, 9% expected) was the most common shrub in understories. Natural openings were the most common edge type in use plots (38% used, 20% expected).

Red squirrels used sites which were closer to nearest woody debris (mean = -0.35 m), had lower heights to live canopy (mean = -1.3 m), had greater Daubenmire coverage of woody debris (mean = 5.0%) and fewer trees 15 cm ≤ d.b.h. < 24 (mean = -8.5 stems) than random plots ($p < 0.05$). Thirty red squirrel use plots and 43 random plots from six sites were used in paired t-tests ($n = 6$). Only random plots located in forests were used to determine average values for each site.

Paired t-tests were also conducted with five sites, excluding one site on the Colorado border (25 red squirrel use plots and 34 random plots in five sites, $N = 5$). The excluded site consisted of a mixture of habitats, including Douglas fir and ponderosa pine. These habitat types did not occur throughout most of the Sierra Madres and Snowy Ranges. Without the Colorado site the same relationships existed. Three different relationships became stronger. Used sites had more moderate slopes (mean = -8.8 % slope, $p = 0.069$), more conifers (mean = 3.1, $p = 0.092$) and lodgepole (mean = 2.0, $p = 0.10$) 23 cm ≤ d.b.h. < 38. All variables were weak predictors (coefficients < 0.09) of use versus random plots (see Table 4).

Red squirrel abundance was highly correlated with percent slope (0.904), total shrub density (0.876), dominant shrub density (0.840), percent coverage of bare ground (-0.734), percent coverage of dead herbaceous litter (0.729), percent coverage of forbes (0.797), and the number of trees < 3 cm in d.b.h. (0.826) ($n = 6$). Red squirrel abundance was negatively correlated with trees of all size classes other than < 3 cm d.b.h. (range -0.118 to -0.510). All variables were related to red squirrel abundance using simple linear regression at $p < 0.10$.

Pearson's correlation coefficients were also generated for the number of squirrels and each continuous variable for five sites, excluding one site on the Colorado border. Red squirrel abundance was again correlated with percent slope (0.891), percent coverage of bare ground (-0.846) and dead herbaceous litter (0.939). Red squirrel abundance was negatively related to the density of all size classes of conifers. Without the Colorado site canopy coverage (0.799) and height to live canopy (0.821) were highly correlated with squirrel abundance while total shrub density (0.514), dominant shrub density (0.105), percent coverage of forbes (-0.120) and number of trees < 3 cm d.b.h. (0.322) were not. Percent slope, percent coverage of dead herbaceous litter, canopy coverage, and height to live canopy were related to red squirrel abundance using simple linear regression at $p < 0.10$. The densities of lodgepole and sub-alpine fir by size class were not correlated with red squirrel abundance.

Least Chipmunk. Least chipmunks were found in all habitats. However, they were most often found in aspen (31% used, 21 % expected) and shrub habitats (33% used, 20 % expected). Least chipmunks used wide ranges of structure (see Tables 5-6), but were often found near edges (mean distance to nearest edge = 34.2 m, s.e. 7.7 m, mode = 0 m, n = 39 plots).

Least chipmunks did not use dominant habitat, topographic position, dominant shrubs, shrub dispersion, and edge type in proportion to their availability ($p < 0.02$). Observed frequencies of categorical variables were calculated from 39 plots in eight sites, while expected frequencies were calculated from 72 plots in eight sites. Least chipmunks were found less than expected in drainages (28% used, 43% expected) and moderate slopes (4% used, 11% expected) and more often on ridge or hill tops (16% used, 9% expected) and gentle slopes (44% used, 31% expected). Southern aspects

(53% used, 40% expected) with a variety of dominant shrubs were used. Least chipmunks were found in areas with clumped shrub dispersions (74% used, 45% expected) and with natural openings as the nearest edge (48% used, 31% expected).

Use plots had less dead herbaceous litter (mean = -16.7, $p < 0.05$) and less percent coverage of forbes (mean = -2.5, $p < 0.05$) and greater coverages of the density board at 0 - 0.3 m (mean = 10.6 %, $p = 0.063$). Paired t-tests of all plots included 39 use plots and 72 random plots from eight sites ($n = 8$).

In forests least chipmunks used sites with lower tree densities and more shrub cover. Forested paired t-tests were conducted on 18 use plots and 49 random plots in seven sites ($n = 7$). Least chipmunks used sites with greater shrub densities (mean = 61.1 stems), greater dominant shrub densities (mean = 60.3 stems), greater coverage of the density board from 0-.3 m (mean = 14.0), lower heights to live canopy (mean = -2.5 m), less coverage of bare ground (median = -6.5 %), dead herbaceous litter (mean = -23.0 %), forbes (mean = -2.2 %) and other (mean = -3.0 %), fewer total conifer stems (mean = -37.0), fewer trees 15 cm ≤ d.b.h. < 23 (mean = -7.6) and 23 cm ≤ d.b.h. < 38 (mean = -3.8) at $p < 0.05$. The number of aspen stems by size class were also tested but no relationships existed. All variables were weak predictors of use versus random plots (see Table 4).

Least chipmunks were most abundant in sites with greater shrub cover (total shrub density $r = 0.829$ and dominant shrub density $r = 0.870$, $n = 8$ sites, $p < 0.05$). In forests least chipmunks were most abundant in sites with greater shrub cover, lower conifer densities and higher aspen densities ($p < 0.16$). Correlation coefficients for forested use plots were generated from 7 sites containing 18 use plots. Least chipmunk abundance was related to total shrub density (0.962), dominant shrub density (0.932), percent coverage of density board at 0 - 0.3 m (0.720), conifer stems < 3 cm d.b.h. (-0.731), 3 cm ≤ d.b.h. < 8 (-0.879), 8 cm ≤ d.b.h. < 15 (-0.863), total number of conifer stems (-0.911), total number of all trees (0.704), number of aspen stems 3 cm ≤ d.b.h. < 8 (0.916) and total number of aspen stems (0.999).

Northern Flicker. Northern flickers were uncommon on kill sites, and only seven plots on four kill sites were measured. Northern flickers used shrub (57% used, 28% expected) and aspen (28% used, 17% expected) habitats on ridge or hill tops (67% used, 33% expected) with southern aspects (86% used, 43% expected) most often. Northern flickers were associated with edges (mean distance to nearest edge = 41.4 m, s.e. = 22.8, mode = 0 m) (see Table 7).

Sagebrush was the most commonly used shrub (49% used, 19% expected), while sub-alpine fir saplings were used less often (17% used, 37% expected). Ground cover dispersions even (86% used, 38% expected). The most common edge types in use plots were aspen (71% used, 34% expected) and natural openings (28% used, 40% expected). Expected proportions of categorical variables were calculated from 7 plots in 4 sites, and observed values from 36 plots in four sites. All categorical variables in use plots were different from available ($p < 0.03$).

Northern flickers used sites with more open understories than random plots ($n = 4$, seven use plots, 36 random plots). When all plots were included in the analysis use plots had less coverage of ($p < 0.10$) dead herbaceous litter (mean = -41.3%), and logs (mean = -4.9%), and lower coverages of density boards at 0.3 - 1 m (mean = - 16.7 %) and 1 - 2 m (mean = - 23.0 %). Aspen, conifer, snag, and total tree densities were not different from random plots.

Gray Jay. Gray Jays used open conifer forests with few shrubs in the understory (mean number of shrub stems = 38.8, s.e. = 20.9, n = 6 plots) (see Table 8). Gray Jays were found near natural openings (mean distance = 50 m, s.e. = 28.6, mode = 0 m, n = 6 plots). Used plots had more conifer stems 38 cm ≤ d.b.h. < 53 (mean = 1.3 stems / 0.04 ha), 23 cm ≤ d.b.h. < 38 (mean = 0.74 stems / 0.04 ha , $p = 0.077$), fewer total stems 8 cm ≤ d.b.h. < 15 (mean = -29.1 stems / 0.04 ha , p =

0.072) and 23 cm $\leq$ d.b.h. < 38 (mean = -1.8 stems / 0.04 ha, p = 0.096), and were farther from the nearest tree (mean = 0.28 m, p = 0.059) than random plots (n = 4 sites).

Uinta Chipmunk. Twelve uinta chipmunks were captured (seven plots sampled), with eleven captures at one with the highest elevation (2860 m). Uinta chipmunks used sites close to edges (use = 12.1 m, random = 35 m), with low heights to live canopy (use = 4.5 m, random = 8.7 m), and open, rocky understories (see Table 9).

Shrews. Sorex spp. (n = 8 captures) were found most often in aspen forests (63% used, 26% expected) in or near drainages or wet meadows. Shrews were found in sites with much structure from 0-0.3 m (mean = 85%, n = 4) near edges (mean = 20 m, n = 4).

Deer Mice. Deer mice used forests during daylight hours (n = 17 captures, aspen 47% used, 26% expected, and conifer 24% used, 41% expected) and open habitats during the night (n = 110 captures, open 17% used, 6% expected and shrub 40% used, 27% expected). Deer mice used sites closer to edges (n = 12 sites, mean = -12.2 m, p = 0.079) than random plots.

Golden-mantled Ground Squirrels. Golden-mantled ground squirrels were detected in only four sites, and four plots were measured in three sites. Golden-mantled ground squirrels used open, rocky areas such as ridgetops and rocky slopes (n = 3) and a log pile along a road edge (n = 1). Golden-mantled ground squirrels were opportunistically observed on two occasions perched on logs in clearcuts. Used plots were close to edges (mean = 16.3 m, n = 4 plots) and had fruiting shrubs (n = 3 plots, serviceberry (Amelanchier alnifolia), juniper, currant (Ribes spp.).

American Robins. American robins were one of the most commonly detected birds on all sites. I did not measure many use plots due to the generalist nature of the species (n = 6 plots on three sites). American robins used clearcuts (n = 3 plots in one site) and lodgepole (n = 3 plots in two sites). American robin use plots were gentle in slope (mean = 11.5 %) and had relatively low dominant shrub densities (mean = 20). Unusually high numbers of American robins (20 versus 4.9, s.e. 1.2 for all kill sites) were observed during point counts in one site in late mid August. Most robins in that site were observed in lodgepole with scattered large ponderosa pine (> 100 cm dbh) and an understory choked with fruiting buffaloberry. Of important goshawk prey, American robins were most often observed in clearcuts.

Hairy Woodpecker. Hairy woodpeckers (n = 4 plots at four sites) were relatively uncommon except for a few sites. One plot was located on an aspen, grassy meadow edge, two plots in lodgepole, and one in a clearcut. Hairy woodpecker used sites closer to edges (mean = -50.4 m, p = 0.070, n = 3 sites) with lower tree densities (mean = -90.4 stems / 0.04 ha, $p < 0.05$) and more open understories (mean density board coverage at 0 - 0.3 m = -10.4 %, p = 0.089).

For the remaining species at most three, and more commonly only one used plot was measured. Habitat measurements for these species are displayed in Tables 10-12.

Discussion:

The results from my study represent habitat characteristics used by prey species in goshawk kill areas in southcentral Wyoming. Although the habitat needs for the red squirrel are relatively well known (Sullivan and Moses 1986, Rothwell 1977 and 1979, Reynolds et al. 1992), no data exist which describe squirrel habitat use in goshawk kill areas. Additionally, few quantitative data exist for habitat use among other goshawk prey in southcentral Wyoming. Without knowledge of prey habitat needs, especially in areas used by goshawks for hunting, the results of management actions on prey species can not be properly evaluated (Garton et al. 1983).

Red Squirrels. Red squirrels are a species of territorial tree squirrel which inhabit conifer forests in the western United States (Reynolds et al. 1992). Lodgepole pine forests provide a lower quality, but constant food source for red squirrels due to the presence of serotinous cones. Other conifer species, such as most firs, provide more food during mast crop years, but may not produce any seeds during some years (Gurnell 1984). Red squirrels need areas with high canopy coverage to provide escape routes, closer foraging areas, and protection from weather during nesting. Closed canopies also provide good environments for storing seed in caches (Rothwell 1979). Large snags, live trees, and fallen logs help support midden structures (Vahle and Patton 1983). Survival and proportion of females reaching breeding maturity is highest in mature forests (Sullivan and Moses 1986).

Red squirrels in my study used conifer habitats, in particular lodgepole habitats, in greater proportion than their availability. When available, ridge tops were used in greater proportion than available, and natural openings were the most common edge type. Red squirrel abundance was positively related with percent slope. Rothwell (1977) found winter densities of red squirrels to increase after a limber pine mast crop year. Limber pine in our study area was limited to ridge tops and south facing slopes. It was not known if 1996 or 1997 were mast years for limber pine. In mixed-species forests male red squirrels often use ridgetops (Uphoff 1990)

Red squirrels used sites which were closer to downed woody debris, had lower live canopy heights, and fewer mid sized trees (15 cm $\leq$ d.b.h. < 24 cm). Vahle and Patton (1983) suggested large (50.8 cm d.b.h.) downed logs were used as feeding perches in mixed conifer forests in Arizona. Red squirrels in our study used woody debris as runways as well as feeding perches. The size of the nearest woody debris in our study did not differ from random plots, but the average d.b.h. was 12.7 cm.

Red squirrels in our study were found in areas with fewer mid-sized trees (15 cm ≤ d.b.h. < 24 cm) and greater densities of large lodgepole pine (mean = 2.0 stems / 0.04 ha, p = 0.10). When all red squirrel use sites and random plots were summarized, red squirrel plots contained an average of 9.4 conifers 23 cm ≤ d.b.h. < 38 versus 4.9 for random plots. Vahle and Patton (1983) suggested the best conditions for red squirrels in mixed conifer forests were undisturbed sites with one or more large trees for seed production.

Least Chipmunks. Least chipmunks occupy dry habitats throughout the state, and are found in more habitats and elevations than other chipmunks in Wyoming (Clark and Stromberg 1987). Large numbers of chipmunks in the Southwestern United States are found in open forests which receive a lot of sunlight and have many shrubs and logs for lookouts, foraging and nesting (Reynolds et al. 1992).

