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Denning ecology of wolves in northwest Montana and southern Canadian Rockies

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DENNING ECOLOGY OF WOLVES IN NORTHWEST MONTANA

AND SOUTHERN CANADIAN ROCKIES

By

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Wolf (Canis lupus) den characteristics and den site selection were studied in 1990 in 4 areas in northwest Montana and the southern Canadian Rockies. Position, cover and other habitat characteristics of den sites (out to 100 m distance from den) and denning areas (out to 1 km distance from den) were compared to those of available habitat, at the pack territory level.

Fourteen of 15 dens were excavations. One was in a hollow log. Most dens had 1 entrance. Average distance between ground surface and den ceiling was 0.9 ± 0.4 m and average length of dens was 3.2 ± 1.2 m. Position and cover values varied widely among dens.

There were significant differences between den sites/denning areas and non-den areas in regard to elevation, slope position, slope, aspect, landform, distance to nearest trail, distance to nearest human habitation, and distance to nearest opening.

Relative to available habitat, wolves use more of the following for den site locations: valley bottoms and lower slopes, flat to moderate slopes, south and east aspects, depositional landforms, and sites close to trails, far from human habitation and activity, and close to meadows and other openings. While soil texture, canopy cover, and hiding cover were not identified as statistically significant factors, they are believed to play roles in den selection at scales less than approximately 0.03 km^2. Distance to nearest road was not identifed as a factor important to den site selection.

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INTRODUCTION

Wolves (Canis lupus) have been rare to absent in the northern Rocky Mountains within the United States for approximately 50-60 years (Weaver 1978, Day 1981, Ream and Mattson 1982). Hunting, trapping, poisoning, bounty laws and predator control programs, along with reduction or extirpation of native prey populations all contributed to the disappearance of the wolf (Bailey 1907, Curnow 1968). Wolves were also persecuted in neighboring portions of Canada. Beginning in the 1860's and '70's, poisoning, trapping, overhunting of prey species, and land settlement and development in Alberta led to a drastic reduction in wolf numbers. By 1900, wolves were very rare along the eastern slopes of the Rockies, and hardly to be found on the prairies (Gunson 1983). A population resurgence in western and northern Alberta during the 1930's and '40s was met with renewed control efforts, even in Jasper and Waterton National Parks (Gunson 1983). In British Columbia, a bounty system was instituted in 1870, and in 1947 the province established a government-run control program. Use of poison bait stations was widespread (BC Ministry of Environment 1985). In 1968, hunting of wolves was stopped on Vancouver

Island and in southeastern B.C. because the animals were nearly extinct in these places (Tompa 1983).

In recent years, wolves have been recolonizing parts of their former range in the western U.S. This may be attributed to the legal protections now afforded this species, along with the development of more favorable attitudes toward the environment and wildlife, including the wolf (Kellert 1985, McNaught 1985, Bath 1987, Bureau of Business and Economic Research 1987). An expanding wolf population in southwestern Alberta and southeastern British Columbia may also be partly responsible for the reappearance of wolves in northwestern Montana (Ream and Mattson 1982). In 1978, the wolf was listed as an endangered species in the lower 48 states (excluding Minnesota) (43 Federal Register 9612, March 9, 1978). British Columbia and Alberta provincial law still allows the regulated taking of wolves. In the United States, there are proposals not only to allow natural recovery, but also to reintroduce wolves to Yellowstone National Park (U. S. Fish and Wildlife Service 1987).

Recovery of endangered wolf populations is dependent on informed management of wolf habitat. This is emphasized in the Northern Rocky Mountain Wolf Recovery Plan (U. S. Fish and Wildlife Service 1987:iv): "Either...(natural recolonization or translocation) ...necessitates conservation of suitable habitat in appropriate recovery areas." Wolves, however, do not always use those areas that would be most convenient, and least controversial, for people. A number of recent episodes in Montana have demonstrated that wolves will, at times, establish home ranges in areas that are relatively accessible to humans (e.g., where there is a high density of roads), where tolerance for their presence is low (e.g., on private ranch land), and where other activities may come into conflict with their continued presence (e.g., timber sales, livestock grazing, oil and gas development). Better information on wolf habitat use in the Northern Rockies will not allow managers to keep free-roaming animals from discovering and colonizing areas that could be conflict-ridden. However, a greater understanding of habitat selection and use, particularly those habitats or sites that are tied to reproduction, may help managers, along with the public, to develop realistic expectations of where wolves may settle, and where they will not. Within any particular area where wolves occur, or may occur in the future, more informed decisions can be made regarding land use and management emphases.

Den Characteristics

As defined in Lawhead (1983:8), a den is "an underground burrow or other sheltered place used by wolves."

While dens may be found at locations other than where pups are whelped (e.g. investigators have identified "secondary" dens, and dens are sometimes found at rendezvous sites [Haber 1968, Clark 1971, Chapman 1977]) my investigation deals solely with "natal" dens (Banfield 1954, Lawhead 1983).

Wolves are certainly one of the most studied large carnivores in North America, yet information specific to den characteristics and denning ecology in the western United States is sparse. Previous work on wolf dens has been conducted in Alaska (Rausch 1969, Stephenson 1974, Chapman 1977, Ballard and Dau 1983, Lawhead 1983), Canada (Criddle 1947, Mech and Packard 1990), and Minnesota (Fuller 1989, Ciucci and Mech 1992, in press). In other studies, wolf den characteristics and den site selection have been topics peripheral to the main objectives of research (Murie 1944 and Haber 1968, 1977 [Alaska]; Joslin 1966, 1967 [Ontario]; Banfield 1954 and Clark 1971 [Canadian arctic]; and Carbyn 1974 [Canadian Rockies]). Ryon (1977) observed denning behavior in a captive wolf pack. Ream et al. (1989) have produced the only account of a wolf den in the U. S. Rocky Mountains, possibly the entire western United States, since the work of Young and Goldman (1944).

The following features are usually described in investigations of wolf den characteristics: soil quality and drainage characteristics, distance to water, aspect, slope, position relative to general topography (valley bottom, hillside, tops of knolls, etc.), visibility, type and density of vegetation surrounding den, type of den (such as an excavation, hollow log or rock cave), and degree of potential or actual human disturbance. In addition, a number of authors have reported den structure characteristics, such as length, depth beneath soil surface, width and number of entrances, and general configuration (see Ryon 1977, Ballard and Dau 1983, Lawhead 1983, Fuller 1989, Ream et al. 1989.)

Wolf pup biology

As with other altricial mammals, wolves are born fairly helpless. Neonates are blind and deaf, have little ability to thermoregulate and receive assistance from the mother to eliminate wastes (Mech 1970). The den serves a relatively brief but important purpose by providing protection from the elements and potential predators for the first few weeks of life. Temperature and humidity within the den are generally moderate and stable, compared to the outside environment (Lawhead 1983).

Little is known about wolf pup biology and the causes of mortality during the first 5 months. (Chapman 1977, Van Ballenberghe and Mech 1975). Chapman (1977) lists mortality factors from various studies of captive or wild wolves.

Disease, malnutrition, predation, and humans are each identified by a number of authors. Van Ballenberghe and Mech (1975) found in Minnesota that most natural (not caused by humans) pup mortality occurred by six months of age. In coyotes, some investigators suspect that most pup mortality occurs fairly early--shortly after whelping (Knowlton and Stoddart 1983) and during or immediately following weaning, when pups no longer have access to the mother's passive-immune system via her milk (R. Crabtree, pers. commun.) It is possible that environmental factors such as temperature and moisture may play a role in determining pup survival at these early stages.

Even after pups emerge from the den and begin to eat semi-solid meat regurgitated by the adults, at approximately 3-4 weeks (Mech 1970), wolf dens temporarily remain the center of activity, the point from which adults go out to hunt and to which they return with food for the young. (The age at which pups are carried or led from the natal den to another den, or rendezvous site, appears to vary considerably. Joslin [1966] reported that one pack moved its litter to a new den when the pups were less than three weeks old. Murie [1944] observed packs abandoning natal dens when pups were 8 to 10 weeks old. The usual time for pups to leave the natal den seems to be closer to that reported in Murie). As discussed in Van Ballenberghe and Mech (1975:59), "The quality and quantity of prey eaten and the frequency of its consumption probably influence the growth of wild wolf pups more than any other single factor." Thus, to the extent which the den's location facilitates, or impedes, swift, easy access to prey, the placement of the den plays a role in the health of pups until the time of its abandonment.

Human Disturbance

Stephenson (1974) and Chapman (1977) explored the impacts of human disturbance to denning wolves. While both concluded that disturbance can have detrimental effects on pups, in most instances the effects were short-lived and not significant. However, Stephenson and Chapman worked in very remote, sparsely populated regions of Alaska. Though the Northern Rockies of the U. S. and southern Canadian Rockies retain large areas of roadless, wild country in comparison to the rest of the continental U. S., relative to the Alaskan study areas, road densities are moderate to high, human population densities are high (both rural and urban), landscapes are more greatly altered by agriculture, subdivisions, and other developments, backcountry recreationists are more numerous, and domestic livestock occupy a large proportion of the region's acreage. Thus, the potential for disturbance appears to be greater than in the areas studied by Stephenson and Chapman. Also, neither author investigated the effect that an ongoing disturbance, or one occurring just prior to parturition, might have on selection of a den site. For the most part, they considered disturbance only after a den was established and pups whelped.

Managers may wish to know whether potential disturbances occurring prior to or at the time of denning (events such as heavy vehicle traffic, road or building construction, and intensive recreational use) are apt to deter denning wolves from particular areas, and if so, if this will have significant, negative consequences for the wolves. One way to begin looking at this issue is to determine whether wolves avoid denning in sites where the potential for disturbance is relatively higher than at other available sites.

Factors in den site use

There has been no study of wolf den site characteristics that has attempted to quantify the differences between den sites and non-den sites. In other words, no previous analysis has tried to discern a pattern in the locations and features of den sites that might distinguish them from the general landscape. Most reports have been simple descriptions of one to several dens (Murie 1944, Criddle 1947, Rausch 1969, Clark 1971). Stephenson

(1974) presented a table of data on 79 dens, but did not attempt to summarize this information in more than a narrative fashion. Ballard and Dau (1983) took measurements at 18 dens as well as 6 rendezvous sites but focused primarily on den architecture. Den characteristics such as elevation and distance to water were summarized, but the authors did not try to compare these to values of the same variables over the entire area of potential denning habitat. Lawhead (1983) gives a relatively detailed report on den characteristics in an area of southcentral Alaska, but again there was no attempt to compare dens to non-dens.

