5-1979

# Development and Validation Test of a Mule Deer Habitat Rule

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DEVELOPMENT AND VALIDATION TEST OF A MULE

DEER HABITAT RULE


by

Glenn Gephart


A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Science


Approved:


Utah State University
Logan Utah

1979

## ACKNOWLEDGMENTS

Glenn Gephart

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ABSTRACT

Development and Validation Test of a

Mule Deer Habitat Rule

by

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Utah State University, 1979

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A mathematical description of Rocky Mountain mule deer (Odocoileus hemionus hemionus) habitat was developed and subjected to validation testing using correlation and multiple regression statistical techniques. Data were collected on a central Utah study area, which was divided into mountain and desert regions.

Data on deer utilization and several habitat components from 86 study plots visited in 1976 were used to develop a habitat rule.  Data from 46 study plots visited in 1977 were used to test the accuracy of the rule.  Deer utilization was determined from pellet group counts on 20 0.001 ha pellet plots at each study plot.

The regression model accounted for 53 and 43 percent of the respective variation in pellet group density in mountain and desert habitats observed in 1976.  However, the same model explained only 8 and 0.02 percent, respectively, of the observed variation in the 1977 validation test data.

Reliability and applicability of statistical habitat models and importance of validation of results are discussed.

(97 pages)

INTRODUCTION

The severity of the impact of mankind's activities upon the world's resources and environment has increased drastically during the twentieth century.  Recognizing the demands of urbanization, population growth, industrial expansion, technological advances, and resource exploitation, Congress enacted the National Environmental Policy Act of 1969 (NEPA). The act established a national policy of using all practical means to create and maintain harmonious conditions between man and nature.  The declared purpose of NEPA includes requiring efforts to enrich the under-standing of the ecological systems and natural resources important to the nation.  The Forest and Rangeland Renewable Resources Act of 1974 (RPA), citing the importance of the renewable resources in forests and rangelands, required periodic assessments of the supply of and demand for these resources (Murphey 1977).  However, no system capable of sup-plying the understanding or assessments required by NEPA nd RPA pres-ently exists.

In order to provide the methods and information needed to fulfill the requirements of NEPA and RPA, the U. S. Forest Service (through the Surface Environment and Mining Program) contracted with a multidisci-plinary group from Utah State University to develop a scientific method, QRD, and an ecosystem classification and information system, ECOSYM (Anonymous 1978, Davis and Henderson 1976).  The acronym QRD stands for question analysis, rules, data.  Question analysis reduces a general

problem to the most specific questions possible. A rule is the formula which includes those variables necessary to answer questions. It transforms data into information from which answers can be developed. Data are the information required for input into rules.

This research was a sub-project in the development of ECOSYM and QRD. The ultimate objective was to construct a predictive rule which, when supplied with data on key environmental components, would describe the value of an area as habitat for Rocky Mountain mule deer (Odocoileus hemionus hemionus).

## The ECOSYM Concept

Davis and Henderson (1976) described the conceptual framework of ECOSYM. The system obtains and delivers information to land managers by means of a comprehensive framework of classification and mapping of ecosystems. To provide the flexibility to serve the needs of a variety of users over a broad geographical area, ECOSYM has three basic characteristics: (1) basic components, (b) hierarchical structure, and (3) objectivity. Basic components are non-integrated, uninterpreted data. These components are bedrock, regolith, topography, climate, soil, current vegetation, surface water, and biotic potential. ECOSYM, therefore, differs from classification methods such as Bailey's (1976) Eco-Region, based on integrated components, or Davis's (1977) physiographic classification of New York state, which uses only one basic component. Hierarchical structure provides various levels of resolution of the components. Thus, data to answer both detailed and more generalized questions are available from one system. Objectivity determines class

boundaries of components (e.g. plant community types) using measurable criteria without interpretation.

## Rules

Rules for wildlife species constitute conceptual models which express in semi-quantitative form the net habitat requirements for a given species (Davis and Henderson 1976). Hence, rules could be used to describe the potential quality of a habitat for a species. Wolfe et al. (1978) discussed the conceptual basis of rule development and utilization of rules in resource management in detail.