Least chipmunk abundance was positively related to shrub stem density. In forested plots least chipmunk abundance was negatively related to conifer densities and positively related to aspen densities. In westcentral Colorado least chipmunk densities did not vary between conifer, conifer-aspen, and aspen stands (Scott and Crouch 1988).

Uinta Chipmunk. Uinta chipmunks occur in greatest densities in lodgepole pine to douglas fir with closed canopies and open understories, but also occur in rocky open areas in the Medicine Bow Mountains (Clark and Stromberg 1987). Brown (1971) described the uinta chipmunk as inhabiting coniferous forests in the western United States and preferring open, rocky areas.

Interestingly, uinta chipmunks were only present in sizable numbers on a site with no least chipmunks. In addition, this site was dominated by spruce-fir forests with a few small meadows and a highway. One uinta chipmunk was captured at a site two miles away, but most captures were of least chipmunks. Competitive exclusion determined habitats occupied by Tamias species (including uinta and least chipmunks), resulting in different Tamias species occupying different altitude zones (Brown 1971, Heller 1971, and Sheppard 1971). In Colorado uinta chipmunks occupied open canopy and open understory forests where least chipmunks did not occur (Teleen 1978).

Northern Flicker. Northern Flickers are large bodied woodpeckers which nest primarily in aspen with heart rot or aspen snags, usually near an opening (Reynolds et al. 1992 and Loose 1993). Northern flickers forage in a wide variety of habitat types, from open fields to forests (Reynolds et al. 1992).

Six of the seven observations were located on southern aspects. No authors have reported flickers using southern aspects in greater proportion than expected. Many dry meadows in my study area are found on southern aspects, while northern aspects are more forested.

My results are similar to habitat use described by Loose (1993). He found foraging woodpeckers to avoid lodgepole and prefer aspen in southeastern Wyoming. Loose (1993) did not report any foraging sites in natural meadows, but did observe flickers foraging in clearcuts.

Golden-mantled Ground Squirrel. The golden-mantled ground squirrel occurs in mountain ranges throughout the western United States. Rocky outcrops are a key habitat feature in Wyoming (Clark and Stromberg 1987), but golden-mantled ground squirrels are also found in forested areas (Bartels and Thompson 1993). Golden-mantled ground squirrel remains occur frequently in pellets collected from goshawk nests in southcentral Wyoming (Squires in prep.)

Only four use plots were measured for golden-mantled ground squirrels, which were observed or captured on four sites. Including opportunistic observations, golden-mantled ground squirrels were found in rocky habitats, including outcroppings, as well as disturbed areas, such as roadsides and clearcuts. The presence of berry-producing shrubs may have been important, with serviceberry, juniper and currant being present on three of the four plots. Our results were similar to habitat preferences summarized in Bartels and Thompson (1983) and McKeever (1964).

American Robin. American robins need no certain habitats except forests for nesting (Reynolds et al. 1992). American robin densities are low in clearcuts with no residual trees (Szaro and Balda 1979 cited in Reynolds et al. 1992).

I collected data at six American robin locations. My data should be interpreted with caution, since measurements of use plots were done opportunistically and may be biased. American robins were found in lodgepole (3) and clearcuts (three from one site). All plots were located on gentle slopes and had few shrubs. However, the largest concentrations of American robins (19 at one point count) were observed in mid August in a mixed conifer forest (ponderosa pine, lodgepole pine, and douglas fir) with heavy cover of buffaloberry in the understory. The site was intensively used by a male goshawk. Berries are an important food source for American robins in the fall (Martin et al. 1951).

Hairy Woodpecker. Hairy woodpeckers in southern Wyoming foraged more often in aspen than expected, in clearcuts in proportion to their availability, and less often in open lodgepole. However, the aversion toward open lodgepole may have been due to low sample sizes. Foraging substrates were trees, snags and logs averaging 26.6 cm d.b.h. Most nests were located in aspen (Loose 1993).

Hairy woodpeckers were uncommon on goshawk kill sites, but a total of four use plots were measured on four sites. All observations were of foraging activity. One plot was on an aspen-meadow edge, two in open lodgepole, and one in a clearcut. Hairy woodpecker plots were closer to edges and had less understory structure than random plots.

Gray Jay. No quantitative data were found for habitats used by gray jays. Goodwin (1986) described the gray jay as inhabiting coniferous forests and sometimes openings and nearby deciduous forests. Gray jays in our study used open forests with more large conifers.

Sorex spp. Although not a prey item of northern goshawks, Sorex spp. were captured eight times during the first run of trapping sessions and four habitat use plots were measured. Shrews in my study used aspen habitats in greater proportion than their availability, and the closest edge at capture sites was most often a natural meadow or aspen. Two habitat measurement plots were located in drainages, and one site was adjacent to a wet meadow. Additionally, two shrews were observed in drainages while observing goshawk nests. Brown (1967a) identified wet meadows as one of two habitats containing the highest densities of shrews in southern Wyoming.

Deer Mouse. Deer mice are usually the most abundant mouse in Wyoming and occur in almost all habitats (Clark and Stromberg 1987). In the Medicine Bow Mountains deer mice are most common in sagebrush and mountain mahogany. Deer mice are also common in aspen and least common in willow, lodgepole and spruce-fir (Brown 1967b).

Deer mice in my study were the most commonly captured small mammal during night trapping sessions, however, 17 deer mice were captured during day sessions. All captures were close to edges. During the day deer mice were captured more often in aspen than expected, and less often than expected in open habitats. The opposite was true during night and evening sessions. No authors have examined if habitat use patterns changed with time of day.

Thermoregulation and predation are two possible reasons. Deer mice active during daylight hours may overheat in sagebrush and open areas, restricting them to aspen. Predation could be another explanation. Deer mice were trapped in areas where goshawks, a diurnal predator, had made kills. Small mammals (mouse sized) comprise 17% of identified deliveries to goshawk nests (see Chapter 5). Perhaps the risk of predation by goshawks forces diurnal deer mice to areas where they would not be easily detected.

Summary. The goshawk is an opportunistic predator (Squires and Reynolds 1997). However, red squirrels, golden-mantled ground squirrels, northern flickers, and American robins appear frequently in goshawk pellets during the breeding season in southcentral Wyoming (Squires in prep.). Red Squirrels are often delivered to goshawk nests (see Chapter 5). These four prey species appear to be most important to goshawks in southcentral Wyoming. Additionally, the four prey species are common in the Medicine Bow National Forest.

Goshawk prey in southcentral Wyoming use a variety habitats. Of the four important prey species, red squirrels are the most specific in habitat requirements. Red squirrels are found almost exclusively in conifer or conifer-aspen forests in southcentral Wyoming. The remaining three prey species are more general in habitat requirements. Northern flickers nest in aspen (Loose 1993), but forage in aspen and open areas. American robins occur in several habitats, and require forests or tall shrubs only for nesting (Reynolds et al. 1992). Golden-mantled ground squirrels are found in rocky openings or ledges, but also occur in forests (Bartels and Thompson 1993).

Although goshawk prey use many habitats, some similarities exist between the species. Golden-mantled ground squirrels and northern flickers frequently use natural openings. Red squirrels use forests in which the nearest edge is most frequently a natural meadow.

Additionally, many natural meadows in southcentral Wyoming are bordered by narrow patches of aspen, preferred nesting habitat of woodpeckers in southern Wyoming (Loose 1993). Golden-mantled ground squirrels and American robins are found in habitats with fruiting shrubs, such as currant and buffaloberry.

Habitats used by goshawk prey resembled habitats most often returned to by male goshawks (see Chapter 2). The most striking similarities were between habitats used by goshawks and red squirrels. Goshawks returned most often to kill sites greater densities of large conifers (23 to 38 cm in d.b.h.) and gentler slopes. At the landscape scale goshawks returned most often to kill sites with greater coverages of conifer. Goshawk kill sites had high canopy coverages (mean = 50 %). Red squirrels were found in areas with greater densities of trees 23 to 38 cm in d.b.h. and gentler slopes than random locations in kill sites. Red squirrels used habitats with high canopy coverages (mean = 60 %). Mature forests allowed goshawks to approach prey unseen while allowing maneuverability (Widén 1989, Beier and Drennan 1997, and see Chapter 2).

At the landscape scale, goshawks returned most often to kill sites with greater densities of small natural openings and aspen patches (See Chapter 3). Both golden-mantled ground squirrels and northern flickers use natural openings. Northern flickers also use aspen for nesting (Loose 1993).

Management recommendations. Large coverages of conifer interspersed with small natural openings and aspen patches are areas used most often by goshawks for hunting (see Chapter 3). These areas also support important prey species such as the red squirrel, golden-mantled ground squirrel, woodpeckers, and American robins. Areas with large forest coverages and high densities of small natural openings and aspen patches should be maintained as foraging areas. Clearcuts should not encompass natural openings because goshawks may hunt along natural edges (see Chapter 3). If clearcuts are seeded, small patches of aspen or shrubs should be created.

Our study was the first to examine habitat use by goshawk prey in lodgepole pine forests. More studies are needed to determine: 1) if red squirrel densities increase with greater slopes on other portions of the study area and; 2) what factors cause increased densities, such as limber pine mast crops.

Additionally, more research is needed to determine how prey populations respond to forest fragmentation by clearcuts. Hairy woodpeckers, American robins, and golden-mantled ground squirrels use some clearcuts, but are absent from others. Future studies should determine what features of clearcuts are important to goshawk prey.

Table 1. Number of animals trapped per session in 21 goshawk kill areas during 1996 and 1997 in southcentral Wyoming (percent of session in parentheses).

Species	Run 1*	Run 2**	Run 3*	Grand Total
Deer Mouse	56(44.8)	17(17.5)	110(65.5)	183(46.9)
Golden-mantled Ground Squirrel	0 (0.0)	1 (1.0)	0(0.0)	1(0.26)
Red Squirrel	2(1.6)	0(0.0)	1(0.60)	3(0.77)
Least Chipmunk	36(28.8)	64(66.0)	19(11.3)	119(30.5)
Sorex spp.	8(6.4)	5(5.2)	4(2.4)	17(4.4)
Meadow Vole (_Microtus pennsylvanicus_)	1(0.80)	1(1.0)	4(2.4)	6(1.5)
Mountain Cottontail	0(0.0)	0(0.0)	1(0.60)	1(0.26)
Red-backed Vole	18(14.4)	4(4.1)	23(13.7)	45(11.5)
Short-tailed Weasel (_Mustela erminea_)	0(0.0)	0(0.0)	2(1.2)	2(0.51)
Uinta Chipmunk	4(3.2)	5(5.2)	3(1.8)	12(3.1)
Unknown Mouse	0(0.0)	0(0.0)	1(0.60)	1(.26)
Grand Total	125	97	168	390

* Runs one and three were conducted from 18:00 to 10:00.

** Run two was conducted from 10:00 to 18:00

Table 2. Summary statistics for red squirrel habitat plots measured during 1996 and 1997 in goshawk kill areas in southcentral Wyoming.

Variable	Mean	Confidence Level (95%)	Standard Error	Standard Deviation	Median	Mode	Min	Max	Count
Distance to nearest edge (m)	46.4	15.9	7.8	42.5	45	50	0	150	30
% Slope	23	5.6	2.7	14.8	23	24	5	83	29
Shrub Stems	66.5	33.2	16.2	88.8	39	44	1	458	30
Dominant Shrub Stems	45.2	32.7	16	87.7	17.5	0	0	450	30
Distance to Nearest Tree (m)	2.7	1	0.5	2.7	2.1	3.1	0.6	15.4	30
Nearest Tree Width (cm)	12.7	2.9	1.4	7.7	10.5	10.1	1.1	26.3	30
Distance to Nearest W.D. (m)	1.1	0.3	0.2	0.9	0.8	0.5	0.2	4.5	30
Nearest W.D. Width (cm)	9.5	2.1	1	5.5	8.3	5.8	3.1	27.8	30
Nearest W.D. Length (m)	7.9	2	1	5.4	7.5	10	0.7	18.8	30
% Canopy Coverage	59.9	6.5	3.2	17.3	61.3	70	22.5	87.5	30
% Coverage D.B. 0 - 0.3 m	64.4	9.6	4.7	25.8	68.3	68.3	3.3	100	30
% Coverage D.B. 0.3 - 1 m	47.3	10.3	5	27.5	41.1	5	5	90.7	30
% Coverage D.B. 1 - 2 m	41.9	8.2	4	22	39.3	42	0	80.5	30
% Coverage D.B. 0 - 2 m	40.4	8.2	4	22	39.3	12.3	3.5	94.8	30
Height to Live Canopy (m)	8.4	0.88	0.43	2.3	9.03	10.6	2.7	12.9	30
% Coverage Grass	7	4.3	2.1	11.4	3	0	0	47.5	30
% Coverage Bare Ground	2.5	1.8	0.9	5	0	0	0	18.5	30
% Coverage of Dead Litter	71.8	9.3	4.6	25	75.8	92.5	13	97.5	30
% Coverage of Woody Litter	14.7	4.5	2.2	12.1	13.5	0	0	43.5	30
% Coverage Rock	1.9	2.2	1.1	6	0	0	0	27.5	30
% Coverage Woody Stems	14.7	6.4	3.1	17.2	6	0.5	0	59.5	30
% Coverage Forbes	5.6	2.6	1.3	6.9	4	0	0	26.5	30
% Coverage Woody Debris	9.8	2.9	1.4	7.8	10	0	0	26	30
% Coverage Other	1.9	2	1	5.3	0	0	0	23	30

W.D. = Woody Debris and D.B. = Density Board

Table 3. Summary statistics for conifer size class densities from red squirrel habit plots during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Tree Size Class	Mean	Confidence Level (95.0%)	Standard Deviation	Standard Error	Median	Mode	Min	Max	Sum	Count
< 3 cm d.b.h.	7.5	4.6	13.6	2.3	2	0	0	74	270	36
3 cm ≤ d.b.h. < 8	20.9	9.1	26.8	4.5	10.5	0	0	129	754	36
8 cm ≤ d.b.h. < 15	19.4	9.8	28.9	4.8	12.5	2	0	162	698	36
15 cm ≤ d.b.h. < 23	14.9	5.8	17.2	2.9	10	3	0	88	538	36
23 cm ≤ d.b.h. < 38	9.4	2.6	7.8	1.3	6.5	2	0	26	339	36
38 cm ≤ d.b.h. < 53	1	0.4	1.3	0.2	0	0	0	4	35	36
53 cm ≤ d.b.h. < 69	0.1	0.1	0.2	0	0	0	0	1	2	36
Grand Total	73.2	22.9	67.7	11.3	58	17	0	384	2636	36

Table 4. Logistic regression results ($p < 0.20$) predicting prey use versus random plots in goshawk kill areas in southcentral Wyoming during the breeding seasons of 1996 and 1997.