Finally, nearly all studies of wolf denning habits have occurred in the Arctic or sub-Arctic zones of Alaska and Canada. Researchers in these areas have identified soil quality, depth to permafrost, slope and aspect, and location of caribou migration routes or calving grounds as possible factors in den site selection (Clark 1971, Stephenson 1974, Chapman 1977, Ballard and Dau 1983, Lawhead 1983). However, it is conceivable that the forested, mountainous character of the Rockies, the diversity and abundance of its prey species, its comparatively milder climate, and the overall higher human density create a different set of constraints on den use.

Workers in the field of avian habitat selection have suggested that habitat use is a hierarchical process, or a "sequence of selection responses to characteristics associated with decreasing spatial scales" (Gutzwiller and Anderson 1987:534; see also Hutto 1985). Important selection criteria may shift with changes in scale. I chose to focus my study on selection within the scale level of the pack territory.

Objectives

My study attempted to overcome some of the deficiencies in knowledge concerning wolf den characteristics and use of den sites in the Northern Rockies. Specific objectives were to:

1) determine physical characteristics of wolf dens in the Northern Rockies;

2) determine whether wolves use den sites that offer lower potential for human disturbance, relative to sites available to them; and

3) determine which factors are correlated with the presence of wolf den sites within the pack territory.

STUDY AREA

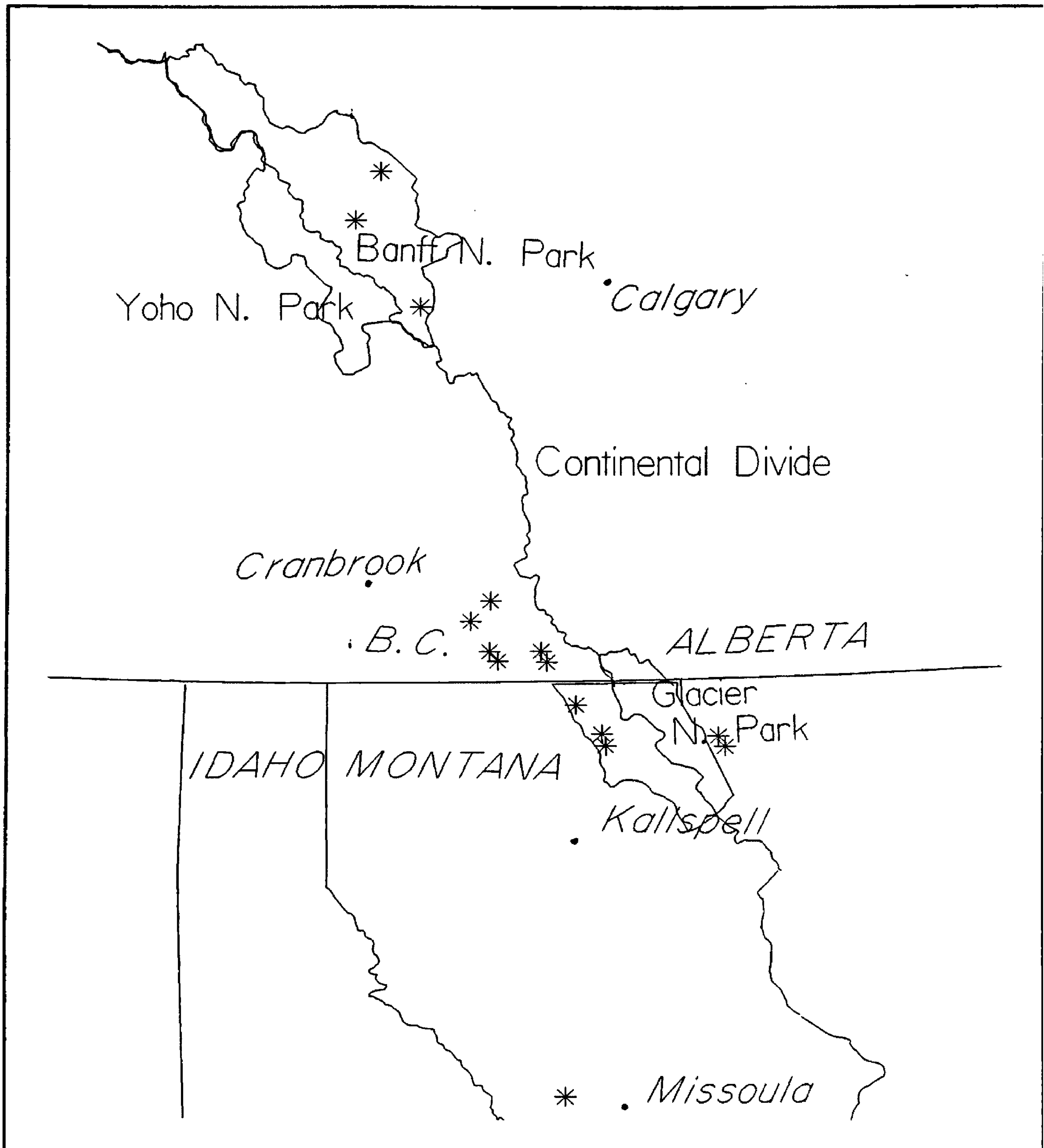
I worked in four separate areas: 1) the North Fork of the Flathead and Wigwam drainages in and near Glacier

National Park, Montana area and southeast British Columbia, 2) the Blackfeet Indian Reservation east of Glacier National Park, 3) Banff National Park, Alberta, and 4) the Ninemile Valley of western Montana (Fig. 1). While distinct from each other in some ways, all four areas belong to a region with similar geologic, climatological and biological characteristics and patterns (Lobeck 1950). In common usage, the term "Northern Rockies" is applied to the mountainous portions of Montana and Idaho, and the ranges of the Continental Divide in Canada are called "Canadian Rockies."

The mountains, composed predominantly of sedimentary rock, tend to be arranged in roughly parallel, northwest/southeast-trending ridges. The entire region has been heavily glaciated, so that the higher peaks are quite rugged, while the lowlands are covered by layers of glacial debris. Elevational extremes range from approximately 760 m to 3500 m, with most valley bottoms at 1200-1550 m.

The region is in a transition zone between more maritime climates to the west and continental climates to the east (Alwin 1983). The barrier-like nature of the mountains, dividing west side and east side, strongly influences weather patterns as well. It is generally wetter and warmer on the western slope, drier and cooler on the eastern side, with the east side also subject to more extreme variation in temperature. The differences between west side and east side are more pronounced in winter.

Fig. 1. Study areas in northwest Montana and southern Canadian Rockies. General locations indicated by asterisk.



Strong winds are a common feature--both winter and summer--of the front ranges and the lands immediately to the east (Gadd 1986).

The western portion of the Rockies, in Montana and British Columbia, is heavily forested, except for occasional meadows, prairies, and human-made clearings. Only the widest, largest valleys are non-forested. In Montana, ponderosa pine (Pinus ponderosa), lodgepole pine (Pinus contortus) and Douglas-fir (Pseudotsuga menziesii) occupy the warmer, drier sites at low elevations. Spruce (Picea spp.) and cottonwood (Populus spp.) are associated with riparian environments; western larch (Larix occidentalis) is common at low to mid-elevations (Shaw and On 1979). Lodgepole pine forms extensive, nearly pure stands in many areas: this is particularly characteristic of the North Fork of the Flathead area in Glacier Park and southeastern B.C. Englemann spruce (Picea englemannii), western red cedar (Thuja plicata) and western hemlock (Tsuga heterophylla) may be found in the most moist forests.

East of the Continental Divide, the mountainous country is dominated by lodgepole pine. Douglas-fir may be found on south and west-facing slopes in the major valleys (Gadd 1986). Spruce and subalpine fir (Abies lasiocarpa) also occupy mature, low elevation forests. Limber pine (Pinus flexilis) and groves of aspen (Populus tremuloides) are intermixed with prairie grassland and shrub communities in the valleys of the front ranges and in the foothills zone (Shaw and On 1979, Holland and Coen 1982).

Major prey species for wolves are white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), elk (*Cervus elaphus*) and moose (*Alces alces*). Bighorn sheep (*Ovis canadensis*) are scattered throughout the region and occasionally may be preyed upon by wolves.

METHODS

Between 6 June and 20 October 1990, I visited 15 wolf dens in the four study areas. Nine dens were located in the North Fork/ Wigwam area and were found by WEP (Wolf Ecology Project) personnel using ground and/or aerial radio tracking information on radio-collared pack members. Two dens occurred on the Blackfeet Indian Reservation, and were first discovered by a tribal game warden while he was trying to locate livestock he had grazing in the area. Dan Carney of the Blackfeet Grizzly Program directed me to these dens. Mike Gibeau and Julie Bauer, workers on a Banff National Park wolf study led by Paul Paquet, directed me to three dens (radio-tracking had allowed them to discover two, the third was a traditional den site in a conspicuous spot along a backcountry trail). Finally, Mike Jimenez, U.S. Fish and Wildlife Service, led me to the single Ninemile Valley den.

Dens occupied during the 1990 season were examined after the wolves had left the area. Dens and sample point locations were marked on topographical maps. For denning areas occurring in Montana, I used 1:24,000 U. S. Geological Survey (7.5 minute quad) maps. For British Columbia denning areas, I used 1:50,000 National Topographical System maps produced by Canada's Department of Energy, Mines, and Resources, along with 1:20,000 maps from the British Columbia Ministry of Crown Lands, Surveys and Resource Mapping Branch. For Banff National Park denning areas I used 1:50,0000 maps produced in conjunction with an ecological classification project in Banff and Jasper National Parks (Holland and Coen 1983).

Sample Design

Available denning habitat, for the purposes of this study, was defined as an area around and including the actual den, within the confines of the wolf pack territory. A sampling scheme was designed for a 314-km^2 area surrounding each den (Fig. 2). In the WEP study area, 95% minimum convex polygon, year-round home ranges were estimated for two packs in 1990 at 938 km^2 and 514 km^2 (Ream et al. 1990). Thus, my sampling area approximated one to two-thirds the size of a wolf pack territory in the Northern Rockies/southern Canadian Rockies region. This seemed adequate coverage for determining what variables were important within the level of the territory.