A basic hypothesis of rule development is that habitat value for a given species is some function of environmental components:

Habitat value = f(component 1, component 2, ...., component n)

The form of the function f and the identification of environmental components must be determined for each species. The validity of this hypothesis is supported by numerous studies. The general habitat requirements for any species are food, water, cover, and interspersion (Dasmann 1964). Shannon et al. (1975) considered habitat selection an expression of a complex response to a large number of intrinsic and extrinsic variables which define the functional environment for an animal. Hirst (1971) described a natural community as a multivariate complex with the distribution of any specific organism therein being a function of the distribution of one or more biotic or physical factors. This multivariate concept of habitat is similar to the multidimensional definitions of niche by Hutchinson (1958) and ecotope by

Whittaker et al. (1973). Webb (1948) and Loveless (1964, 1967) considered an understanding of the basic environmental needs of mule deer fundamental to intelligent management. McConnell and Smith (1970) analyzed pellet group frequency distributions for deer and elk (Cervus canadensis) and concluded that deer responded more to environmental than social forces.

Rules in the ECOSYM concept can provide resource managers with information necessary to answer three categories of questions: (1) outcome; (2) place; and (3) action (Davis and Henderson 1976).

Outcome Questions: Rules may predict the effects of an activity on a certain site. Example: What would be the changes in habitat value resulting from a clearcut of a specific watershed?

Place Questions: If an outcome is desired from a given action, rules can determine which areas have the necessary characteristics. Example: Where could deer be successfully introduced?

Action Questions: Which management actions will provide a specific outcome on a specific site. Example: What habitat component can be changed to enhance the habitat value in a certain locale?

Thus, equipped with a rule and acknowledging time, feasibility, and economic constraints, managers may make effective, sound decisions without being personally familiar with the species or process involved. Puglisi and Hassinger (1977) described a method whereby important

habitat components identified by rules could be inventoried from aerial photographs. Rules which have been constructed during development of ECOSYM are aesthetic visual vulnerability (Gropper and Fuhriman 1978), mass failure (DeGraff 1978b), surface erosion and runoff (Wigington and Hart 1978), range productivity (Roberts and Workman 1978), timber production (Kerr and Henderson 1978a), grey-headed junco (Junco caniceps) habitat (Grainger 1978), and snowshoe hare (Lepus americanus) habitat (Wolfe et al. 1978).

The rule concept is not unique to ECOSYM. Stocker and Gilbert (1977) developed a rating system for white-tailed deer (Odocoileus virginianus) habitat in Ontario. Habitat resources considered important to evaluate the potential of an area as white-tailed deer habitat were identified from the literature. A list of biological uses was developed. Biological use was defined as "use of the habitat to derive benefit for a biological function" (Stocker and Gilbert 1977:434). Compatibility matrices were constructed to establish the relationship between habitat resources, biological uses, and habitat types (Stocker et al. 1977). These matrices were used to rate 100 ha winter and summer habitat cells in five qualitative classes from optimum to unsatisfactory. Analysis of corresponding deer densities and movements to validate the system has not been completed.

Slough and Sadlier (1977) used multiple regression techniques to construct a land capability classification system for beaver (Castor canadensis) in British Columbia. Land capability is the inherent capacity of land to provide the biophysical requirements for production of

specific resources.  Slough and Sadlier (1977) stressed the importance
of objective quantification as is also stressed in ECOSYM (Davis and
Henderson 1976).

Studies by Ffolliott and Patton (1975) and Patton (1977) illustra-
ted the development and use of rules for Abert squirrels (_Sciurus aberti_)
in Southwestern United States.  These investigators employed production
rating functions to provide simple decision models which describe rela-
tionships between wildlife and other resources.  Ffolliott and Patton
(1975) graphically illustrated the relation between volume classes of
ponderosa pine (_Pinus ponderosa_) which optimize food and nests for
Abert squirrels and those which optimize timber production.  Thus,
managers can coordinate both wildlife needs and timber harvest sched-
ules.  Patton (1977) developed a simple habitat evaluation technique
using cover, food, and stand diversity components.  The technique could
provide managers with the information needed to maintain or improve
habitat quality as well as predict the effects of management programs
on a given site.

Black et al. (1976) assumed that forage, water, and cover are the
usual limiting factors for elk and mule deer.  Optimal amounts, types,
and juxtaposition of cover, forage, and water were identified from the
literature.  Three functions for cover were identified:  (1) concealment,
(2) moderation of thermal extremes, and (3) parturition sites.