Prey Species	Variable	Chi-Square value	Chi-Square significance	Variable coefficient	Overall % Correct Classification	Number of cases
Red Squirrel	Canopy coverage (%)	4.102	0.0428	-0.0279	60.34	58
Red Squirrel *	Canopy coverage (%)	2.775	0.0957	-0.0247	60.42	48
Red Squirrel	Distance to edge (m)	1.913	0.1667	-0.0092	63.16	57
Red Squirrel *	Distance to edge (m)	2.559	0.1096	-0.0132	62.50	48
Red Squirrel	Log ground coverage (%)	2.302	0.1292	-0.0488	63.79	58
Red Squirrel	Log length (m)	2.092	0.1481	-0.0810	56.90	58
Red Squirrel *	Percent slope (%)	2.722	0.0990	0.0373	55.32	47
Red Squirrel *	Trees < 3 cm dbh (# stems / 0.04 ha)	2.418	0.1199	0.0353	50.00	50
Least Chipmunk	Canopy coverage (%)	2.651	0.1035	0.0131	58.97	78
Least Chipmunk	Canopy height (m)	5.635	0.0176	0.0575	58.49	53
Least Chipmunk	Distance to edge (m)	1.989	0.1585	0.0066	59.74	77
Least Chipmunk	Distance to nearest log (m)	1.815	0.1780	-0.2089	58.18	55
Least Chipmunk	Distance to nearest tree (m)	2.068	0.1505	-0.2025	51.79	56

* Excluding one site on the Colorado-Wyoming border.

Table 5. Least chipmunk habitat use measurements for all plots during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	Mean	Confidence Level (95.0%)	Standard Error	Median	Mode	Standard Deviation	Min	Max	Count
Distance to nearest edge (m)	34.2	15.6	7.7	15	0	48	0	175	39
% Slope	23.1	3.6	1.8	23	23	11.2	4	46	39
Shrub Stems	230.5	58.5	28.9	188	145	180.3	20	630	39
Dominant Shrub Stems	181.9	58.2	28.7	118	0	177.1	0	614	38
Distance to Nearest Tree (m)	3.1	1	0.5	2.3	#N/A	2.7	0.7	11.2	28
Nearest Tree Width (cm)	9.9	2.7	1.3	10	10	7	0.3	24.5	28
Distance to Nearest Woody Debris (m)	2	0.9	0.4	1.1	#N/A	2.2	0	9.6	27
Nearest Woody Debris Width (cm)	10.8	2.1	1	10	5.3	5.3	3.3	25.5	27
Nearest Woody Debris Length (m)	5.1	1.7	0.8	4	1.5	4.4	0.7	18.9	27
% Canopy Coverage	26.9	8.5	4.2	27.5	0	26.1	0	87.5	39
% Coverage Density Board 0 - .3 m	77.4	7	3.5	80	100	21.7	13.3	100	39
% Coverage Density Board .3 - 1 m	38.7	8.6	4.3	30.7	46.4	26.6	0	97.1	39
% Coverage Density Board 1 - 2 m	24.1	8.6	4.2	19	0	26.5	0	93	39
% Coverage Density Board 0 - 2 m	38.8	7.1	3.5	36.5	23	21.8	3	95.5	39
Height to Live Canopy (m)	6.3	1.2	0.6	6.5	3.1	3.0	1.6	10.7	26
% Coverage Grass	17.3	4.9	2.4	14.5	0	15.3	0	54.5	39
% Coverage Bare Ground	12	5.3	2.6	3.5	0	16.3	0	66.5	39
% Coverage of Dead Litter	29.9	11.3	5.6	13.5	0	34.9	0	97.5	39
% Coverage of Woody Litter	8.2	4.1	2	3.5	0	12.8	0	71	39
% Coverage Rock	7.6	5	2.5	0	0	15.5	0	87.5	39
% Coverage Woody Stems	17.6	5	2.5	16	0	15.5	0	60.5	39
% Coverage Forbes	3.8	1.3	0.7	3	0.5	4.1	0	16	39
% Coverage Buckwheat	2.7	1.6	0.8	0	0	4.8	0	19.5	39
% Coverage Woody Debris	5.9	4.6	2.3	0	0	14.1	0	59.5	39

Table 6. Least chipmunk habitat measurements in forested areas during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	Mean	Confidence Level (95.0%)	Standard Error	Median	Mode	Standard Deviation	Min	Max	Count
Distance to nearest edge (m)	31.1	21.1	10.2	10	0	47.7	0	140	22
Percent Slope	22.3	5.8	2.8	20	15	13	4	46	22
Shrub Stems	188.8	79.7	38.3	117.5	58	179.7	20	630	22
Dominant Shrub Stems	156.5	80.3	38.6	86	0	181.1	0	614	22
Distance to Nearest Tree (m)	2	0.4	0.2	1.9	#N/A	0.8	0.7	3.5	22
Nearest Tree Width (cm)	9.6	2.9	1.4	9.1	5	6.5	1.5	21.5	22
Distance to Nearest Woody Debris (m)	1.5	0.6	0.3	1	#N/A	1.4	0	5.3	22
Nearest Woody Debris Width (cm)	10.3	2.3	1.1	10.3	5.3	5.2	3.3	25.5	22
Nearest Woody Debris Length (m)	5.4	2.1	1	4.1	1.5	4.7	0.7	18.9	22
% Canopy Coverage	45	8.8	4.2	45	55	19.8	5	87.5	22
% Coverage Density Board 0 - 0.3 m	81.7	7.9	3.8	87.5	100	17.7	43.3	100	22
% Coverage Density Board 0.3 - 1 m	53.4	10.8	5.2	49.6	46.4	24.4	17.1	97.1	22
% Coverage Density Board 1 - 2 m	37.9	12	5.8	31.3	#N/A	27.1	3	93	22
% Coverage Density Board 0 - 2 m	38.4	8.7	4.2	38.8	23	19.6	5	95.5	22
Height to Live Canopy (m)	6.8	1.3	0.61	7.4	#N/A	2.9	1.6	10.7	22
% Coverage Grass	15.3	6.5	3.1	10.3	0	14.7	0	43	22
% Coverage Bare Ground	4.7	4.4	2.1	0	0	9.9	0	37	22
% Coverage of Dead Litter	48.8	15.9	7.7	51.8	97.5	35.9	0	97.5	22
% Coverage of Woody Litter	12.9	6.8	3.3	9.5	3.5	15.3	0	71	22
% Coverage Rock	2.4	2.8	1.4	0	0	6.4	0	21.5	22
% Coverage Woody Stems	18.3	7.1	3.4	16	0.5	16	0	60.5	22
% Coverage Forbes	4.6	2.1	1	3	0.5	4.8	0	16	22
% Coverage Buckwheat	0.3	0.4	0.2	0	0	1	0	3.5	22
% Coverage Woody Debris	10.3	8.2	3.9	0.5	0	18	0	59.5	21

Table 7. Summary statistics for northern flicker use plots measured during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	Mean	Confidence Level (95.0%)	Standard Error	Median	Mode	Standard Deviation	Min	Max	Count
Distance to nearest edge (m)	41.4	55.8	22.8	15	0	60.3	0	170	7
Percent Slope	30	23.2	9.5	18	#N/A	25.1	4	74	7
Shrub Stems	208.9	137.8	56.3	288	#N/A	149	8	364	7
Dominant Shrub Stems	133.7	120	49.1	143	0	129.8	0	284	7
Distance to Nearest Tree (m)	3.8	2.7	1	3.2	#N/A	2.6	1	8.6	6
Nearest Tree Width (cm)	14.5	6.2	2.4	14.3	#N/A	5.9	7.3	24.5	6
Distance to Nearest Woody Debris (m)	2.5	1.6	0.6	2.5	#N/A	1.3	1.1	4.4	5
Nearest Woody Debris Width (cm)	9.5	8.5	3.1	7.3	#N/A	6.8	3.5	21	5
Nearest Woody Debris Length (m)	4.7	4.6	1.7	3.4	#N/A	3.7	1.3	10	5
% Canopy Coverage	19.3	23	9.4	7.5	0	24.9	0	60	7
% Coverage Density Board 0 - 0.3 m	71.7	24.1	9.9	76.7	36.7	26.1	36.7	100	7
% Coverage Density Board 0.3 - 1 m	25.2	15.2	6.2	27.1	#N/A	16.4	0	43.6	7
% Coverage Density Board 1 - 2 m	12.8	13.1	5.4	7	0	14.2	0	32.5	7
% Coverage Density Board 0 - 2 m	48.4	26.9	11	61.5	#N/A	29	6.5	83	7
Height to Live Canopy (m)	3.3	2.0	0.7	3.1	#N/A	1.6	0.9	5.2	5
% Coverage Grass	27.1	20.2	8.2	26	26.5	21.8	4	73	7
% Coverage Bare Ground	20.4	22.2	9.1	10.5	#N/A	24	0	59.5	7
% Coverage of Dead Litter	10.5	18	7.4	3.5	3.5	19.5	0	54.5	7
% Coverage of Woody Litter	4.4	3.8	1.5	3	3	4.1	0	10.5	7
% Coverage Rock	12	15.5	6.3	0.5	0	16.7	0	43	7
% Coverage Woody Stems	10	10.2	4.2	3.5	3.5	11	0.5	29.5	7
% Coverage Forbes	4.6	4.6	1.9	3	3	5	0	13.5	7
% Coverage Buckwheat	3.4	4.6	1.9	0.5	0	5	0	12.5	7
% Coverage Woody Debris	1.8	4.4	1.8	0	0	4.7	0	12.5	7

Table 8. Summary statistics for gray jay habitat use plots measured during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	Mean	Confidence Level (95.0%)	Standard Error	Median	Mode	Standard Deviation	Min	Max	Count
Distance to nearest edge (m)	50	73.6	28.6	10	10	70.1	0	150	6
% Slope	23.3	12.3	4.8	25	#N/A	11.7	4	35	6
Shrub Stems	38.8	53.8	20.9	15.5	#N/A	51.3	0	129	6
Dominant Shrub Stems	38.8	53.8	20.9	15.5	#N/A	51.3	0	129	6
Distance to Nearest Tree (m)	3.4	1.3	0.5	3.3	#N/A	1.2	1.7	4.8	6
Nearest Tree Width (cm)	18.4	7.8	3	17.1	#N/A	7.4	10.1	31.8	6
Distance to Nearest Woody Debris (m)	2.8	2.9	1.1	1.9	#N/A	2.8	0.9	8.3	6
Nearest Woody Debris Width (cm)	11	3.3	1.3	11.4	#N/A	3.2	7	13.9	6
Nearest Woody Debris Length (m)	5.9	4.9	1.9	4.4	#N/A	4.7	1.9	14	6
% Canopy Coverage	50.4	21.3	8.3	50	#N/A	20.3	17.5	72.5	6
% Coverage Density Board 0 - 0.3 m	64.4	15.7	6.1	67.5	#N/A	15	36.7	80	6
% Coverage Density Board 0.3 - 1 m	45	20.4	7.9	45	#N/A	19.5	21.4	72.9	6
% Coverage Density Board 1 - 2 m	39.4	13.1	5.1	41.8	#N/A	12.5	23.5	51.5	6
% Coverage Density Board 0 - 2 m	28.9	28.6	11.1	20.9	#N/A	27.2	3.5	82	6
Height to Live Canopy (m)	5.0	3.4	1.3	4.7	#N/A	3.2	0.7	8.6	6
% Coverage Grass	2.3	4.3	1.7	0	0	4.1	0	10	6
% Coverage Bare Ground	3.1	7.7	3	0	0	7.3	0	18	6
% Coverage of Dead Litter	50.7	25.8	10	56	#N/A	24.6	3	71	6
% Coverage of Woody Litter	24.2	12.6	4.9	18	18	12	14.5	45	6
% Coverage Rock	5.6	12.6	4.9	0.3	0	12	0	30	6
% Coverage Woody Stems	25.7	23.3	9.1	22.5	#N/A	22.2	4.5	60	6
% Coverage Forbes	9.9	14.8	5.7	4.3	#N/A	14.1	0.5	37.5	6
% Coverage Buckwheat	4.2	10.5	4.1	0	0	10	0	24.5	6
% Coverage Woody Debris	4.9	10.9	4.2	0.3	0	10.4	0	26	6