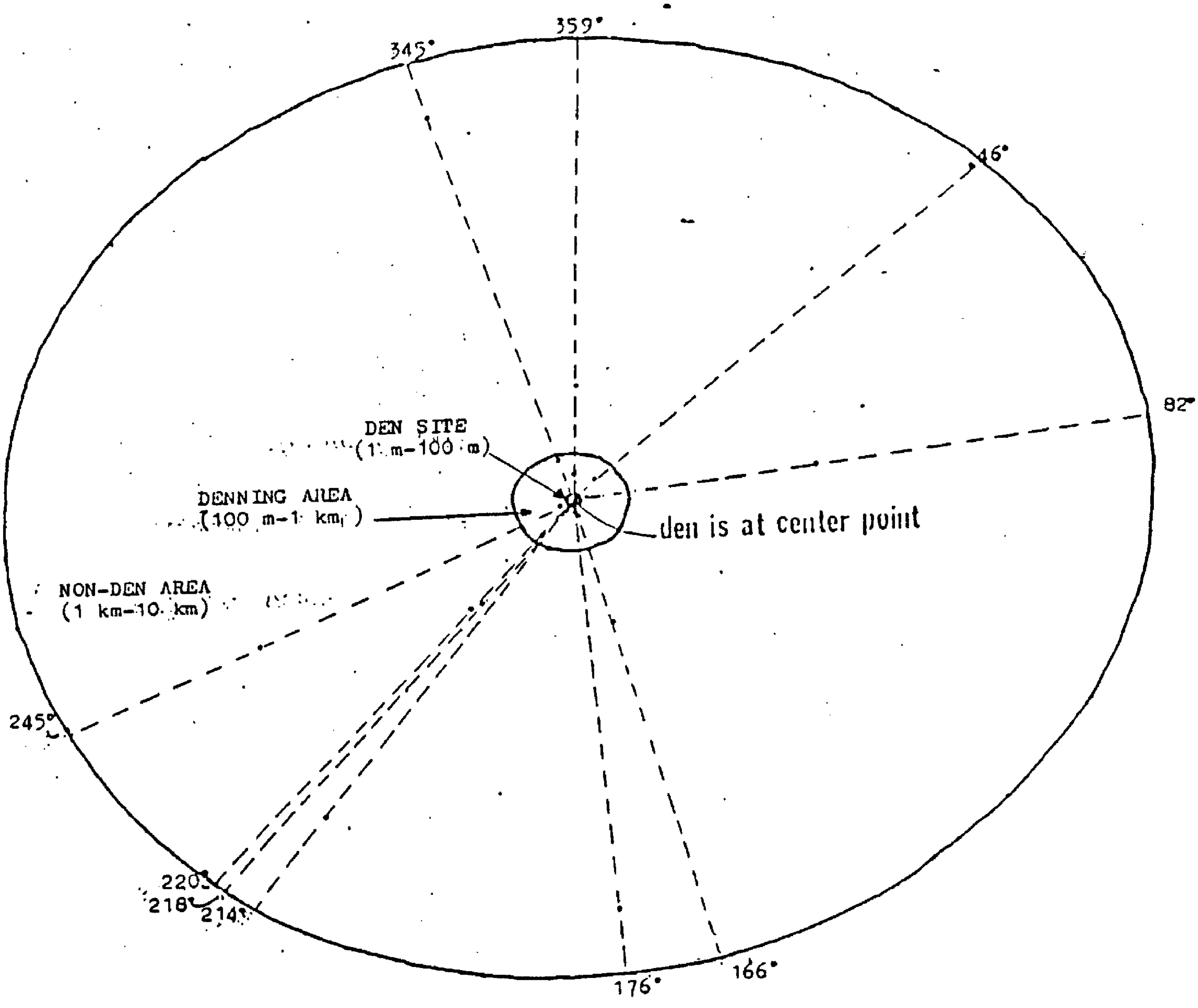
I also reasoned that the area in closest proximity to the den was likely to contain many points very similar to the spot that was actually used. Therefore, I decided to treat the area within 100 m radius from the den--an area I chose after initial visits to several dens--as a unit, called the "den site" (DS), to be compared to non-den sites.

However, because several dens in the study areas occurred within a distance of several hundred meters from one another, it seemed unreasonable to treat the area immediately beyond 100 m distance as strictly "non-use." I therefore designated the area between 100 m and 1 km distance from the den as the "denning area" (DA).

Finally, I chose to designate the area beyond 1 km distance from the den as the non-use, or non-den area (ND). DS, DA, and ND each contained 10 sample points so that 30 records were associated with each den and sampling area. In short, my study was set up to test how sites within the pack territory, but at some remove from the den, were like or unlike the areas closest to the den itself.

Locations of sampling points were determined before each sampling area was visited. For each, 10 azimuths were chosen. For the first 8, I chose 2 azimuths within each of the 4 compass quadrants (0-89, 90-179, 180-269 and 270-359 degrees). The 2 azimuths within each quadrant were

Fig. 2. Sampling design.[1]



[1]Den 1 used as an example. DS, DA, and ND each contain 10 sample points; DS is too small here to show sample point locations. Three sample points, 1 each in DS, DA, and ND, are located along each of the 10 azimuths. There are 30 sample points total. Within DS, DA, and ND, distances from the center point (den) are determined randomly.

determined using a random number table. I took a 2-digit number, disregarding the numbers '90' through '99', and added it to the number representing the "lower" boundary of the quadrant in question. Thus, if the assigned quadrant were northeast and the two-digit random number was 18, I added 18 degrees to 0 degrees to obtain an azimuth of 18 degrees. The remaining two slots were assigned azimuths at random from the full 360 degree compass.

Along each azimuth 3 sample points were located, 1 within the DS, 1 in the DA, and 1 in the ND. The distance of each sample point from the den was determined with a random number table.

Descriptions of the variables quantified are presented in Table 1. Parameters that could be measured in the field but not with topographical maps are represented only in records for DS and DA. All data gathered for ND were obtained via maps.

Variables Measured

Macro relief, as adapted from Stephenson (1974) and Lawhead (1983), is here defined as the vertical height of the den above the nearest rolling to flat terrain--or a slope of no more than 8%. Percent overstory canopy cover was estimated visually. Hiding cover was evaluated by averaging the percent coverage estimates of a red-striped

Table 1. Description of variables.

Abbreviation	Description, categories
MACRO(m)	**Macro relief:** vertical height of den or sample point above nearest rolling to flat terrain, or a slope not greater than 8%.
ELEV(m)	**Elevation**
SLOPE(%)	**Slope**
ASPECT	**Aspect:** level/gently rolling, north (315-360 and 0-44 degrees), east (45-134 degrees), south (135-224 degrees), and west (225-314 degrees).
ROAD(m)	**Distance to nearest road:** at minimum, a "road" must appear on one of the topo maps used for this study, be a bladed route suitable for 4 wheel drive travel, and have been open to vehicles at some time during the period in which the wolf pack(s) that used the den were likely in the area.
WATER(m)	**Distance to nearest water:** can be standing or running, and must appear on one of the topo maps used.
TRAIL(m)	**Distance to nearest trail:** must appear on one of the topo maps used.
HUMAN(m)	**Distance to nearest human habitation/activity center:** must appear either on topo maps used in study, or be an ongoing, prominent center of human activity during late winter, spring, and early summer.
OPEN(m)	**Distance to nearest meadow or other opening:** a clearcut, marsh, field of low shrubs, beach along a lake, or gravel bar along a large river, in addition to a meadow. Essentially, any non-forested area that is not a road.
POSITION	**Slope position:** plains, short slope (neither upper nor lower), valley bottom, lower slope, mid-slope, upper slope.

Table 1. Continued.

Abbreviation	Description, categories
NETRAD(cal/ cm/day)	**Net direct solar radiation:** result of calculation combining slope and aspect, as well as latitude and time of year. It estimates the amount of solar radiation reaching the ground. Calculated here for 50 degrees north latitude and 16 April (approximately when dens are selected and first used).
CC(%)	**Canopy cover**
HC305(%)	**Hiding cover at 30.5 m**
HC61(%)	**Hiding cover at 61 m**
EDGE	**Edge presence:** present if change in structural class visible from den or sample point.
ECO	**Ecosystem type:** aquatic, nonvegetated terrestrial, coniferous forest, alpine, wetland, woodland, shrubland, or grassland.
LAND	**Landform:** floodplain, wetland, glaciofluvial/glaciolacustrine, glacial till, convex slopes 20-60%, breaklands (slopes >60%).
SOIL	**Soil texture:** sand, loam, silt, clay.
STRUCT	**Structural class:** nonvegetated, herbaceous, shrub, sapling, pole/sapling, young/mature, old growth.

2.5 cm square, 1 m long pole. The pole was placed at plot center, and viewed from the 4 cardinal directions at distances of 30.5 m (100 feet) and 61 m (200 feet). The presence of edge was affirmed if there was a change in structural class visible from the den. Ecosystem type, as described in the Forest Service Ecosystem Classification Handbook (U. S. Forest Service 1987), was evaluated through general reconnaissance in the vicinity of the den. Values for structural class were determined within the boundaries of a circular 0.1 acre plot around the den. I modified the landtype categories of Martinson and Basko (1983), and classified landform via topographic map examination and field reconnaissance. Soil texture was determined by the "feel method"[2] (W. Basko, pers. commun.). Elevation, slope position, and distances to nearest road, water, trail, human habitation, and opening were estimated on topographic maps. At sample points within DS and DA, macro relief, slope, and aspect were estimated in the field and later compared to values derived from topographic maps. Only the following subset of variables was examined at ND sample points: net radiation, elevation, slope, aspect, slope position, landform and distances to the nearest road, water, trail, human habitation, and opening.

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[2]See Appendix C for the Forest Service instruction sheet on the "feel method", given to me by W. Basko, of the Flathead National Forest.

In addition to measuring and recording the parameters shown in Table 1, I made sketch maps of the den layout (see Appendix A), and wrote narrative descriptions of the den and general setting (see Appendix B for sample den data form). I noted features such as numerous, shallow or incomplete excavations or other subsidiary dens, bones, and trails leading into the den site. Prey use and human activity in the vicinity was briefly noted.

Photographs of each den were taken. These included views of the den from the four cardinal directions, at 30.5 m and 61 m distance.

Data Analyses

Means and standard deviations for DS, DA, and ND were calculated for continuous variables. To assess normality, I examined frequency distributions and probability plots. Differences in continuous variables among DS, DA, and ND were initially examined using Student's t-test (for variables measured within DS and DA) and ANOVA (for variables measured in all 3 categories).

Despite the apparent large differences among dens (e.g., differences in actual elevations and distances from human habitation), I felt that commonalities might exist among all of them. I.e., wolves may not use den locations with exactly the same variable values, from one pack territory to the next. However, they may be using locations, from one pack territory to another, that are comparable. Thus given that wolves could, and do, inhabit a variety of environments in northwest Montana and southern Canadian Rockies, actual values were of less interest than relative values. I chose to adopt a rank-based method of analysis which placed all the dens on the same "ruler" so that differences among DS, DA, and NS could be assessed. (E.g., if wolves tend to den at lower elevations within a given area, then ranks for DS should be lower than ranks for DA, which should be lower than ranks for ND, across all dens, regardless of the actual base elevations and whether terrain surrounding a den rises up steeply or moderately.) All numerical variables were subjected to rank transformation, then analyzed using the nonparametric Friedman test.

Categorical variables were analyzed with chi-square procedures.

Because of the large number of dependent variables, I chose a relatively conservative α-level. All t-tests, ANOVAs, Friedman test, and chi-square analyses were considered significant at $P \leq 0.005$.

RESULTS

Dens

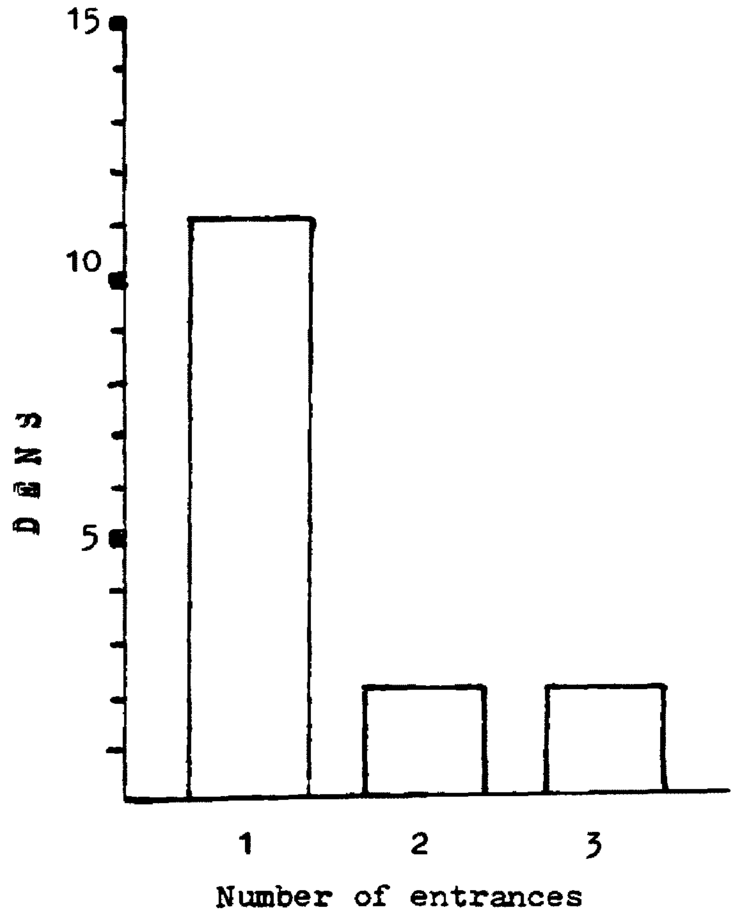
Of the 15 natal dens examined, 14 were excavations--i.e., burrows dug into the soil. One den was in a large, downed, hollow log, probably a western larch. The entrance was located at the base of the tree, in the root system, and the soft, rotted material inside the log had probably been cleared out by wolves, or perhaps a previous animal occupant. A very similar, second hollow log den, was observed approximately 1 km away. However, since this was probably not a natal den, it was not included in any analysis.

Eight of the 15 dens were located at the base of trees or stumps, with den entrances often framed by tree roots. One den entrance was located in a narrow space between fallen lodgepole pines, and the den had been dug beneath a jumble of crisscrossed trees.

Mean diameter of den entrances was 41 ± 10 cm (SD). Most dens had 1 entrance; 4 had 2 or 3 entrances (Fig. 3). Average distance between the ground surface and den ceiling was 0.9 ± 0.4 m, while den passages averaged 3.2 ± 1.2 m in total length, from entrance to back wall of the den. Maps of several dens are displayed in Appendix A.

Values of positional and cover variables (Table 2)

Fig. 3. Number of entrances per wolf den.



varied widely among the dens.

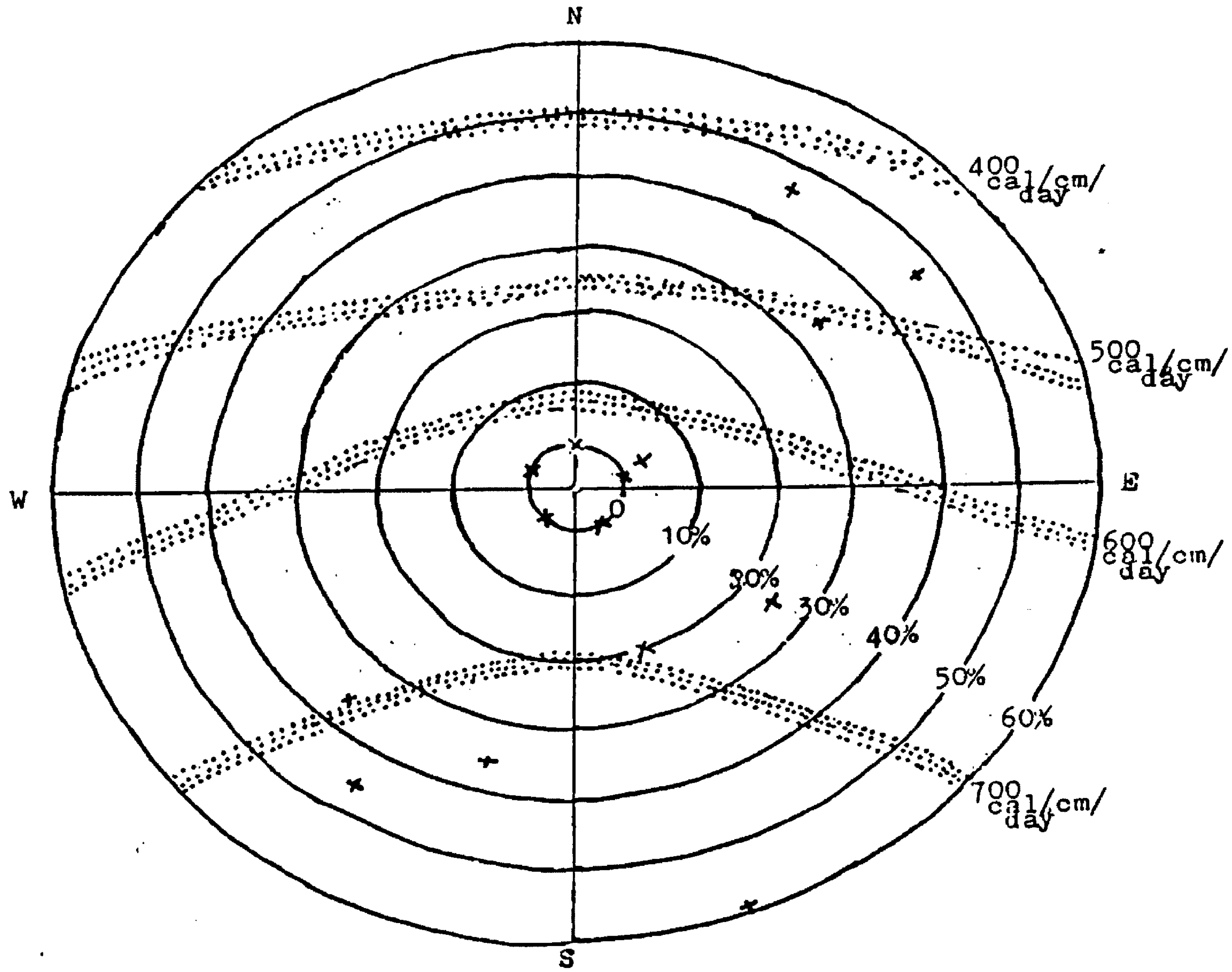
Wolf dens received an average net solar radiation of 618.2 ± 105.0 cal/cm/day (Fig. 4). Five dens were located on terrain with zero slope. However, of the 10 other dens, 5 faced in a southerly direction, 4 faced generally eastward, and only one faced northward. No dens were oriented toward the west. Seven of the 15 dens were located on lower slopes, 6 on valley bottoms, and 2 on short slopes. Presence of edge was split nearly evenly between "yes" and "no." Edge was visible from 8 dens, and not visible from 7. All dens but 1 were located within a coniferous forest ecotype; a single den was sited in a grassland ecotype. Of the various landforms on which dens occurred, glacial till was the most common. Seven dens were located on till, while 5 occurred on glaciofluvial or glaciolacustrine deposits. Convex slopes of 20-60% were the sites of 2 dens, and 1 den was located in a floodplain. Soil textures associated with the dens were: sandy soils--7 dens, loamy soils--6 dens, and silty soils--2 dens. Eight wolf dens occurred in the young-mature forest structural class, 5 in the pole/sapling class, and 1 each in the sapling forest and herbaceous structural classes.

Table 2. Positional and cover characteristics of wolf dens in northwest Montana and southern Canadian Rockies.

Variable[1]	Mean	SD
MACRO (m)	8.8	13.2
ELEV (m)	1350.9	227.9
SLOPE (%)	23.2	21.1
CC (%)	50.0	26.5
HC305 (%)	70.7	27.5
HC61 (%)	95.6	11.1
ROAD (m)	1117.8	1681.6
WATER (m)	206.0	160.4
TRAIL (m)	4190.1	5216.3
HUMAN (m)	7543.1	7994.3
OPEN (m)	149.3	122.5

[1]Variable abbreviations are defined in Table 1.

Fig. 4. Slope(%), aspect, and net solar radiation of wolf dens.[1]



[1]Stippled bars are approximate isograms of net radiation. Slope increases with distance from the center.