Table 9. Summary statistics for uinta chipmunk habitat plots during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	Mean	Confidence Level (95.0%)	Standard Error	Median	Mode	Standard Deviation	Min	Max	Count
Distance to nearest edge (m)	13.1	13.8	5.8	7.5	5	16.5	0	50	8
Percent Slope	23.3	7.1	3	25	13	8.5	13	36	8
Shrub Stems	31	46.5	19.7	7	6	55.7	2	166	8
Dominant Shrub Stems	20.6	42.1	17.8	3	0	50.4	0	145	8
Distance to Nearest Tree (m)	3.1	1.4	0.6	3	#N/A	1.6	1.1	5.3	8
Nearest Tree Width (cm)	19	11.6	4.9	12	#N/A	13.9	4.6	44	8
Distance to Nearest Woody Debris (m)	2.9	1.4	0.6	3.2	#N/A	1.7	0.8	5.8	8
Nearest Woody Debris Width (cm)	10.7	5.5	2.3	8.7	7	6.6	3.8	21.5	8
Nearest Woody Debris Length (m)	5	3.4	1.5	3.9	#N/A	4.1	1	11.2	8
% Canopy Coverage	45.9	12.8	5.4	50	57.5	15.3	15	60	8
% Coverage Density Board 0 - 0.3 m	48.1	20.1	8.5	44.2	#N/A	24.1	21.7	98.3	8
% Coverage Density Board 0.3 - 1 m	29.8	21	8.9	21.1	#N/A	25.1	2.9	78.6	8
% Coverage Density Board 1 - 2 m	24.1	18.8	7.9	16.8	#N/A	22.5	5.5	72.5	8
% Coverage Density Board 0 - 2 m	43.3	12	5.1	48.4	53.3	14.4	19	56.3	8
Height to Live Canopy (m)	4.1	1.4	0.6	4.3	#N/A	1.7	1.6	6.6	8
% Coverage Grass	2	1.7	0.7	1.3	0.5	2	0	6	8
% Coverage Bare Ground	4.9	5.6	2.4	0.5	0	6.7	0	15.5	8
% Coverage of Dead Litter	44.3	21	8.9	48.3	10.5	25.1	10.5	78.5	8
% Coverage of Woody Litter	15.6	11.5	4.9	15	#N/A	13.8	0	42.5	8
% Coverage Rock	11.6	9.3	3.9	10.8	3.5	11.1	0	28.5	8
% Coverage Woody Stems	17.4	13.1	5.5	16.3	25	15.6	0	38.5	8
% Coverage Forbes	8.8	6.1	2.6	8.5	8.5	7.2	0	20.5	8
% Coverage Buckwheat	0	0	0	0	0	0	0	0	8
% Coverage Woody Debris	2.7	4.5	1.9	0	0	5.4	0	15.5	8

Table 10. Habitat characteristics for selected bird and mammal species measured during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Species *	Habitat	Topographic Position	Aspect	Dominant Shrub	Shrub Dispersion	Ground Dispersion	Distance to edge (m)	Edge Type	Percent Slope
COTT	Conifer	Drainage	S	Sub-alpine Fir	clumped	clumped	5	Stream	11
DEJU	Shrub		S	Sagebrush	even	even	25	Aspen	29
DOWO	Aspen		S	Snowberry	clumped	clumped	5	Natural Opening	8
EPID	Open	Gentle Slope	N	Lodgepole	even	even	60	Lodgepole	9
GTTO	Conifer	Ridge Top	N	Buffaloberry	clumped	clumped	0	Natural Opening	33
GTTO	Shrub		S	Sagebrush	even	even	25	Aspen	34
GTTO	Shrub	Ridge Top	W	Sagebrush	clumped	even	30	Aspen	9
HETH	Conifer	Moderate Slope	E	Sub-alpine Fir	clumped	clumped	80	Natural Opening	17
HETH	Aspen	Drainage	N	Aspen	even	clumped	35	Clearcut	23
LISP	Aspen		S	Lodgepole	clumped	even	0	Natural Opening	5
RBNU	Conifer	Drainage	S	Sub-alpine Fir	clumped	clumped	25	Aspen	17
RECR	Conifer	Gentle Slope	W	Aspen	random	clumped	100	Natural Opening	3
WAVI	Open	Drainage	W	Alder	clumped	even	20	Aspen	0
WETA	Aspen	Drainage	S	Snowberry	clumped	clumped	4	Aspen	11
WWPE	Aspen		S	Lodgepole	clumped	even	10	Natural Opening	9

* Codes are described on Table 12.

Table 11. Habitat measurements for selected species** during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Variable	COTT	DEJU	DOWO	EPID	GTTO *	HETH *	LISP	RBNU	RECR	WAVI	WETA	WWPE
Shrub Stems	46	367	110	113	389	34	5	23	48	24	645	50
Dominant Shrub Stems	46	285	110	21	367	11	3	9	2	21	550	46
Distance to Nearest Tree (m)	0.9	0	2.4	4.8	3.1	1.8	0.9	2.9	2.4	0.3	5.7	0.9
Nearest Tree Width (cm)	3.5	0	19.8	1	12.6	7.7	6.9	22.9	14.2	2.5	7.3	15.1
Distance to Nearest W.D. (m)	0.6	0	0.1	0.4	1.1	1.7	4.5	1.3	1.2	0	6.9	0.6
Nearest W.D. Width (cm)	8.8	0	2.8	17.4	3.3	8.2	3.6	3.5	8.1	0	3.6	1.9
Nearest W.D. Length (m)	5.5	0	9.2	3.2	0.4	1.6	3.4	1.4	5.4	0	2.1	1.1
% Canopy Coverage	75	0	30	0	15.8	45	32.5	42.5	52.5	0	7.5	52.5
% Coverage D.B. 0 - 0.3 m	95	65	91.7	75	100	59.2	91.7	33.3	41.7	73.3	88.3	78.3
% Coverage D.B. 0.3 - 1 m	80.7	9.3	40.7	20	53.8	33.6	25.7	20	38.6	25	37.9	54.3
% Coverage D.B. 1 - 2 m	54.5	0	22.5	0	23	51.5	25	20.5	32.5	17.5	20	43.5
% Coverage D.B. 0 - 2 m	28.8	7.8	14.8	18.3	17.9	69.4	35.3	21.3	36	28.5	82.3	52.5
Height to Live Canopy (m)	6.6	0	7.0	0	2.3	8.3	0.8	9.0	7.9	0	3.1	9.1
% Coverage Grass	4.5	43	43	15	18.7	1.8	39.5	0	13.8	56.5	25.5	6
% Coverage Bare Ground	12.5	18.5	7	0	6	0	0	0	0	3.5	6	0
% Coverage Dead Litter	66.5	0.5	0	3	24.8	52	25.5	56	62.5	0	0.5	78.5
% Coverage Woody Litter	16.5	0	4	0	16.3	16.3	0	4	23	0	0	30.5
% Coverage Rock	0	15	0	0	3.5	0.3	0	0.5	0	17	3	0.5
% Coverage Woody Stems	17	45	0.5	4	30.7	23	0	13.5	0	3	28.5	0.5
% Coverage Forbes	0.5	0	0.5	0	4	10.5	55	1.5	7.5	9.5	0	14.5
% Coverage Buckwheat	0	12.5	0	0	5.2	0	7.5	0	0	0	12.5	0
% Coverage Woody Debris	3	0	0.5	52	2	3	0	0	3.8	0	0	0
% Coverage Other	0.5	0	0	0	0.2	19.8	3	19.5	0	0	0	0

W.D. = Woody Debris and D.B. = Density Board. * GTTO is shown as the average of 3 plots and HETH the average of 2 plots.

** Codes are described on Table 12

Table 12. Size classes of all trees found within prey** habitat use plots measured during 1996 and 1997 in goshawk kill areas of southcentral Wyoming.

Species	COTT	DOWO	GTTO *	HETH *	LISP	RECR	SWTH	WAVI	WETA	WWPE
< 3 cm d.b.h.	28	1	1.5	27	60	8	7	21	6	25
3 cm ≤ d.b.h. < 8	59	4	4.5	41	103	2	2	15	7	20
8 cm ≤ d.b.h. < 15	23	21	5	12	1	5	14	0	22	20
15 cm ≤ d.b.h. < 23	21	31	8	7	0	3	28	0	1	28
23 cm ≤ d.b.h. < 38	4	7	2.5	6	0	0	5	0	0	8
38 cm ≤ d.b.h. < 53	0	0	0	1.5	0	0	0	0	0	0
Grand Total	135	64	21.5	94.5	164	18	56	36	36	101

* GTTO and HETH are the average of 2 plots.

** Codes are described on Table 12.

Table 13. Key to codes used in Tables 9-11.

Code	Common Name
COTT	Mountain Cottontail
DEJU	Dark-eyed Junco
DOWO	Downey Woodpecker
EPID	Empidonax spp.
GTTO	Green-tailed Towhee
HETH	Hermit Thrush
LISP	Lincoln's Sparrow
RBNU	Red-breasted Nuthatch
RECR	Red Crossbill
WAVI	Warbling Vireo
WETA	Western Tanager
WWPE	Western Wood-peewee

Literature Cited

Bartels, M.A., and D.P. Thompson. 1993. Spermophilus lateralis. Mammalian Species no. 440: 1-8.

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7: 564-571.

Boal, C.W. and R.W. Mannan. 1994. Northern goshawk diets in ponderosa pine forests of the Kaibab Plateau. Studies in Avian Biology no. 16: 97-102.

Brown, L.N. 1967a. Ecological distribution of six species of shrews and comparison of sampling methods in the Central Rocky Mountains. Journal of Mammalogy 48(4): 617-623.

Brown, J.H. 1967b. Ecological distribution of mice in the Medicine Bow Mountains of Wyoming. Ecology 48(4): 677-680.

Brown, J.H. 1971. Mechanisms of competitive exclusion between two species of chipmunks. Ecology 52(2): 305-311.

Clark, T.W., V.A. Saab, and D. Casey. 1980. A partial bibliography of Wyoming mammals. Northwest Science 54(1): 55-67.

Clark, T.W. and M.R. Stromberg. 1987. Mammals in Wyoming. University Press, Lawrence, Kansas.

Doyle, F.I. and J.M.N. Smith 1994. Population responses of northern goshawks to 10-year cycle in numbers of snowshoe hares. Studies in Avian Biology no. 16: 122-129.

Garton, E.O., P.H. Hayward and G.D. Hayward. 1989. Management of prey habitats and populations. National Wildlife Federation Scientific and Technical Series no. 12: 298-304.

Goodwin, D. 1986. Crows of the World. The British Museum (Natural History), Suffolk, England.

Gurnell, J. 1984. Home range, territoriality, caching behavior and food supply of the red squirrel (Tamiasciurus hudsonicus) in a sub-alpine lodgepole pine forest. Animal Behavior 32: 1119-1131.

Heller, H.C. 1971. Altitudinal zonation of chipmunks (Eutamias): interspecific aggression. Ecology 52(2): 312-319.

James, F.C., and H.H. Shugart. 1970. A quantitative method of habitat description. Audubon Field Notes 24(6): 727-736.

Lindén, H. and M. Wikman. 1983. Goshawk predation on tetraonids: availability of prey and diet of the predator during the breeding season. Journal of Animal Ecology 52: 953-968.

Loose, S.S. 1993. Woodpecker habitat use in the forests of southeast Wyoming. Master's Thesis, University of Wyoming, Laramie.

Martin, A.C, H.S. Simm and A.L. Nelson. 1951. American Wildlife and Plants, A Guide to Wildlife Food Habits. Dover Publications, Inc., New York.

McKeever, S. 1964. Biology of the golden-mantled ground squirrel. Ecological Monographs 34(4): 383-401.

Noon, B.R. 1980. Techniques for sampling avian habitats. Forest Service General Technical Report RM-82: 42-52.

Reynolds, R.T., R.T. Grahm, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. U.S.D.A. Forest Service General technical Report RM-217. Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado.

Rothwell, R. 1977. The effects of forest type and mast crop on winter territories and populations of red squirrels (Tamiasciurus hudsonicus baileyii) in the Laramie Range of southeastern. Master's Thesis, University of Wyoming, Laramie.

Rothwell, R. 1979. Nest sites of red squirrels (Tamiasciurus hudsonicus) in the Laramie Range of southeastern Wyoming. Journal of Mammalogy 60(2): 404-405.

Scott, V.E., and G.L. Crouch. 1988. Summer birds and mammals of aspen-conifer forests in westcentral Colorado. Research Paper RM-280. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station. 6p.

Sheppard, D.H. 1971. Competition between two chipmunk species (Eutamias). Ecology 52(2): 320-329

Squires, J.R. 1998. Food habits of goshawks in southcentral Wyoming. In prep.

Sullivan, T.P. and R.A. Moses. 1986. Red squirrel densities in natural and managed stands of lodgepole pine. Journal of Wildlife Management 50(4): 595-601.

Szaro, R.C., and R. Balda. 1979. Effects of harvesting ponderosa pine on nongame populations. Research Paper RM-212. Fort Collins, Colorado: U.S. Department of Agriculture,Forest Service, Rocky Mountain Forest and Range Experimental Station. 8p.

Telleen, S.L. 1978. Stuctural niches of Eutamias minimus and E. umbrinus in Rocky Mountain National Park. Master's Thesis, University of Colorado, Boulder.

Uphoff, K.C. 1990. Habitat use and reproductive ecology of red squirrels (Tamiasciurus hudsonicus) in central Arizona. Master's Thesis, Arizona State University, Tempe, Arizona.

Vahle, J.R. and D.R. Patton. 1983. Red squirrel cover requirements in Arizona mixed conifer forests. Journal of Forestry 81(1): 14-15.

Ward, J.M., and P.L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile northern goshawks. Auk 113: 200-208.

Widén, P. 1989. The hunting habitats of goshawks Accipiter gentilis in boreal forests of central Sweden. Ibis 131: 205-231.

Chapter 5 - Goshawk nest observations in southcentral Wyoming

Introduction:

Most northern goshawks (Accipiter gentilis) breeding in southcentral Wyoming are migratory, wintering in Colorado mountainous areas as well as southern Utah (Squires and Ruggerio 1995). Goshawks return from wintering areas between 23 March and 12 April (Squires and Ruggerio 1995), with nest construction beginning shortly afterward (McGowan 1975). Copulation occurs 30-40 days prior to egg laying, as well as immediately before laying (Squires and Reynolds 1997). Females may choose nest sites and do the majority of incubating while males provide food to the female and young throughout the breeding season (Squires and Reynolds 1997). Females may help to provision the nest during late nestling stages (Palmer 1988), but males continue to provide the majority of the food (Squires and Reynolds 1997).