Den site selection

Examination of the distributions of the continuous variables revealed strongly non-normal data. Standard deviations among DS, DA and ND were compared and found to differ greatly (Table 3) for certain variables, making the results of t-tests and ANOVAs suspect. Also, on initial examination, variability among dens for certain variables appeared to be great. For example, mean elevation in DS ranged from 1095 m to 1809 m, and mean distance to nearest road ranged from 39 m to 5960 m. Nonparametric tests were employed to help correct for the heteroscedastic nature of the data, and to allow comparison of DS to DA, and both DS and DA to ND.

The ranking of elevation, slope and distances to nearest trail, human habitation and opening differed significantly among DS, DA, and ND (Table 4).

Inspection of the sums of ranks indicated that the trend for elevation was lowest elevations overall within DS, somewhat higher elevations in DA, and highest elevations in ND.

Terrain within DA might have been slightly flatter overall (more moderate slopes) than within DS, according to the sums of ranks. However, the major difference in slope appeared to lie between ND, with the steepest slopes, and DS and DA.

Table 3. Characteristics of den sites (DS), denning areas (DA), and non-den areas (ND) in northwest Montana and southern Canadian Rockies. *=largest s.d. more than 2x smallest s.d.

Variable	DS mean s.d.	DA mean s.d.	ND mean s.d.	P[1]
MACRO(m)*	9.5 13.7	37.1 163.0	N/A	0.040
ELEV(m)	1351.9 221.4	1370.3 225.3	1557.3 381.2	0.000
SLOPE(%)	15.5 18.8	15.6 20.2	23.2 22.1	0.001
NETRAD(cal/ cm/day)	629.4 60.3	626.4 54.0	596.0 88.2	0.000
CC(%)	18.9 21.3	14.0 18.5	N/A	0.040
HC305(%)	66.1 27.3	58.4 31.6	N/A	0.030
HC61(%)	91.0 17.3	84.9 25.6	N/A	0.020
ROAD(m)	1117.3 1641.3	1181.5 1646.6	1735.3 2477.0	0.012
WATER(m)	207.5 156.8	255.3 240.7	307.8 284.0	0.001
TRAIL(m)*	4957.0 11445.3	4169.3 5035.0	5528.3 9534.1	0.429
HUMAN(m)*	7509.3 7771.5	7561.5 7806.5	9791.5 17858.2	0.178
OPEN(m)*	143.0 118.3	215.5 269.5	391.9 575.4	0.000

[1]Test statistic t for variables measured in only DS and DA. F ratio for variables measured in DS, DA, and ND.

Table 4. Numerical variables (d.f.), Friedman's test statistic (T), and approximate critical level (p).

Variable	T	p
MACRO(1)	3.84	0.05
ELEV(2)	66.59	<0.0005
SLOPE(2)	10.79	0.005
NETRAD(2)	9.24	0.01
CC(1)	6.69	0.01
HC305(1)	7.66	0.006
HC61(1)	4.67	0.03
ROAD(2)	2.43	>0.25
WATER(2)	2.84	0.24
TRAIL(2)	20.34	<0.0005
HUMAN(2)	14.00	0.0009
OPEN(2)	15.72	<0.0005

Similarly, distance to nearest trail was greatest for ND, and about the same for DS and DA.

Distance to nearest opening was least for DA, but DS was only slightly further from nearest opening. ND had the greatest distances to nearest opening, and the difference between the average distances in ND, versus DS and DA, appeared to be substantial.

While differences between DS and DA for canopy cover, and hiding cover at 30.5 m and 61 m, were not statistically significant, all three variables showed a trend toward greater cover in DS, and somewhat less cover in DA.

Aspect differed significantly among DS, DA, and ND (X^2=36.5, d.f.=8, $P \le 0.001$). From visual inspection of the data, it appeared most of the difference in aspect existed between DS and ND, as well as DA and ND. Sample points within DS and DA appeared to occur much more frequently on flat to rolling terrain than sample points in ND. On sloping ground, the southern aspect was predominant within DA and DS, and eastern and western aspects were somewhat more common among sample points in ND (Fig. 5 and Table 5).

Slope position also differed significantly among DS, DA, and ND (X^2 =86.2, d.f.=10, P=0.000). As with aspect, DS and DA seemed fairly similar. The most frequent classification in DS and DA was valley bottom or lower slope. While lower slope was the most frequent slope position for ND, there were considerably more midslope (20%

Fig. 5. Frequency histogram of slope aspects in den sites (DS), denning areas (DA), and non-den areas (ND). Frequency of zero aspects indicated by length of diagonal "arrows" pointing to center of circles.

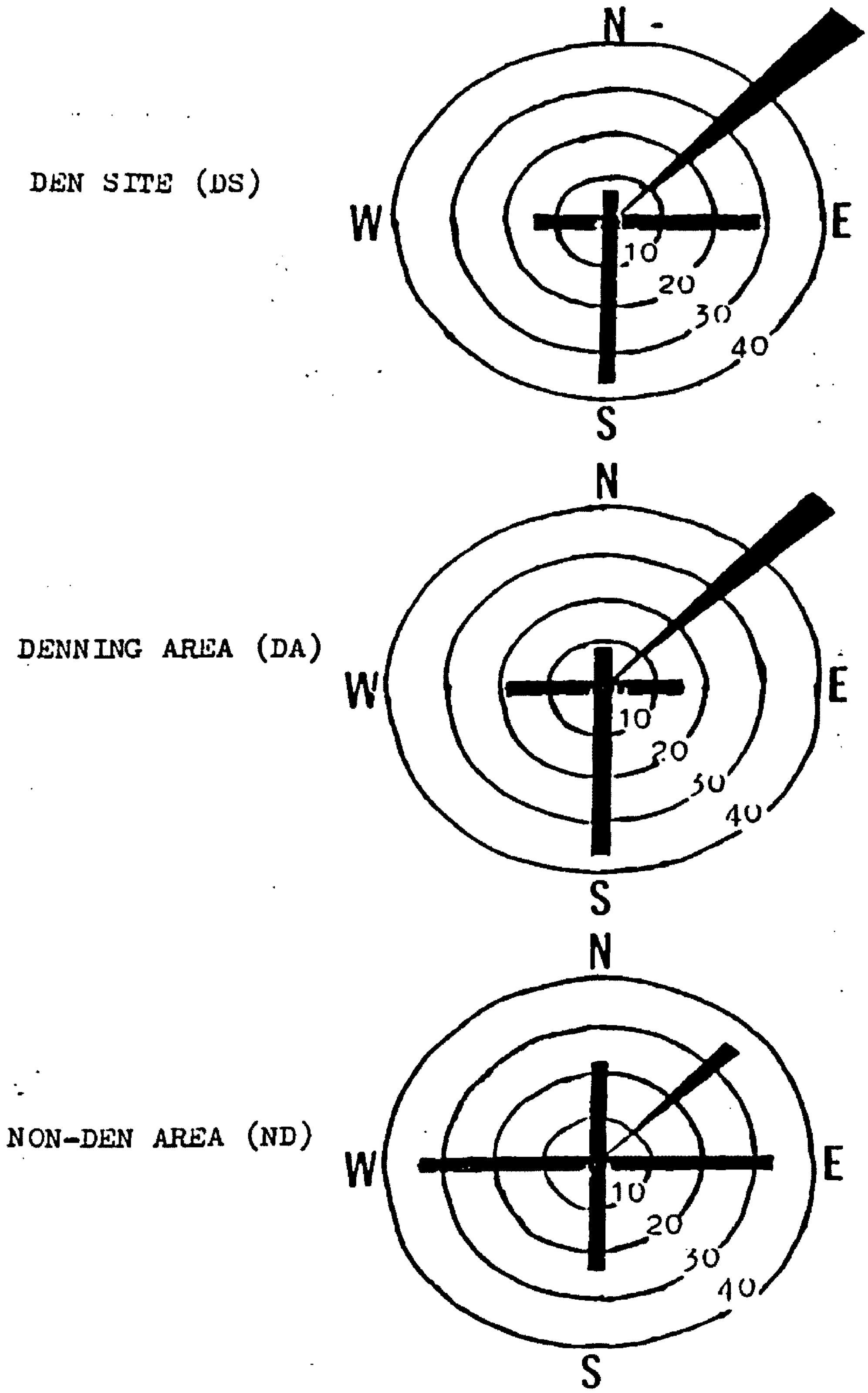


Table 5. Percentage of sample points on various slope aspects, in den sites (DS), denning areas (DA) and non-den areas (ND).[1]

Aspect	DS (n=150)	DA (n=150)	ND (n=150)
LEVEL/ GENTLY ROLLING	41.3	38.7	24.0
NORTH	4.7	6.0	15.3
EAST	19.3	10.7	22.0
SOUTH	24.7	25.3	16.0
WEST	10.0	19.3	22.7
total	100.0	100.0	100.0

[1]Pearson chi-square=36.5, d.f.=8, P=0.000.

in ND, zero in DS) and upper slope (8% in ND, 1.3% in DS) classifications in ND than in DS or DA (Table 6).

There were significant differences among DS, DA, and ND for landform (X^2=52.9, d.f.=8, P=0.000). Glacial till was the most frequent landform type in all 3 categories. However, the differences probably lay in the greater proportion of convex slopes and breaklands within ND than in DS or DA. DS and DA contained more glaciolfluvial/glaciolacustrine and floodplain landforms than non-den areas (Table 7). Edge and ecotype did not differ significantly (P>0.005) between DS and DA (Table 8).

Neither did soil texture differ significantly between DS and DA. Nevertheless, the most frequent texture type in den sites was loam (44.7%), whereas in denning areas, the most frequent texture type was silt (45.2%). Structural class does not differ either between den sites and denning areas (Table 9).

Table 6. Percentage of sample points at various slope positions, in den sites (DS), denning areas (DA) and non-den areas (ND).[1]

Slope position	DS (n=150)	DA (n=150)	ND (n=150)
Plains	0.7	5.3	4.0
Short slopes	11.3	6.7	8.7
Valley bottom	45.3	39.3	17.3
Lower slopes	41.3	44.7	42.0
Mid-slopes	0.0	4.0	20.0
Upper slopes	1.3	0.0	8.0
total	100.0	100.0	100.0

[1]Pearson chi-square=86.2, d.f.=10, P=0.000.

Table 7. Percentage of sample points on various landforms, in den sites (DS), denning areas (DA), and non-den areas (ND).[1]

Landform	DS (n=150)	DA (n=150)	ND (n=150)
Floodplain	9.3	6.0	15.3
Glaciofluvial/ glaciolacustrine	34.7	28.0	12.7
Glacial till	48.7	57.3	56.7
Convex slopes, 20-60%	7.3	8.0	17.3
Breakland, rockland	0.0	0.7	9.3
total	100.0	100.0	100.0

[1]Pearson chi-square=52.9, d.f.=8, P=0.000.

Table 8. Percentage of sample points in various ecotypes and having edge, in den sites (DS) and denning areas (DA).[1]

Variable	DS	DA
	(n=150)	(n=150)
Ecotype:		
Wetland	1.3	0.7
Grassland	3.3	6.7
Woodland	2.7	4.0
Shrubland	12.0	14.0
Coniferous forest	80.7	74.7
	(n=149)	(n=146)
Edge presence	53.7	56.2

[1]For ecotype, Pearson chi-square=3.0, d.f.=4, P=0.561. For edge, Pearson chi-square=0.18, d.f.=1, P=0.670.

Table 9. Percentage of sample points with various soil textures and structural classes, in den sites (DS) and denning areas (DA).[1]

Variable	DS	DA
Structural class:	(n=150)	(n=147)
herbaceous	4.7	8.8
shrub	12.0	15.0
sapling	14.0	5.4
pole/sapling	39.3	40.8
young/mature	30.0	29.3
old growth	0.0	0.7
Soil texture:	(n=150)	(n=146)
clay	0.7	2.1
silt	31.3	45.2
loam	44.7	28.1
sand	23.3	24.6

[1]For structural class, Pearson chi-square=9.1, d.f.=5, P=0.107. For soil texture, Pearson chi-square=10.4, d.f.=3, P=0.015.

DISCUSSION

The structure, dimensions, and layout of wolf dens in this study appear to be similar to those in other investigations. While there were no rock cave dens as reported by other researchers (Joslin 1967, Stephenson 1974, Mech and Packard 1990), both Joslin and Fuller (1989) documented the use of hollow logs. Excavated burrows were the most common type of wolf den encountered in this study, and appear to be in most other localities, as well (Lawhead 1983). Several workers have suggested that wolves enlarge dens of other species, such as foxes (Mech 1970, Lawhead 1983). While there is no way to prove this with the dens I examined, I suspect that in the Rocky Mountain region, abandoned coyote dens may be used by denning wolves.

Most of the dens in this study were quite simple structurally, with a single entrance and one main passageway, and occasionally one short, subsidiary tunnel branching off from the main tunnel. The one distinct exception to the pattern, in this study, of fairly simple dens was the Panther River "den complex" in Banff National Park (the complex consisted of 3-4 dens, in close proximity to one another, which were accessed by 2-3 entrances each. There were two dozen incomplete dens or small holes dug into the bank.) Haber (1968, 1977) and Lawhead (1983) theorized that structurally complex dens (multiple entrances, multiple passageways, several dens adjacent to one another) represented older structures, with complexity of dens increasing with increasing age. In 1947 (p. 144), Cowan reported on a traditional den site (which wolves had been using for at least 8 years) on the Panther River, at approximately the same location as the one I examined. Cowan also indicated that the Panther site was one of the few places in the park in 1943 that showed any evidence of resident wolves (pp. 150-151). In more recent times, denning wolves have been observed at the Panther River site since 1982 (M. Gibeau, pers. commun.). Thus, the den site was at least 8 years old when I visited it, and quite likely had been used, off and on, for at least 50-60 years.

The simple dens of the pioneering wolf population further to the south, in southeastern B. C. and Montana, also seem to correspond with Haber's and Lawhead's ideas regarding den age.

Habitat selection

Habitat selection[1] by large carnivores such as the

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[1]"Selection," is not used here to imply any conscious action. It is quite possible that for certain species--and the wolf would likely be one--some "selection" does occur on a conscious level. However, whether choices are made consciously or not, to the extent that options do exist (including the option to pick a very maladaptive situation) animals **are** "selecting," in the ultimate sense.

wolf has been given little consideration, relative to other faunal groups such as birds (e.g., selection of nest sites, roost sites, foraging sites) and ungulates (e.g., winter and summer ranges, selection of calving sites). The question has perhaps been of less interest because "habitat" in its usual sense--i.e., a distinctive vegetative type--probably has little direct bearing on the well-being and survival of a primarily flesh-eating species.

However, during a brief but critical period of the year, wolves modify their habitat use. During the denning season, they switch from travelling in a circuit-type pattern within their home range to travelling out radially from a central place. This unavoidable, temporary restriction on mobility may require that prey be locally even more abundant and accessible than is necessary throughout the rest of the year. Also, suitable habitat must provide security and cover for vulnerable young. Thus, selection of a den site, unlike wolves' habitat selection during most of the year, may be more directly constrained by the types of parameters typically examined in other studies of habitat choice.

Avian biologists theorize that habitat selection occurs as a series of hierarchical decisions that vary with geographic scale (Hutto 1985). At the broadest, largest scales, "extrinsic" factors such as habitat accessibility or lack of knowledge about a particular habitat, determine whether a habitat is used or not. As scale shrinks, and "decisions" are made at a more local level, "intrinsic" factors such as food and cover become overriding considerations (Hutto 1985:457). The "microhabitat," the local conditions in which an animal occurs at any given time, is "chosen" on the basis of cues closely tied to the ultimate factors that determine success. And in fact, at the microhabitat level, those cues are likely to be equal to those ultimate factors. This study focuses on the selection of a particular microhabitat--the wolf den site--from within the confines of an established pack territory.

Study Design

Within any wolf home range, there are probably a number of suitable denning areas. On the other hand, in heterogeneous environments such as the Rocky Mountains, there are likely areas within any given wolf home range that are clearly unsuitable for denning. Such places would include mountaintops, cliffs and lakes. Instead of sampling the entire home range, I focused on areas that, on a gross level, had some ostensible denning potential. These areas were sites within moderate distance of the dens themselves. (I selected a radial distance of 10 km.) I considered the area beyond 1 km distance from the den as generally representative of available denning habitat, which I compared to the area that was **actually** used as denning habitat (den sites and denning areas). By this method I hoped to establish average conditions at den sites and denning areas and determine whether they differed from those in the surrounding landscape. For certain variables[1] I was unable to take measurements in the non-den areas, so could assess their importance at the den site/denning area level only.

While rank transformation helped with some of the difficulties posed by non-normality (Conover and Iman 1981) they were not entirely satisfactory in resolving the problem of how to compare a group with densely-packed sample points (den site and denning area) to a group with less-densely packed sample points (non-den area). Nonetheless, I do believe the basic conclusions of this investigation hold true, and that by taking a fairly conservative approach to significance levels, I did not erroneously identify any factors as important that do not play a primary role in den site location within the pack territory level.

However, there is room for further work at broader scales. One way to approach this would be to compare my sampling areas, centered around actual dens, to sampling areas centered on random locations. This work could be done at the level of a valley or drainage in which a wolf pack is

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[1]Macro relief, canopy cover, hiding cover, ecotype, edge, structural class, and soil texture.

located, or at even greater scales, such as all of western Montana, with randomly located sampling areas scattered throughout the region compared to the sampling areas in my study. At this very broad level, and particularly if other variables could be incorporated into the investigation (such as prey density and human population density), the results might point to future sites for wolf territory establishment.

Den Site Selection Factors

Nearly all variables that were identified as significant are related to elevation. Elevation itself was strongly significant in all tests, using both parametric and non-parametric methods. It appears that elevation is an overriding selection factor within the pack territory.

Wolves tended to den at lower elevations, on valley bottoms and lower slopes. Landforms near dens were most often depositional types: glacial till and glaciolfluvial/ glaciolacustrine deposits. Further away from wolf dens, the proportion of erosional landforms increased (convex slopes, rock and breaklands). Slope generally increased with distance from wolf dens, which would be expected with increases in elevation and erosional landform types. This also explains the greater proportion of "zero" aspects in den sites and denning areas, and in non-den areas, higher percentages of east and west aspects. Because of the tendency for valleys and mountains to run roughly north-south in the region, more mountain slopes tend to face east or west.

Cover may be a factor in den site location. Although distance to nearest opening was the only significant variable among the four cover-related variables (canopy cover and hiding cover at 30.5 and 61 m were the other three), cover values appeared to be somewhat greater for den sites than for denning areas. My observation in the field, bolstered by these patterns, was that denning areas occurred generally in areas with a mosaic of meadows, grassland, or other large openings, and forest. However, the dens themselves were very often located in relatively dense cover, in close proximity to more open sites. Cover values went up, and distances to nearest opening went down, once one moved beyond the denning area, probably because the terrain was also rising in elevation, and slopes were steeper and more forested.

While net solar radiation did not appear to be an important factor in determining the location of a den, there was a tendency for slopes in den sites to face south and east. Western and northern aspects were relatively uncommon at den sites compared to non-den areas. Thus, wolves probably select, to a moderate extent, for south and east-facing slopes.

Soil texture, while not statistically significant, probably is a factor in den site location at the smallest scales, perhaps at scales even smaller than those I attempted to account for in this investigation. Wolves appeared to den within areas that had a somewhat higher proportion of loam, and a lower proportion of silt, than surrounding areas. As suggested by Mech (1970), the use of loamy and sandy soils is probably tied to ease of digging and/or drainage characteristics, with silts and clays draining less readily than coarser-textured soils. Dens may be short-lived, however, where sand predominates. The ceilings of several dens in my study had partially collapsed, and I noted a tendency for these dens to be located in relatively sandy soils.

Human Disturbance Factors

Distance to nearest road did not appear to be a factor in wolf den site use. However, many of the roads I identified, including those nearest to den sites, were not heavily traveled, nor even open year round. Wolves establish dens when many backroads--including logging roads on national forests and other remote byways--are still undriveable either because they are covered with snow or are too muddy. Therefore, at the time wolves are selecting den sites, roads may not function as roads. Without the appropriate cues (sight and sound of traffic) wolves may not respond to the proximity of roads, even though it could be a disturbance factor later on, as the roads become passable.

It is also possible wolves will select against sites near roads only when traffic is greater than a certain level. My working definition of a road may have been too broad on this count, and should have excluded roads where traffic was very light.