Food habits of northern goshawks (Accipiter gentilis) have been well studied (Zachel 1985, Boal and Mannan 1994, Reynolds et al. 1994, Kennedy 1991, Bull and Hohman 1994, Reynolds and Meslow 1984, Doyle and Smith 1994, Schnell 1958, Squires in prep.), however, fewer studies have described adult behavior at the nest during breeding (Schnell 1958, Boal 1994a, Boal 1994b, Zirrer 1947, Lee 1981, Allen 1978). As part of a goshawk habitat use study in southcentral Wyoming (see Chapter 2) I monitored nests to confirm prey deliveries by males through the nestling and fledgling stages.

Our objectives were to:

1) Confirm and identify prey deliveries to goshawk nests by adults.

2) Describe behavioral characteristics of nesting goshawks and their young.

Methods:

Nest observations were conducted in conjunction with an adult habitat use study (see Chapter 2). Both male and female goshawk movements were monitored with radio telemetry. Nest observations were conducted concurrently with radio tracking so that prey deliveries to nests by male goshawks could be confirmed. All nests were observed from camouflage hunting blinds placed on the ground. Blinds were placed as far away from the nest as possible while allowing a clear view of the nest (approximately 50 m). Observations were conducted with a 20x-60x spotting scope and field glasses.

A total of eight nests were monitored during the summers of 1996 and 1997. Nests were chosen for observation: 1) if the territory had not been tracked in previous years of the study and; 2) if topography surrounding nests allowed efficient radio-tracking. Observations were conducted from 29 June 1996 to 14 August 1996 and 27 June 1997 to 13 August 1997. Observations spanned the time nestlings or young goshawks were approximately 8 to 62 days old during 1996 and 1997. During 1996 two nests were not followed for the entire breeding season. One nest was observed only twice before it failed on 25 June 1996. Nest observations were halted by 31 July 1996 at a second nest due to a lack of prey deliveries by the male after six days of observation. All nests observed in 1997 were followed through the nestling and fledgling phases. Nests were observed at least once every two weeks (sometimes more) from dawn until the male had delivered food at least once. Nest observations were also conducted during afternoons and evenings preceding morning observations until male goshawks delivered prey or roosted for the night. Length of observations averaged six hours, with a total of 295 observation hours over two years.

During observations, all prey deliveries were classified as made by the male, female, or unknown. The type of prey and feeding time were recorded when possible. Male deliveries were identified by monitoring male movements and determining if he had visited the nest stand within approximately 30 minutes of the delivery, or if he was heard or observed at the nest during the delivery. Deliveries were attributed to females when 1) males did not appear to be hunting prior to the delivery and 2) the male had not visited the nest stand within 30 minutes of the delivery. Deliveries observed when radio-tracking was not conducted were given unknown designation. After the young had fledged and were being provisioned by the adults away from the nest, deliveries were confirmed by sound and verification was attempted visually. Audio confirmations consisted of 1) presence of an adult near the juveniles verified by radio telemetry and 2) intense begging by the juveniles which ended in one to two minutes.

Adult and nestling behavior were documented every two to five minutes. Adult males and females were differentiated at the nest by relative size and radio telemetry. Nest observers were in radio contact with telemetry personnel, so they could verify the presence of telemetered birds at the nest. After young had fledged, the observer kept within hearing distance of the young and behavior was noted opportunistically. Nestling ages were approximated through observations conducted around hatching dates and by aging nestlings during banding operations. All ages were reported as midpoints of five day intervals.

Results and Discussion:

Brooding activity and roost locations. The first observations were conducted when nestlings were approximately eight days old. Two females were observed brooding young during three days of observation. Nestlings were approximately 11, 12 and 27 days old during brooding events. Males did not brood during nest observations. During one observation a female brooded 27 day old chicks during a short rain storm. Boal (1994a) reported brooding behavior by goshawks to end when nestlings were 12-14 days old.

Blinds were often entered at the beginning of or shortly after dawn, not allowing observers to note roost locations of females and fledged young. A female was observed roosting at the nest when nestlings were approximately 21 days old. A juvenile at a different nest was observed roosting at the nest (age approximately 37 days) after it had fledged. Schnell (1958) reported a female goshawk roosting at the nest when brooding the young during the night.

Time of first activity. Most activity began around sunrise. The earliest activity of an adult goshawk was movement by a female goshawk at 5:32 (first light). Prey deliveries were observed as early as 6:24. The earliest activity by a nestling was movement at 5:23 (first light). Nestlings were observed feeding as early as 5:37. Nestlings were stretching or preening by 6:00, and nestlings were more active when the nest was sunlit. Median prey delivery time for males and females was 10:30, however, most deliveries occurred between 7:00 - 8:00 and 8:00 - 9:00. The frequency of deliveries declined during the afternoon, but peaked again between 18:00 and 19:00 (see Fig. 1). Schnell (1958) reported activity beginning at first light, with deliveries peaking from 6:00 to 7:00. Squires and Reynolds (1997) reported deliveries to occur throughout the day, with peaks during early morning, midmorning and late afternoon and evening.

Nest Maintenance. Two nests were decorated with fresh pine needles and aspen leaves. One adult female was observed re-arranging greenery (fresh pine needles or aspen leaves) and placing sticks from other trees in the nest (nestling age = 27 days). Two nests were partially and totally fallen out of the nest tree (nestling age 55 and 45 respectively). The young had fledged by the time of nest degradation, and the nests were not rebuilt immediately. One nest which partially fell was rebuilt the next summer. Schnell (1958) observed a female placing greenery on the nest during the nestling stage.

Prey transfers and intraspecific aggression. Prey items were transferred from the male to the female away from the nest on three occasions during the nestling stage. The male delivered prey directly to the nest on seven occasions during the nestling stage. In all seven cases the female was not at the nest during the delivery. Males left immediately after delivering prey, but one male stood on the nest rim for 30 seconds until the female returned. Females were aggressive toward males during food deliveries at nests, giving dismissal calls and alarm calls. On one occasion a male attempted to land on the nest with prey, but the female appeared to block his attempt and gave an alarm call. Aggression of females toward males was noted by Schnell (1958), who suggested aggressive actions could be a way to increase male delivery rates.

After the young had fledged, four deliveries on four separate days occurred directly at nests. Juveniles were present at the nest prior to the delivery on two occasions. The ages of juveniles were 45, 45 46 and 55 days. Prey items were also delivered away from the nest on eight occasions (ages were 39, 49, 53, 55, 46, 37, 61, 62). Distance of the prey transfer to nests varied from 25 m to 400 m. Most transfers were within 125 m. Squires and Reynolds (1997) reported adults feeding fledglings away from the nest and Boal (1994a) described adults as providing food away from the nest at 45 days post-hatch.

Behavioral development of young. Only females were observed feeding nestlings. Nestlings were fed by females from ages eight to 43 days. Nestlings fed themselves as they aged, the earliest being 20 days. The female did the majority of feeding (90 %) until approximately 26 to 27 days. Schnell (1958) observed a female feeding young until 25 days after hatching.

Nestlings flapped their wings as early as 20 days of age, and were observed jumping and flapping as early as 23 days of age. Boal (1994a) observed nestlings beating their wings for three to five seconds at 19 days of age.

Young fledged (were located away from nest tree) by approximately 36, 37, 38, 45, 45, and 55 days post-hatch. No attempt was made to determine the sex of fledglings. Most fledging dates are overestimates and fledging occurred between observations. However, young at one nest had not fledged by 43 days. Boal (1994a) reported male juveniles to fledge as early as 36 days and females by 42 days.

Juveniles were provisioned by adults up to 62 days post-hatch. Adults may have provisioned juveniles longer, but observations were not conducted past 62 days.

Male and female prey deliveries. A total of 69 deliveries were observed during 1996 and 1997. Males made 42 deliveries, females 17 deliveries, and on 10 deliveries I was unable to determine which adult made the delivery. Of known deliveries, males made 71% of the deliveries and females 29%. Females delivered more frequently than males at two nests. At one nest the male made no deliveries and the female made at least five deliveries during six days of observations. At the other nest the male made two deliveries and the female three deliveries during seven days of observation. Other investigators reported males providing the majority of food to nests (Zachel 1985, Schnell 1958, Younk and Bechard 1994). Zachel (1985) reported two females providing 12.1% and 8.8% of food delivered to nests. Schnell (1958) reported a female providing 15% of food to the nest. Younk and Bechard (1994) found females to not provide any food during the nestling stage. Our results indicate females provide much more food to nests in southcentral Wyoming than do female goshawks in other regions. The number of female deliveries may be artificially high. It was difficult to determine if females were hunting or simply retrieving a cache. However, one of our nests was provisioned entirely by the female during six days of observation. Additionally, I had the advantage of confirming the presence of male goshawks in the area using radio telemetry.

Ward and Kennedy (1996) found females at nests supplemented experimentally with food remained in the nest area more often than females at control nests. Female goshawks at control nests may have spent more time hunting. I suggest males in southcentral Wyoming had difficulty capturing prey, forcing females to spend more time hunting.

Prey delivery rates. The number of deliveries by male and female goshawks was 0.23 per hour. Delivery rates varied between nests (see Table 1). Our prey delivery rate (0.23 items/hr, n = 69), was slightly lower than delivery rates reported for Arizona (0.25 items /hr, n = 381 deliveries, Boal and Mannan 1994) and Nevada (0.31 items/hr, n = 51 deliveries, Younk and Bechard 1994). Squire and Reynolds (1997) suggested deliveries per hour have limited interpretation due to variability in prey mass.

Male delivery rates peaked early in the nestling stage, drop during the middle, and peak again near the end of the fledgling stage (see Fig. 2). Unknown delivery rates were low early and high when male delivery rates were lowest (see Fig. 3), explaining the drop in male delivery rates from 28 - 37 and 38 - 47 days. Total delivery rates (male, female and unknown) peaked during early nestling stages, dropped slightly during middle stages, and peaked again later (see

Fig. 4). Male and female delivery rates were 0.14 items / hr and 0.06 items / hr respectively. Møller (1987) described males as delivering prey to the female through incubation and early nestling stages at a constant rate.

Female delivery rates were low, but peaked early and declined as the young aged and male delivery rates increased (see Fig. 2). Male and female delivery rates were weakly correlated ($n = 8, r = 0.147$) using all goshawks. The goshawks at the Angel Creek nest were outliers, having the highest delivery rates for males and females (see Table 1). Without Angel Creek male and female delivery rates were negatively correlated ($n = 7, r = -0.763$). The relationship was significant using simple linear regression (see Fig. 5). I agree with Ward and Kennedy (1996) and Squires and Reynolds (1997), who suggested female foraging activities were related to male delivery rates.

Food habits. Few deliveries were identified to species. Red squirrels, unknown birds and chipmunks or ground squirrels were most often delivered (see Table 2). Percent biomass was not calculated due to the low number of deliveries identified to species.

Birds comprised 20% and mammals 80% of identified deliveries ($n = 38$ deliveries). This is one of the lowest proportion of birds described in breeding goshawk diets. Lee (1981), Zachel (1985), and Boal and Mannan (1994) reported avian prey items (percent frequency) comprising 18%, 21%, and 24% of goshawk diets while nesting. Percentages of avian prey by biomass in goshawk diets are lower. Zachel (1985), Boal and Mannan (1994) and Doyle and Smith (1994) reported 10%, 6% and 13% respectively. Other investigators reported avian prey to comprise (percent frequencies) 32%, 38%, 68%, 51%, 61%, 59%, and 55% of goshawk breeding season diets (Younk and Bechard 1994, Reynolds et al. 1994, Bloom et al. 1986, Kennedy 1991, Gryzbowski and Eaton 1976, Bull and Hohman 1994, Reynolds and Meslow

1984) . Only two studies which reported percent avian prey in goshawk diets were conducted using nest observations (Boal and Mannan 1994, Younk and Bechard 1994).

Direct observation of raptor nests is the most accurate and unbiased assessment of raptor diets, although some problems exist (Boal and Mannan 1994). Boal and Mannan (1994) describe the probability of identifying prey types brought to nests as not being equal because prey are often plucked or pelage removed before delivery. Ground squirrels are often delivered to nests intact, while birds are often plucked (Younk and Bechard 1994). This bias may be especially important when nests are observed from the ground. In our study mammalian prey were often delivered intact, while avian prey were plucked. Unknown prey types comprised 45 % of nest deliveries. Avian prey may have comprised the majority of deliveries which were not identified.

Observation dates were divided into three time periods (6/27 - 7/14, 7/15 - 7/31, and 8/4 - 8/13). Delivery rates of prey types were plotted against time periods and nestling age (see Fig. 6 and 7). Delivery rates of birds were low and decreased as the breeding season progressed. Mammal, red squirrel and unknown delivery rates peaked early, dropped during the middle of the season, and peaked again toward the end of the season. Wikman and Tarsa (1980, cited in Squires and Reynolds 1997) and Marquiss and Newton (1982) suggested goshawk diet diversity may increase during the nestling stage when juvenile birds are available. Although I could not determine if the birds delivered to goshawk nests were juveniles, I found avian prey were more often delivered during the early and middle nestling stages.

Conclusions:

Male northern goshawks in southcentral Wyoming delivered prey less frequently than other populations, however females delivered more often when compared to other populations (Boal and Mannan 1994, Younk and Bechard 1994, Zachel 1985, Schnell 1958). Male and female delivery rates were negatively correlated.

Ward and Kennedy (1996) found females spent more time at nests experimentally supplemented with food, whereas females at control nests were found less often in nest areas, presumably hunting. Higher nestling survival rates at treatment nests was attributed to females spending more time guarding nestlings against predation. Considering the high percentage of food provided by females in southcentral Wyoming, prey availability may have been low.

Adult and juvenile nest behavior were similar to behaviors described by Schnell (1958) and Boal (1994a). Red squirrels were the prey item most often delivered to nests. Avian prey made up a small portion of goshawk diets; however, nest observations may have been biased due to different plucking rates of mammals and birds.

Further research should determine if plucking rates vary between birds and mammals. Until potential biases are known blinds should be placed in trees during nest observations if diets are to be quantified.

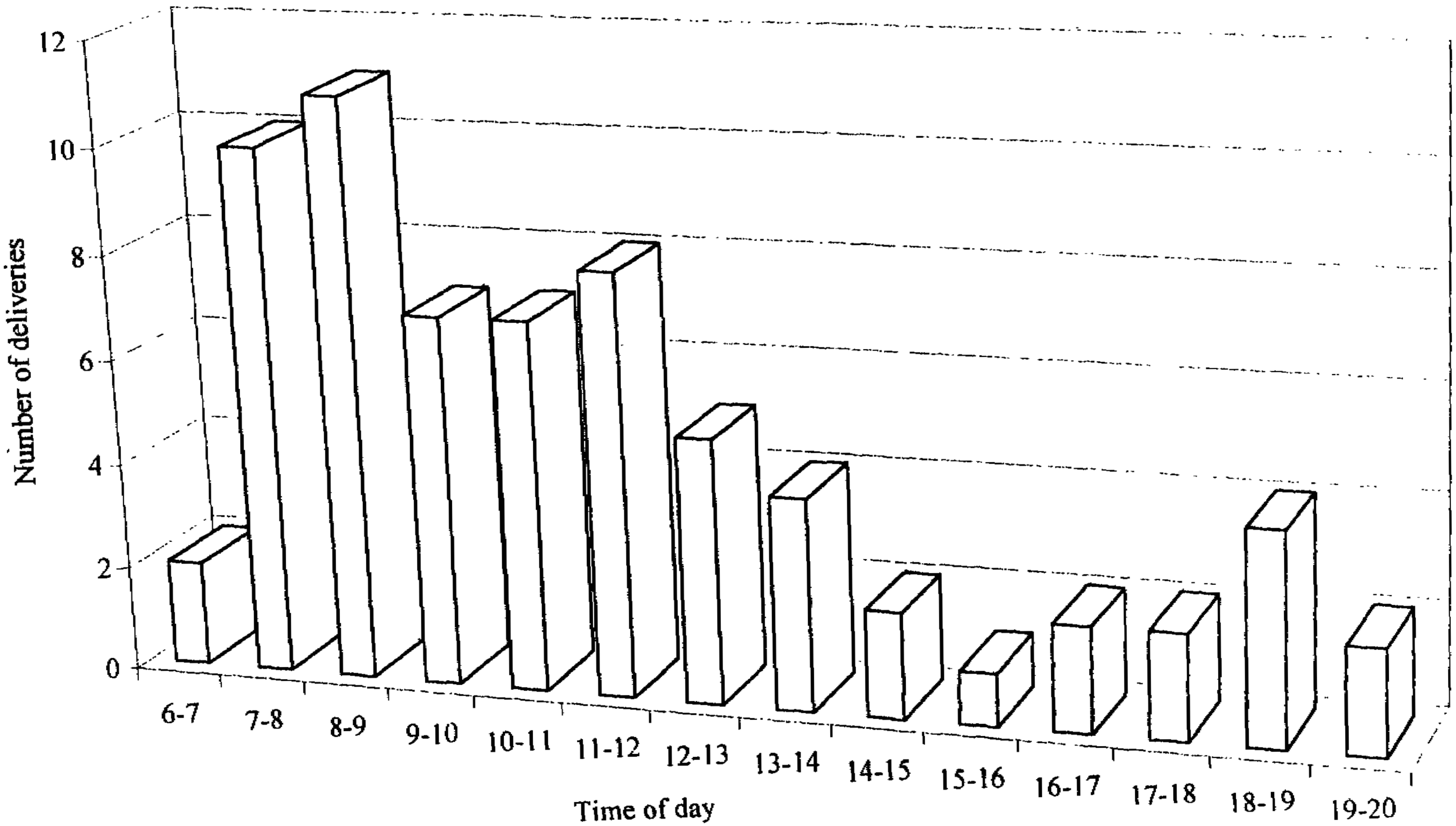

Figure 1. Distribution of male and female prey delivery times for nesting goshawks in southcentral Wyoming during 1996 and 1997.

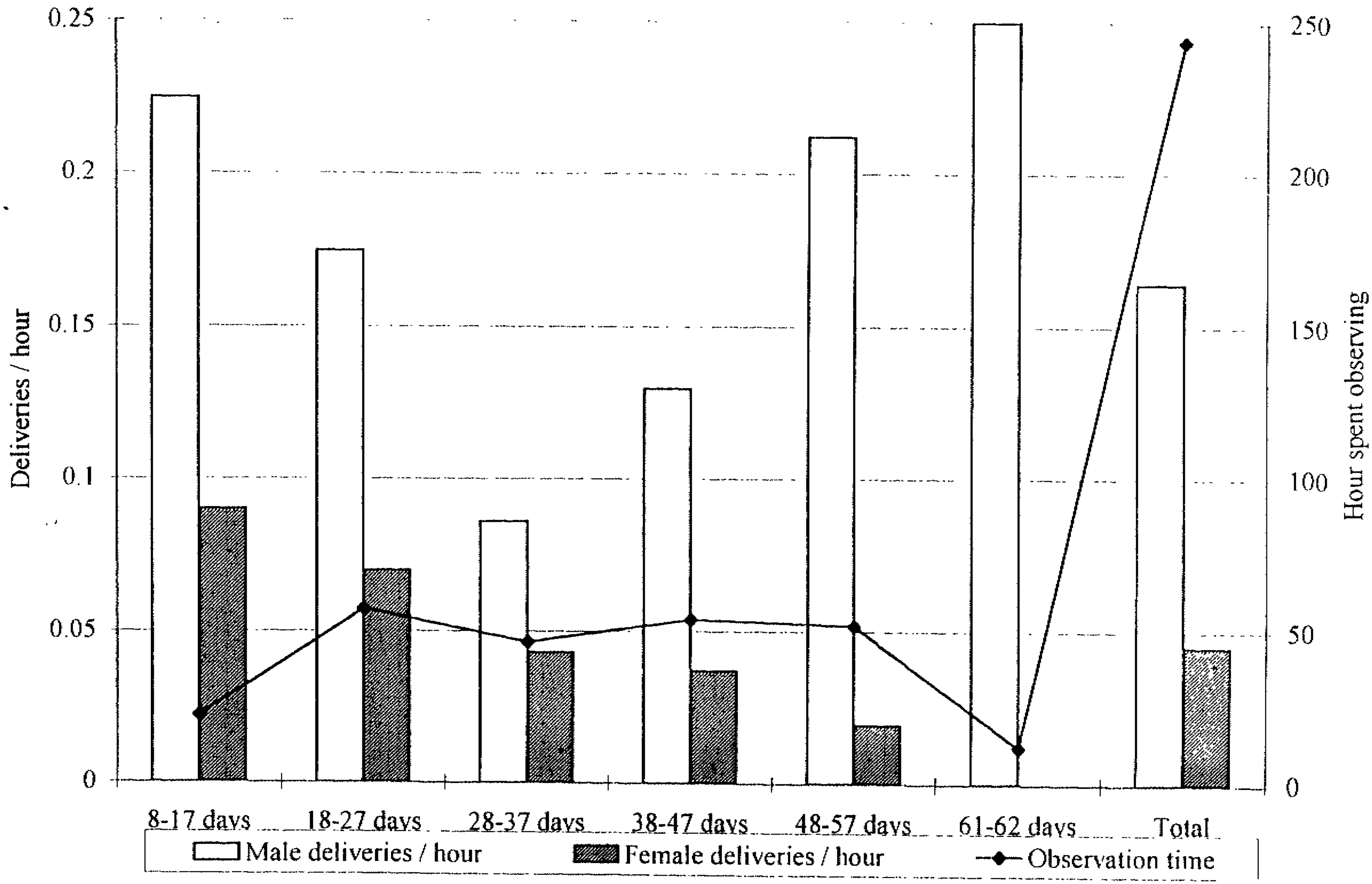

Figure 2. Prey delivery rates to goshawk nests and observation time throughout nestling and fledgling phases in southcentral Wyoming.

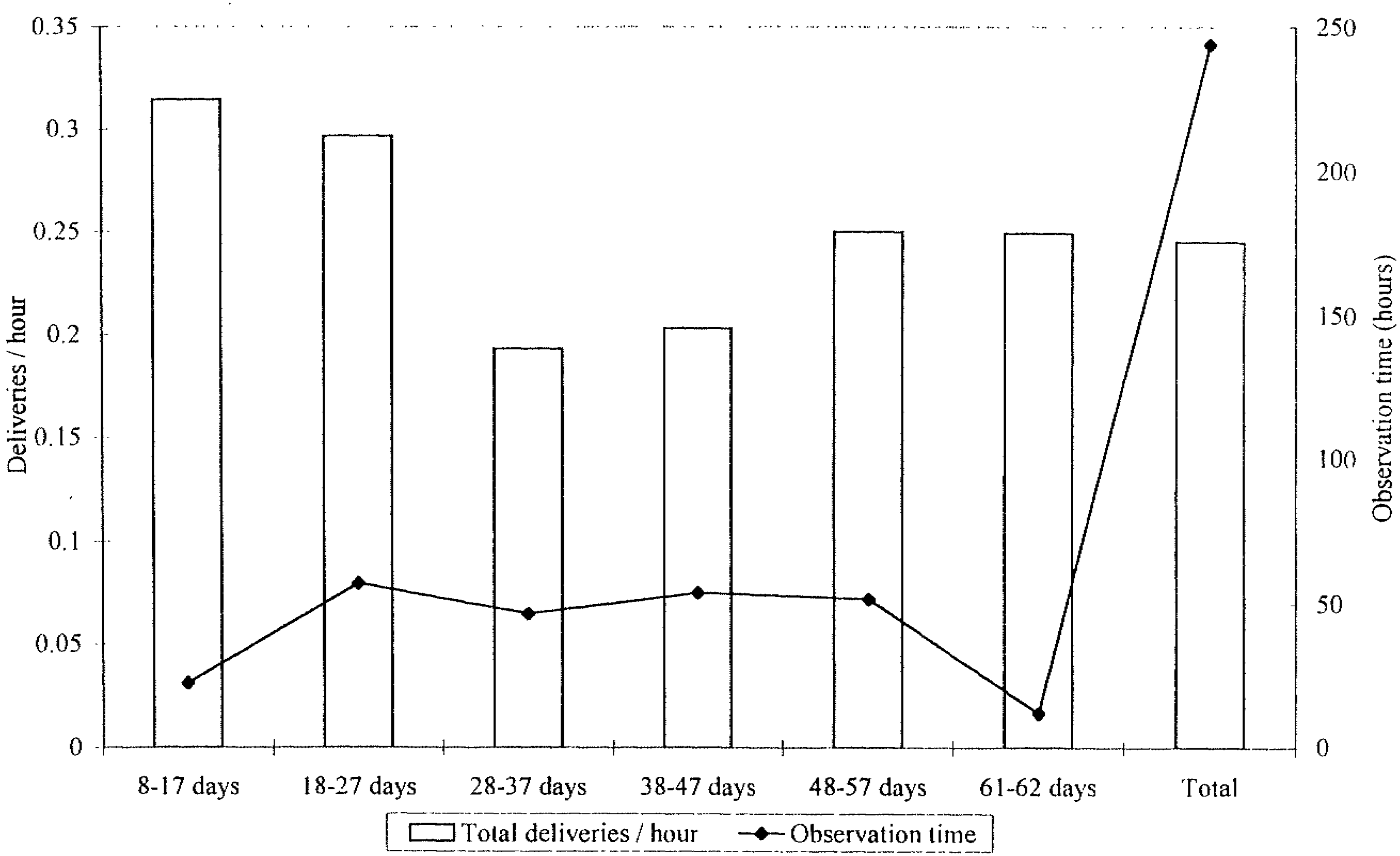

Figure 3. Goshawk total prey delivery rates and observation time during nestling and fledgling phases in southcentral Wyoming during 1996 and 1997.