Land-use activities (e.g. logging, mining, ORV recreation, hunting, sight-seeing, wildlife observation) and the motives and behavior of people traveling the roadways probably affects the degree to which wolves are disturbed, harmed, or killed (Mech et al. 1988). Over time, wolves may learn to avoid roads in areas where these corridors pose regular and serious danger, and may habituate to roads where human presence is relatively innocuous (as in a national park.) The time at which wolves abandon natal dens, moving their pups to other dens or rendezvous sites varies, and the role of disturbance in prompting the moves is not clear (Mech 1970). Chapman (1977) found that the levels of human disturbance characteristic of national parks probably do not significantly affect the survival of pups, though disturbance at dens can result in responses ranging from barking and howling to den site abandonment.

The question of whether wolves avoid roads, during the denning season or at any time of year, is different than the question of whether wolves can **survive** near heavily used roads or in areas of high road density. In Minnesota (Mech et al. 1988) and Wisconsin (Thiel 1984) wolves do not occur where road densities exceed approximately 0.58 km/km^2. This is due primarily to ease of accessibility by humans and concomitantly high, human-caused wolf mortality. To my knowledge, in the 4 study areas, no wolf litters were lost during the denning season due to proximity to roads. In Minnesota, a large part of known wolf mortality is human-caused (Mech 1977, Fritts and Mech 1981, Berg and Kuehn 1982). This appears to be true as well for wolves in the WEP study area (Ream et al. 1987, 1988, 1989). Therefore, human access to areas inhabited by wolves, and proximity of wolves to areas of high human use, must be considered a leading problem for wolf conservation.

Given certain overriding considerations for den site location, such as elevation and proximity to food resources, wolves tended to den further away from human habitation and activity centers than expected. While this might seem to contradict the apparent lack of selection against roads, the difference may be that human residences represent a predictable stimulus in response to which wolves can easily adjust their travel patterns. Road traffic, particularly in the kinds of places where wolves have established themselves in the region, is usually intermittent to rare. There are other potential reasons for the apparent discrepancy between selection against human habitation and roads, including the fact that roads are used as travel corridors by wolves. It is possible that roads are such efficient paths for movement, perhaps particularly when the ground is snow-covered and roads are cleared or compacted, that a tendency to select against areas of human activity is, in this instance, overwhelmed by other imperatives. Also, human occupants were sparsely distributed in most of the areas I examined, but often roads were not. Even if selection against roads was a factor in den site location, wolves could not easily locate dens away from roads and still meet other habitat requirements (such as use of valley bottoms and proximity to prey species).

Other Considerations

In Minnesota, wolves avoid denning in the outer fringes of their territories, perhaps to avoid neighboring packs (Ciucci and Mech 1992, in press). Wolves also den closer to territory center as the size of the territory increases; this may be an attempt to minimize travel distances to and from the den. I did not attempt to assess this issue in my study. However, wolf densities are still relatively low in northwest Montana and the southern Canadian Rockies, and lack of interpack strife may be more characteristic of this region's population than of populations in other areas.

Also, territory boundaries were not known for several wolf packs in my study areas, but it appeared to me that for the packs whose territories had been mapped, den sites were not particularly close to territory centers. In a mountainous region (compared to a relatively flat to rolling region such as Minnesota), where travel corridors run in parallel fashion along valley bottoms, there may be less advantage to denning at territory center.

Selection of a den site may depend to a great extent on the location of previous den sites within the home range. Traditional den use was apparent among the dens I examined, though I did not statistically analyse this phenomenon. In most cases, it appeared that wolves returned to the same general location from one year to the next, but usually did not re-use a den from a previous year. Within the traditional areas I studied, dens were located several hundred meters to a little over a kilometer apart. Among WEP study animals, there have been at least two instances where not only has the same alpha female returned to a particular area to den, but later on her offspring has also gone to that same vicinity to whelp her pups. In Ciucci's and Mech's study in Minnesota, 86% of denning alpha females returned to denning areas previously used by them.

Management Implications

Land managers may want to consider that once an established pack is in an area, there is a high probability that the wolves will use the same denning area that they have in years past. For these traditional denning areas in particular, but in other areas as well, where there is either a) a current, high potential for the establishment of breeding pairs (e.g., reports of wolves in the area are numerous and reliable) or b) management emphasis is on preserving future options for wolf recovery, habitat managers should strongly consider the following policy:

1) Minimize open road densities. In areas where potential for human-caused mortality is high, roads should be closed, and not just during the denning season, because this is not necessarily when the most danger is posed to wolves by roads. New roads should not be built if at all possible, but if they are, traffic should be limited by administrative order and physical barriers, if necessary.

2) Maintain adequate cover in places suitable for denning.

3) Be alert to the effect of human occupancy in proximity to wolf denning areas. On public land, work

camps, permanent structures, and similar facilities which are operational at least from winter to early summer (June) are probably best located a minimum of 7-10 km from any traditional denning area. If possible, they should also be located away from valley bottoms and areas where mosaics of meadow and timber make attractive habitat for both prey animals and wolves.

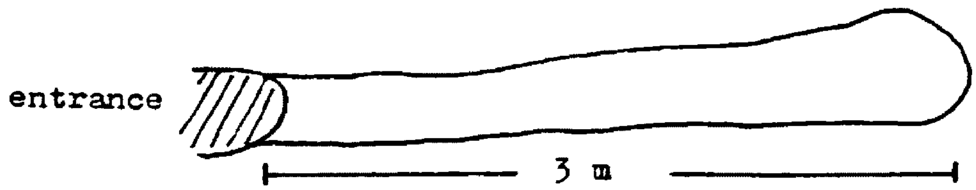
Summary

Wolves in northwest Montana and the southern Canadian Rockies appeared to den in valley bottoms and on lower slopes, and in areas characterized by a higher proportion of meadows and other openings than non-den areas. However, the den site itself may have been more densely forested than the denning area in general. Wolf den sites tended to be found closer to trails used for horsepacking and hiking than areas further removed from wolf dens, probably as a consequence of both wolf dens and trails being concentrated in the lower elevations. Den sites and denning areas occurred on flat to moderate slopes, with southern and eastern exposures more common than western or northern aspects. Human habitation lay at somewhat greater distances from areas near dens than from non-den areas.

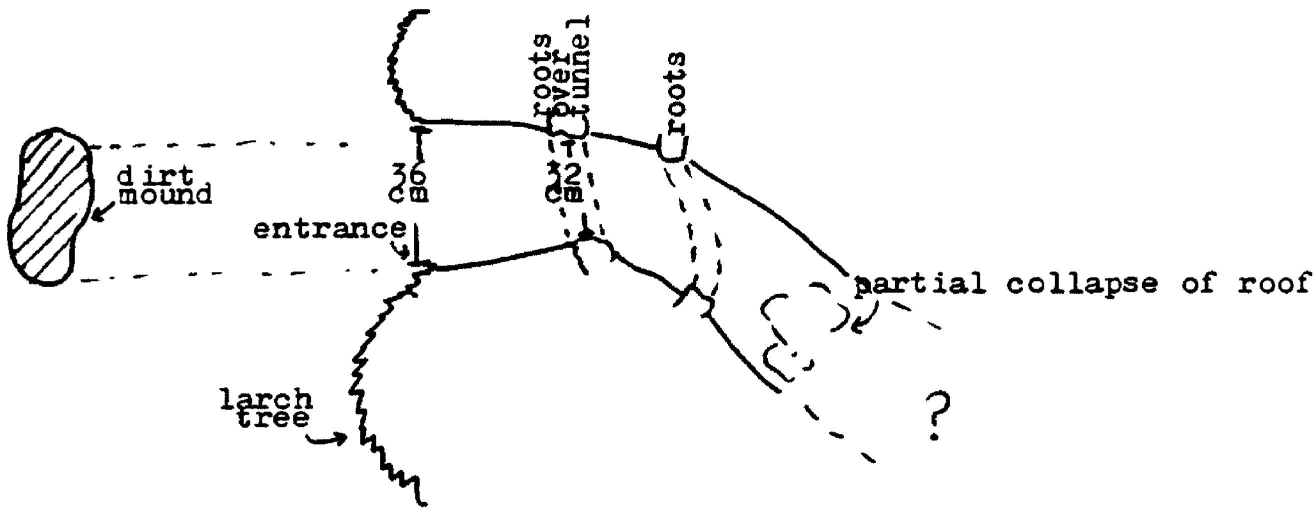
There was no difference among areas close to dens and those farther away in regard to distance to nearest road or distance to nearest water. Also, macro relief, net radiation, ecotype, presence of edge, and structural class did not appear to be important in determining the location of wolf den sites. Soil texture, canopy cover, and hiding cover, while not identified as statistically significant factors, are still believed to play roles in den selection at the extreme local level--perhaps within an area smaller than a 100-m-radius circle.

APPENDIX A

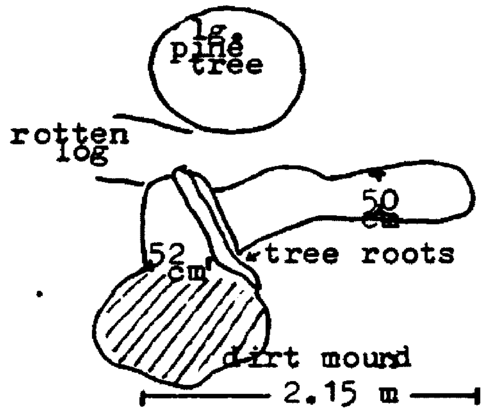
CONFIGURATION OF SEVERAL WOLF DENS IN
NORTHWEST MONTANA AND SOUTHERN CANADIAN ROCKIES
(not to scale)