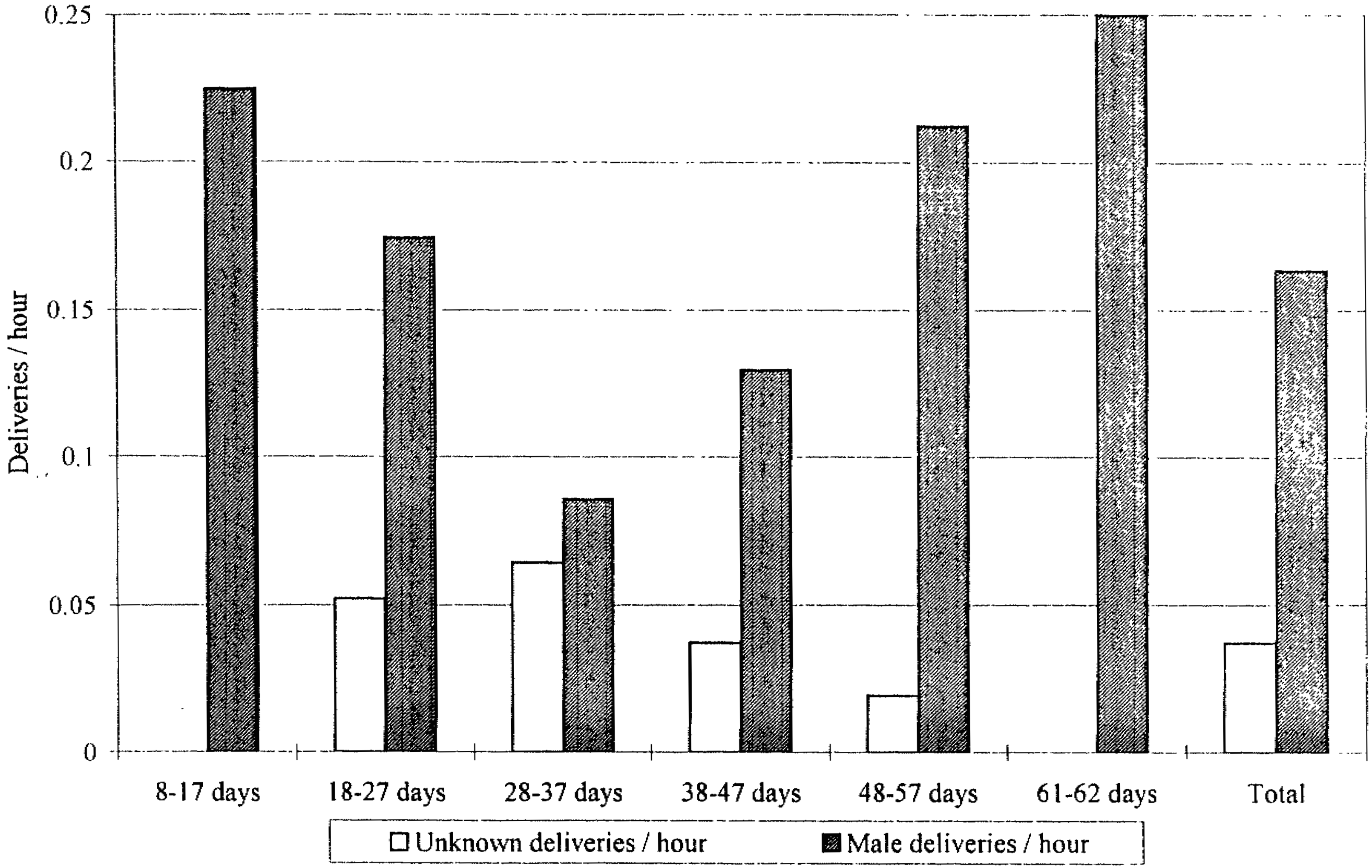

Figure 4. Male and unknown prey delivery rates to goshawk nests in southcentral Wyoming during 1996 and 1997.

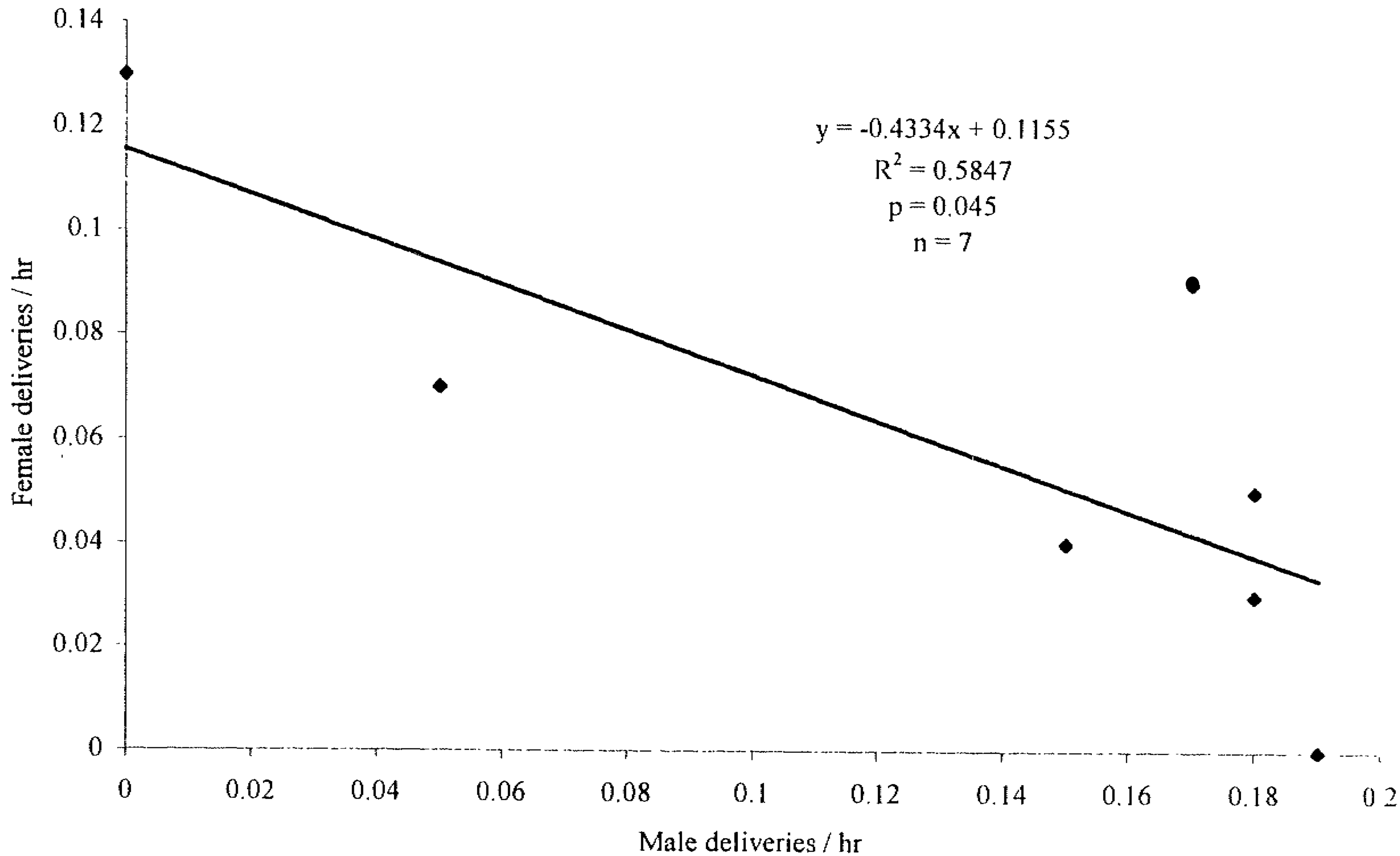

Figure 5. Regression line predicting female delivery rates by male delivery rates in southcentral Wyoming during the breeding seasons of 1996 and 1997.

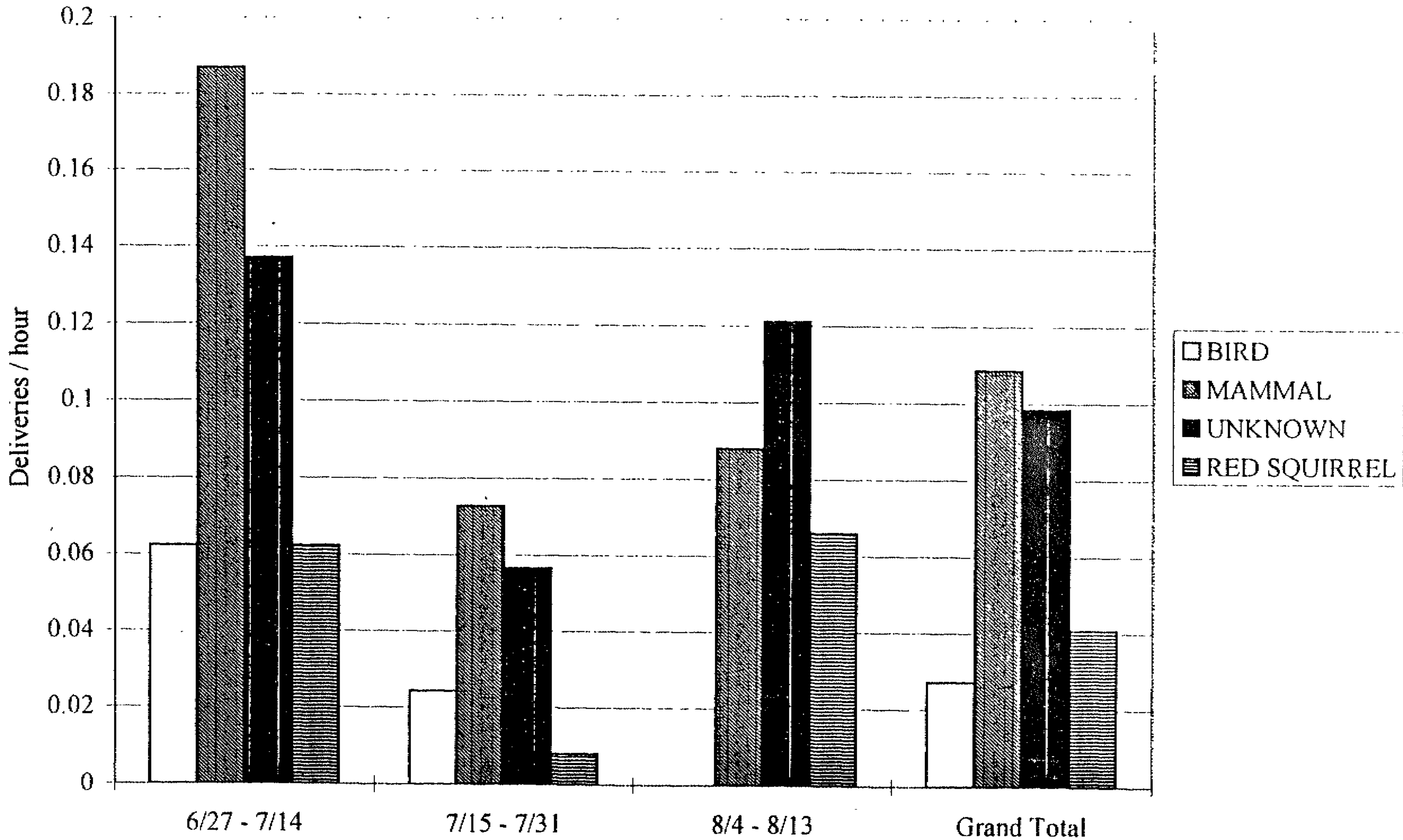

Figure 6. Goshawk delivery rates of prey groups by time period in southcentral Wyoming during 1996 and 1997.

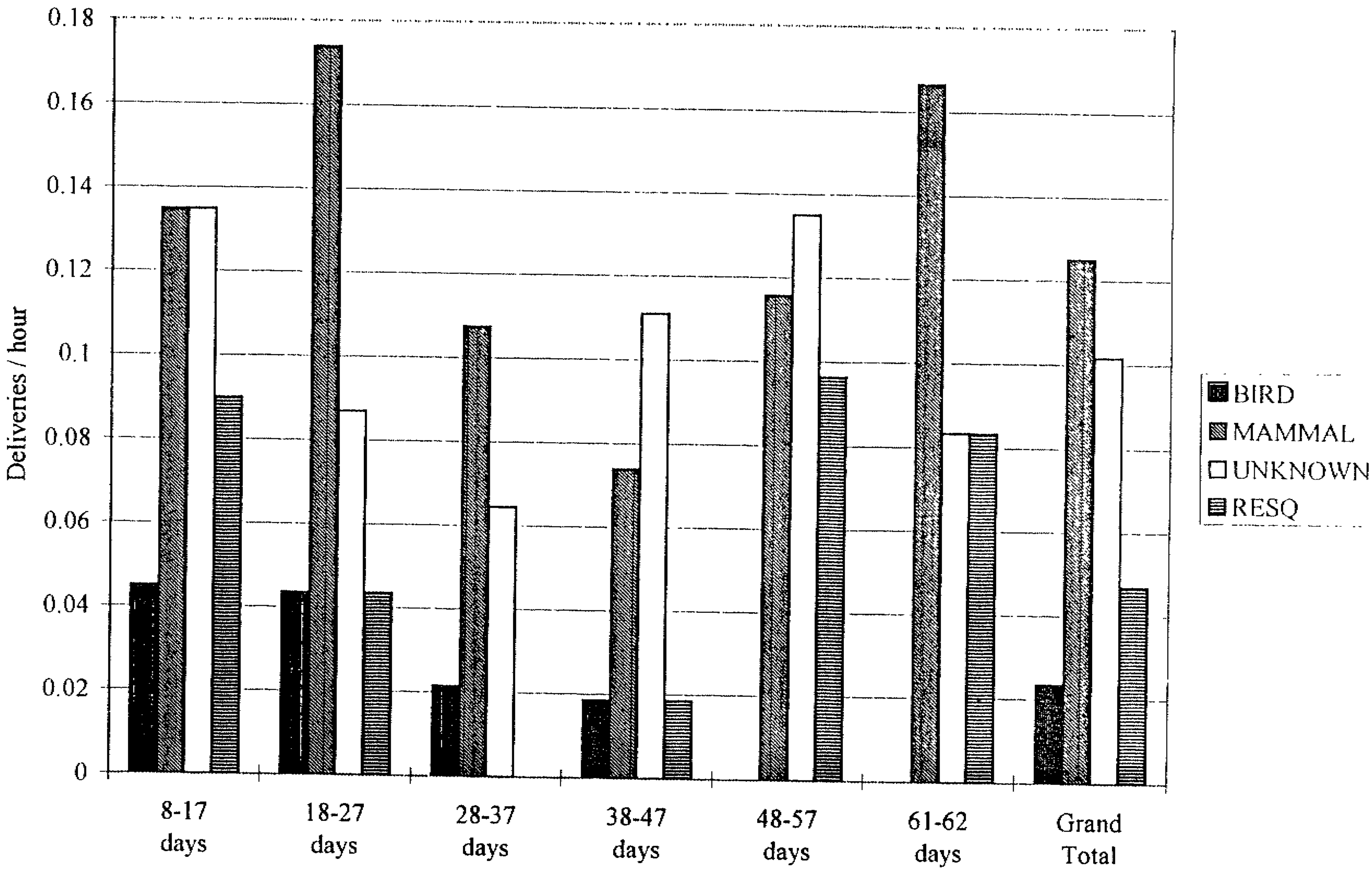

Figure 7. Goshawk prey delivery rates of prey groups during nestling and fledgling stages in southcentral Wyoming during 1996 and 1997.

Table 1. Delivery rates to goshawk nests in southcentral Wyoming during 1996 and 1997.

Nest	Male deliveries / hr	Female deliveries / hr	Total deliveries / hr	Hours of observation
Marten	0.17	0.09	0.34	11.75
Boundary	0.05	0.07	0.15	40.5
Grande	0.18	0.05	0.24	38
Glass	0.19	0.0	0.19	47.5
Divide	0.18	0.03	0.30	67
Simpson's	0.0	0.13	0.13	39
Elk	0.15	0.04	0.22	27
Angel	0.34	0.17	0.57	24
Grand Total	0.14	0.06	0.23	294.75

Table 2. Summary of prey items delivered to goshawk nests in southcentral Wyoming during 1996 and 1997.

Prey item	Number Delivered	Percent of Total	Percent of Identified Deliveries	Average Feeding Time in Minutes *
Unknown Bird	5	7.25%	13.16%	7.5 (n = 2)
American Robin	2	2.90%	5.26%	9 (n = 1)
Northern Flicker	1	1.45%	2.63%	N/A
Red Squirrel	12	17.39%	31.58%	17 (n = 5)
Ground Squirrel or Chipmunk	4	5.80%	10.53%	44 (n = 2)
Least Chipmunk	1	1.45%	2.63%	3 (n = 1)
Medium Unknown Mammal	5	7.25%	13.16%	14.4 (n = 5)
Lagomorph	1	1.45%	2.63%	81 (n = 1)
Large Unknown Mammal	1	1.45%	2.63%	18 (n = 1)
Mouse Sized Mammal	5	7.25%	13.16%	16.5 (n = 2)
Unknown Mammal	1	1.45%	2.63%	37 (n = 1)
Unknown	31	44.93%	N/A	12 (n = 12)
Grand Total	69	100.00%	100.00%	17.7 (n = 33)
Bird Total	8	N/A	20%	N/A
Mammal Total	32	N/A	80%	N/A

Medium = Size of least chipmunk to golden-mantled ground squirrel.

Large = Size of red squirrel to snowshoe hare.

* Feeding times are only for the nestling stage and include a wide range of nestling ages.

Literature Cited

Allen, B.A. 1978. Nesting ecology of the goshawk in the Adirondacks. Master's Thesis, State University of New York, Syracuse.

Bloom, P.H., G.R. Stewart, and B.J. Walton. 1986. The status of the northern goshawk in California, 1981-1983. Administration Report 85-1. State of California, Department of Fish and Game, Sacramento.

Boal, C.W. 1994a. A photographic and behavioral guide to aging nestling northern goshawks. Studies in Avian Biology no. 16: 32-40.

Boal, C.W. 1994b. Unusual parental behaviors by male northern goshawks. Journal of Raptor Research 28: 120-121.

Boal, C.W. and R.W. Mannan. 1994. Northern goshawk diets in ponderosa pine forests of the Kaibab Plateau. Studies in Avian Biology 16: 97-102.

Bull, E.L. and J.H. Hohman. 1994. Breeding biology of northern goshawks in northeastern Oregon. Studies in Avian Biology no.16: 103-105.

Doyle, F.I. and J.M.N. Smith 1994. Population responses of northern goshawks to 10-year cycle in numbers of snowshoe hares. Studies in Avian Biology no. 16: 122-129.

Gryzbowski, J.A., and S.W. Eaton. Prey items of goshawks in southwestern New York. Wilson Bulletin 88(4): 669-670.

Kennedy, P.L. 1991. Reproductive strategies of northern goshawks and Cooper's hawks in north-central New Mexico. Ph.D. dissertation, Utah State University, Logan.

Lee, J.A. 1981. Comparative breeding behavior of the goshawk and Cooper's hawk. Master's Thesis, Brigham Young University, Provo, Utah.

McGowan, J.D. 1975. Distribution, density and productivity of goshawks in interior Alaska. Federal Aid Wildlife Restoration Project Report W-17-4, W-17-5, W-17-6, Job 10.6A. Alaska Department of Fish and Game.

Marquiss, M., and I. Newton. 1982. The goshawk in Britain. British Birds 75: 243-260.

Møller, A.P. 1987. Copulation behavior in the goshawk Accipiter gentilis. Animal Behavior 35: 755-763.

Palmer, R.S., ed. 1988. Handbook of North American birds. Vol. 4. Diurnal Raptors (part 1). Yale University Press, New Haven, CT.

Reynolds, R.T., S.M. Joy and D.G. Leslie. 1994. Nest productivity, fidelity, and spacing of northern goshawks in Arizona. Studies in Avian Biology no. 16: 106-113.

Reynolds, R.T., and E.C. Meslow. 1984. Partitioning of food and niche characteristics of coexisting accipiter during breeding. Auk 101: 761-779.

Schnell, J.H. 1958. Nesting behavior and food habits of goshawks in the Sierra Nevada of California. Condor 60: 377-403.

Squires, J.R. 1998. Food habits of goshawks in southcentral Wyoming. In prep.

Squires, J.R. and R.T. Reynolds. 1997. Northern Goshawk (Accipiter gentilis). In The Birds of North America. No. 298. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Squires, J.R. and L.F. Ruggerio. 1995. Winter movements of adult northern goshawks that nested in southcentral Wyoming.

Ward, J.M., and P.L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile northern goshawks. Auk 113: 200-208.

Wikman, M., and V. Tarsa. 1980. Kanahaukan pesimäaikaisesta ravinnosta Länsi-Uudellamaalla 1969-1977 [Food habits of the goshawk during the breeding season in southwestern Finland 1969-1977]. Suomen Riista 28: 86-96.

Younk, J.V., and M.J. Bechard. 1994. Breeding Ecology of the northern goshawk in high-elevation aspen forests of northern Nevada. Studies in Avian Biology no. 16: 119-121.

Zachel, C.R. 1985. Food habits, hunting activity, and post-fledging behavior of northern goshawks (Accipiter gentilis) in interior Alaska. Master's Thesis. University of Alaska, Fairbanks.

Zirrer, F. 1947. The goshawk. Passenger Pigeon 9: 79-94.

Chapter 6 - Summary

What have I found? I examined four factors which could affect the relative use of goshawk kill areas: 1) prey abundance, 2) habitat characteristics, 3) landscape patterns, and 4) habitat needs of prey species. I complemented investigations of these factors with studies of food habits and knowledge of delivery rates from nest observations. Male northern goshawks in southcentral Wyoming delivered prey less frequently, however females delivered more frequently than other populations (Boal and Mannan 1994, Younk and Bechard 1994, Zachel 1985, Schnell 1958). High female delivery rates may indicate that prey is less available in southcentral Wyoming than in other populations. Goshawks delivered red squirrels more often than other prey types, and no golden-mantled ground squirrels were delivered to nests during nest observations.

Most goshawks did not return more often to kill sites with higher prey abundances. However, two goshawks did return most often to sites with high abundances of least chipmunks, red squirrels, American robins, and medium sized birds (18-46 g). The relative use of kill areas was more frequently correlated with habitat characteristics than prey abundance. Goshawks returned most often to sites with more mature forests, gentler slopes, lower coverage of woody plants, and higher densities of larger conifers. Habitats in the most often used kill areas resembled habitats used by red squirrels. Goshawk kill areas were often associated with small natural openings as were many prey species.

At the landscape scale goshawks returned most often to kill sites which were closer to nests, had higher percent coverages conifer, greater densities of small natural openings, and small aspen patches in 1 km circles. In 300 m circles goshawk use showed similar patterns, but they also returned most often to areas with greater numbers of patch types.

Are foraging activities of goshawks affected by forest management? Clearcuts were found near kill sites for three of the birds studied. Goshawks returned most often to areas with higher coverages of clearcuts. I attributed this use to the presence of mature stands of timber adjacent to clearcuts.

Red squirrels are the most frequently delivered prey species to goshawk nests in southcentral Wyoming. Red squirrels reach maximum abundance in large patches of mature forests (Reynolds et al. 1992). Goshawks return most often to kill sites in mature forests. Other authors suggest mature forests allow goshawks to approach prey unseen while allowing for maneuverability (Widén 1989, Beier and Drennan 1997). Reducing the amount of mature forest cover near nests by clearcutting can negatively affect foraging goshawks by: 1) Creating habitats in which goshawks may not be able to approach prey undetected; 2) Decreasing the amount of red squirrel habitat; and 3) Forcing male goshawks to expend more energy delivering prey by hunting farther from nests.

Alternatively, goshawks could have used forest clearcut edges to capture prey. Goshawks made kills along forest edges in areas where most prey species occurred along forest edges in Sweden (Kenward and Widén 1989). However, few goshawk prey were observed in clearcuts or near clearcut edges in kill areas in our study.

Research and management recommendations. Clearly forest management has the potential to reduce the quality of habitat for foraging goshawks. Goshawks returned most often to sites with larger trees on gentler slopes, areas usually targeted for timber harvest. Of the four national forests in Wyoming, the most board feet per year from 1950 to 1991 were harvested from the Medicine Bow National Forest. In 1991 approximately twice the amount of timber board feet was harvested from the Medicine Bow National Forest compared to other national forests in Wyoming (Knight 1994). As mature stands of timber become scarce, pressure to harvest these forests could increase. If increased deliveries by female goshawks are an indication that prey are less available, forest management could have already had negative impacts on goshawk populations in southcentral Wyoming.

Our results indicate that goshawks make kills in a variety of habitats. However, areas with lots of mature conifer cover, interspersed with small natural openings and aspen patches near nests are used most often. In the Medicine Bow National Forest buffers of varying sizes are placed around nests to preserve mature forest cover, but much of the surrounding mature forest is cut. Forest cover within 2 km (the average distance of kill sites to nests) of nests should be retained. If cuts are made within 2 km of nests, small natural openings and aspen patches should be retained. When possible, cuts which remove select trees while retaining much of the overstory should be used in place of clearcuts. Stands targeted for select cuts should have canopy coverages of at least 50 % after cutting operations. Although some debris from select cuts should be retained for prey species, most should be removed. If thinning is conducted cut trees should be removed.

Future research in southcentral Wyoming should focus on 1) goshawk productivity and 2) prey habitat needs. Future studies of habitat use should be conducted in conjunction with productivity and delivery rate studies. Additionally, nests should be monitored in areas of with high and low levels of forest fragmentation due to clearcuts. The following questions need to be addressed:

1) What level, if any, of forest fragmentation by clearcuts negatively impacts the ability of male goshawks to capture and deliver prey to nests?
2) If the ability of male goshawks to secure food is negatively impacted by forest management, what are the mechanisms behind the impact? Do competitive interactions between goshawks and other raptors play a role?
3) Do decreased delivery rates result in decreased productivity? If so, at what rates of prey delivery are nest productivity affected?

Further studies should also focus on how prey populations are affected by forest management. The following questions need to be addressed:

1) Do prey species such as the golden-mantled ground squirrels increase following clearcutting? If so do goshawks hunt these areas?
2) Are prey populations more vulnerable to extinction in areas of high fragmentation?
3) What habitats support the highest densities of prey species, and what habitats support the highest reproductive rates of prey species? Do prey populations fluctuate, and what factors cause those fluctuations?

Literature Cited

Beier, P.. and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7: 564-571.

Boal, C.W. and R.W. Mannan. 1994. Northern goshawk diets in ponderosa pine forests of the Kaibab Plateau. Studies in Avian Biology no. 16: 97-102.

Kenward, R. and P. Widen. 1989. Do goshawks Accipiter gentilis need forests? Some conservation lessons from radio tracking. in Raptors in the Modern World. eds. B.U. Meyburg and R.D. Chancellor. WWGBP: Berlin, London and Paris. pp 561 - 567.

Knight, D.H. 1994. Mountains and Plains. The Ecology of Wyoming Landscapes. Yale University Press, New Haven and London.

Schnell, J.H. 1958. Nesting behavior and food habits of goshawks in the Sierra Nevada of California. Condor 60: 377-403.

Ward, J.M., and P.L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile northern goshawks. Auk 113: 200-208.

Widén, P. 1989. The hunting habitats of goshawks Accipiter gentilis in boreal forests of central Sweden. Ibis 131: 205-231.

Younk, J.V., and M.J. Bechard. 1994. Breeding Ecology of the northern goshawk in high-elevation aspen forests of northern Nevada. Studies in Avian Biology no. 16: 119-121.

Zachel, C.R. 1985. Food habits, hunting activity, and post-fledging behavior of northern goshawks (Accipiter gentilis) in interior Alaska. Master's Thesis. University of Alaska, Fairbanks.

Appendix 1. An explanation of landscape analyses.

The program r.le utilizes the Geographic Information System known as G.R.A.S.S. (Geographic Resources Analysis Support System). The program r.le measures landscape patterns in areas around sites or entire maps. However, r.le. version 2.1 analyzes landscapes around sites using squares.

In order to analyze landscape characteristics in circles a macro created by Erin O'Doherty (G.I.S. research scientist, Rocky Mountain Forest Service Experimental Station, Laramie, Wyoming) was used. Circles of 300 m or 1 km radius were drawn around each kill and random site using the G.R.A.S.S. command v.circle. The circle was then converted to a mask using the r.mask command. The mask simply made everything outside the circle 'invisible' to r.le, so that only landscape features within 300 m or 1 km of kill or random sites were measured.

A list and description of the variables measured using r.le version 2.1 are shown in Chapter three, Table three. Patch richness was consistently underestimated by one patch type. The Shannon index, Dominance index, and inverse Simpson's index were also consistently underestimated. Elevations were also measured with r.le by using a D.E.M. (Digital Elevation Model) of 30 m resolution as the base layer. The average pixel value of all pixels within 300 m circles was calculated and used as the average elevation for that site.

Distance from the nest to each kill site was measured using Idrisi for Windows version 1.01.004. The distance command was used to generate a distance layer for each nest. Kill sites were then overlaid on nest distance layers to determine distances from nests.