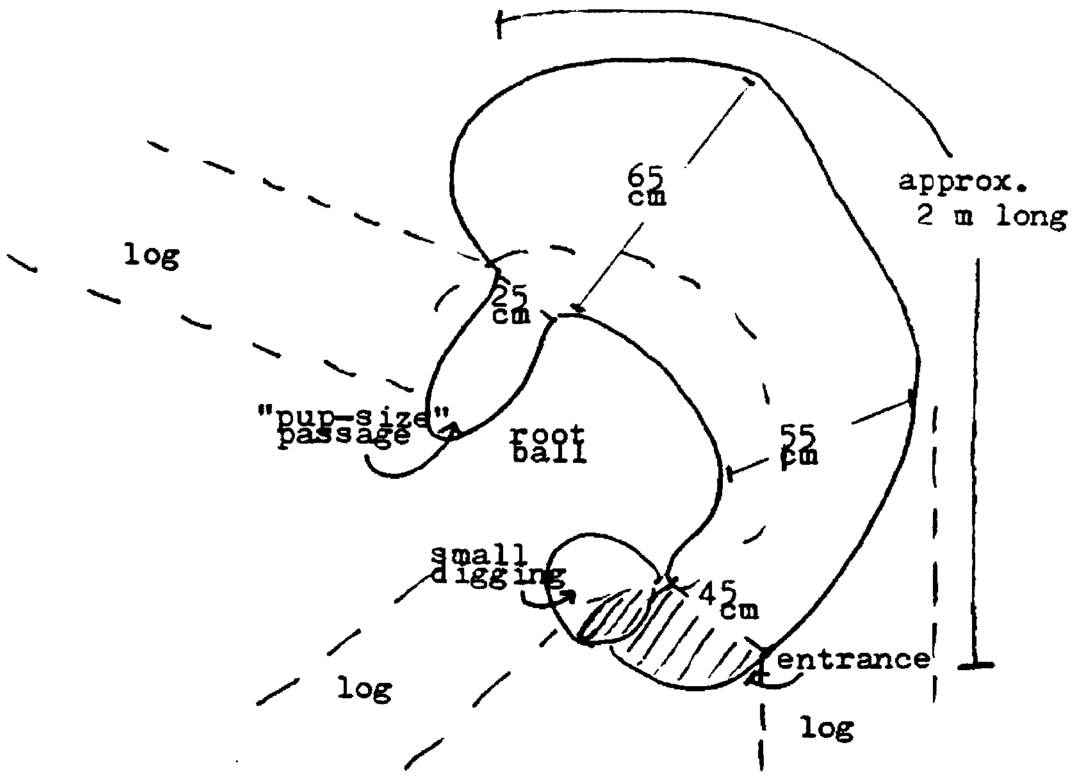
North Fork Flathead drainage, B. C. 1987 den. Under group of small spruces.



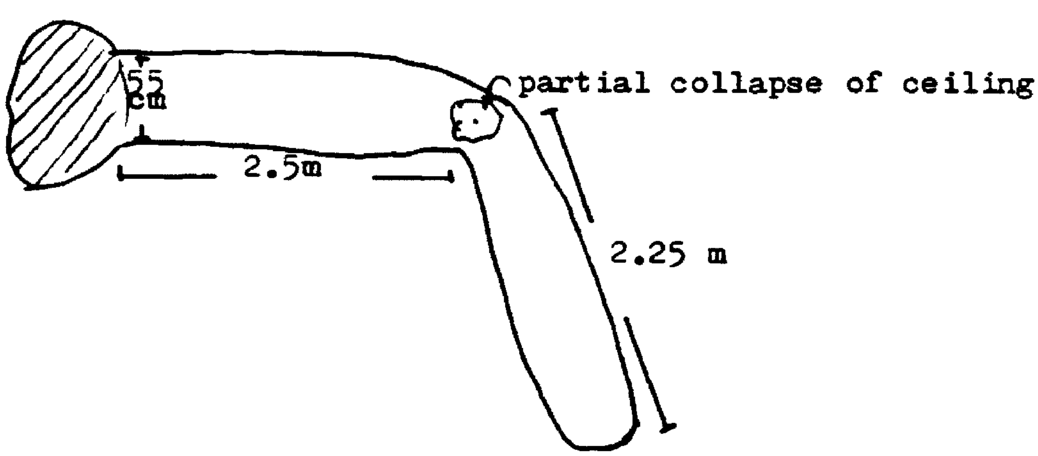
Wigwam drainage, B. C. 1988 den. Dug under large larch tree. 3 m long.



North Fork Flathead drainage, B. C. 1989 den. At base of large pine.



Glacier National Park, MT. 1990 den. Under root ball of downed log.



Blackfeet Indian Reservation, MT. 1987 den. Tree roots frame entrance.

APPENDIX B

DEN DATA FORM

DEN NAME____

DATE________________________ PERSONNEL____________________

PACK______________________ YR. OF CONSTRUCTION__________

UTM NORTH______.______ EAST _______.____ (ZONE__________)

GENERAL LOCATION____

____

SLOPE POSITION____

MACRO RELIEF (above nearest level terrain)______________m

ELEV_________m SLOPE_________% ASPECT_________degrees

CANOPY COVER _________% EDGE yes no

HIDING COVER	N	E	S	W	
30.5m	____	____	____	____	X=___
61m	____	____	____	____	X=___

ECOTYPE____

GENERAL DESCRIPTION OF HABITAT, SETTING___________________

____

____

MAJOR TREE SPP.____

MAJOR SHRUB/FORB SPP._____________________________________

LANDFORM________________ SOIL TEXTURE____________________

STRUCTURAL CLASS_______________

DISTANCE TO NEAREST:

ROAD________________m describe________________________________

WATER________________m describe________________________________

TRAIL________________m describe________________________________

HUMAN________________m describe________________________________

OPEN________________m describe________________________________

DEN TYPE (excavation, hollow log, etc)____________________

NO. OF ENTRANCES__________ DIA. OF MAIN ENTRANCE___________cm

DEPTH BELOW GROUND____________m LENGTH OF PASSAGE(S)________m

DID YOU ENTER? IF SO, DESCRIBE______________________________

____

SPACE FOR SKETCH MAP OF DEN:

IF DEN USED THIS YEAR, WHAT DO YOU OBSERVE ABOUT THE SITE IN TERMS OF VEGETATION?____

____

OTHER OBSERVATIONS ("PUP" HOLES, SCAT, BONES, TRAILS)________

____

____

ANY OBSERVATIONS ON PREY USE/DENSITY IN AREA?________________

____

ANY OBSERVATIONS ON HUMAN USE OF AREA?________________________

____

OTHER REMARKS:____

____

____

___ soil sample?

___ photos?

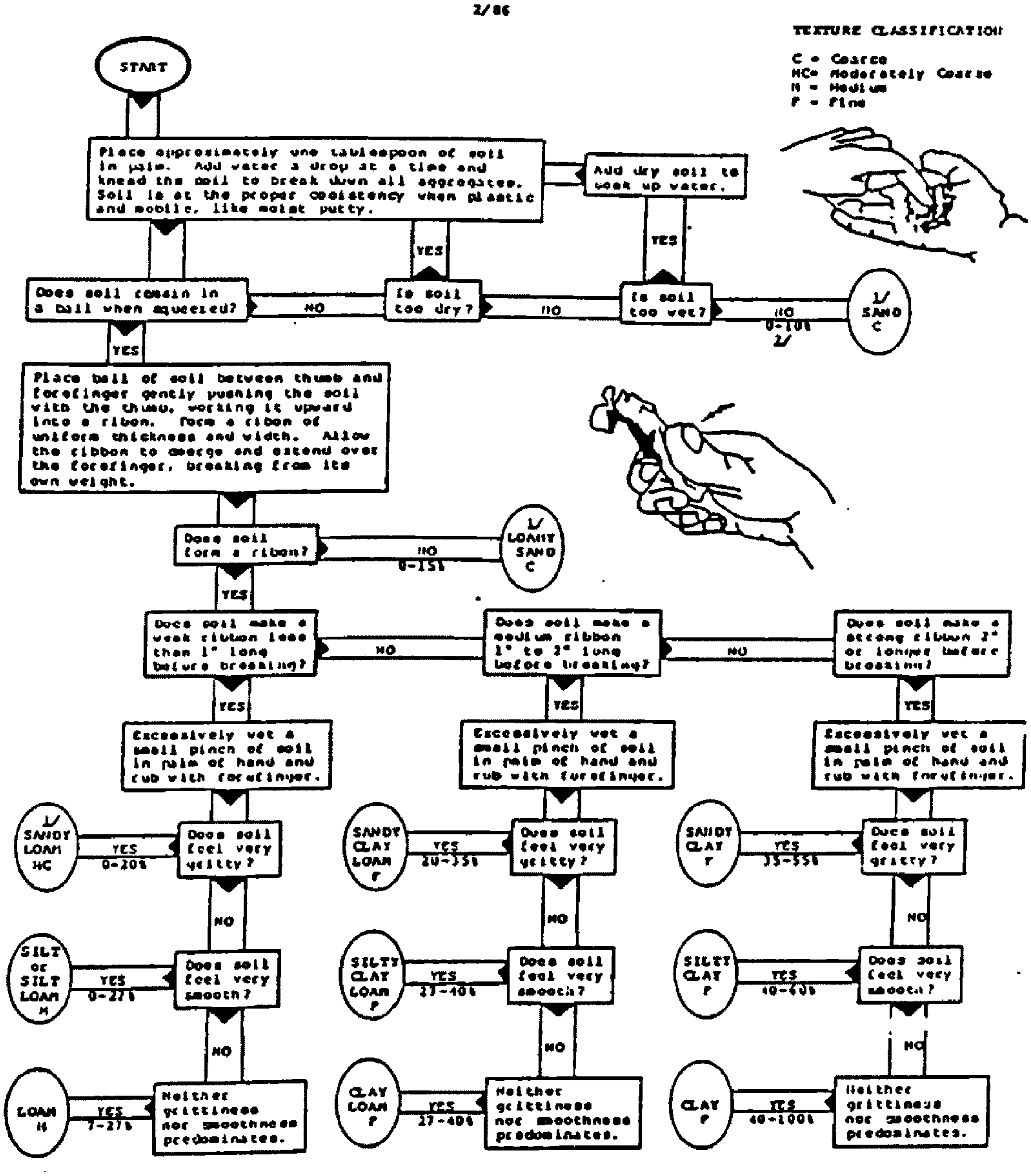
___ map drawn?

APPENDIX C

PROCEDURE FOR DETERMINING SOIL TEXTURE BY THE "FEEL METHOD"[1]

DETERMINING SOIL TEXTURE BY THE "FEEL METHOD" 3/

2/86



1/ Sand particle size should be estimated (very fine, fine, medium, coarse) for these textures. Individual grains of very fine sand are not visible without magnification and there is a gritty feeling to a very small sample ground between teeth. Some fine sand particles may be just visible. Medium sand particles are easily visible. Examples of sand size descriptions where one size is predominant, are: very fine sand, fine sandy loam, loamy coarse sand.

2/ Clay percentage range.

3/ Modified from: Thien, Steve J.; Kansas State University, 1979 Jour. Agronomy Education.

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[1]Form obtained from W. Basko, soil scientist, Flathead National Forest.

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