Various correlation and multivariate statistical techniques have
been used to investigate animal-habitat relationships.  Species studies
include snowshoe hare (Meslow and Kieth 1971), woodpeckers (Conner and
Adkisson 1977), several small forest mammals (Miller and Getz 1977),

livestock and big game (Julander and Jeffery 1964, Mueggler 1965, Cook 1966, Anderson et al. 1972, Terrel 1973, Hudson 1975, 1977, Shannon et al. 1975, Hudson et al. 1976), and African ungulates (Hirst 1971, Schijf 1978).

The previously cited studies indicate a high probability that rules can be constructed for stenotypic species which have a single, easily identifiable limiting habitat component. Analysis of the limiting factor provides an analysis of habitat quality for such species. An important question, and a major hypothesis tested in this study, is whether rules can be developed for eurytypic species which have broad ecological tolerances and complex habitat requirements.

Two basic approaches to rule development can be identified. Wildlife-habitat relationships may be derived from existing literature (Black et al. 1976, Stocker and Gilbert 1977, Wolfe et al. 1978), or they may be quantitatively measured in the field (Slough and Sadlier 1977, Patton 1977). In this study, an extensive literature review provided a preliminary identification of the determinants of mule deer habitat quality. A field study was then conducted in which habitat components and deer utilization of habitat were measured. Statistical analysis described the relationships between habitat components and utilization, which were used to develop a rule. Finally, an independent set of data was used to validate the rule.

Three criteria support the selection of mule deer for this study: (1) the species is of considerable economic and aesthetic importance; (2) it has been the subject of numerous studies which provide the basis

for preliminary identification of habitat components; and (3) it in-
habits a broad spectrum of habitats, exhibits migration, and exploits
numerous food species, thereby testing the capabilities of rule develop-
ment.

## Objectives

1.  To determine from the literature those environmental para-
    meters which appear to be determinants of mule deer habitat.

2.  To measure habitat parameters and corresponding utilization
    by deer on a specific study site.

3.  To construct and validate a predictive rule which, when sup-
    plied with data on key environmental parameters, will des-
    cribe the value of an area as mule deer habitat.

## LITERATURE REVIEW

The Rocky Mountain mule deer inhabits most of the western United States and Canada.  It has the widest distribution of any North American big game subspecies (Cowan 1936, 1956).  Mule deer habitat is generally described as open forests and brushlands in hilly and rugged terrain (Cowan 1956, Einarsen 1956).  However, responses to and tolerances within different parts of its range show wide variations (Smith 1952, Hill 1956, Martinka 1968, Miller 1970, Anderson et al. 1972, and others).

### Habitat Parameters

A review of the literature identified a series of variables as potential components for a habitat rule:  (1) opening and mix of shrub and timber types; (2) proximity of feeding areas to cover areas; (3) migration routes; (4) presence of preferred forage species; (5) height of forage species;  (6) range productivity; (7) plant community type; (8) optical density and cover of plant communities; (9) snow characteristics; (10) temperature; (11) solar radiation; (12) wind; (13) aspect; (14) slope; and (15) elevation.

Components of both summer and winter habitat should be analyzed. Winter range has commonly been suggested as the limiting factor for mule deer because often during winter; (1) forage abundance and nutritional quality are lowest, (2) snow limits the amount of available range and covers much of the existing forage, and (3) there is a greater dissipation of body heat due to cold ambient temperatures (Robinette et al.

1952, Julander 1966, Loveless 1967, Gilbert et al. 1970, Moen 1973, Wallmo et al. 1977). However, Julander et al. (1961) noted variations in productivity which they attributed to summer range condition. Although winter ranges may be depleted, animals migrating from good summer range in a better nutritional plane have generally higher reproductive success. Stocker and Gilbert (1977) listed several mutually exclusive uses of summer and winter habitat. Exclusive summer uses were parturition, lactation, weaning, breeding, and protection from insects. Exclusive winter uses were gestation and protection from deep snow, wind chill, and low temperatures.

## Plant community interspersion

Opening and mix of shrub and timber types and proximity of feeding areas to cover areas are measures of plant community interspersion (edge). Interspersion is important because it combines areas which serve several crucial functions (e.g. feeding, parturition, bedding, escape, thermal insulation). Protective cover adjacent to adequate forage is critical to deer survival during severe winters (Julander 1966). Black et al. (1976) considered the ratio and arrangement of forage and cover areas to be the keys to predicting effects of timber management decisions on deer and elk. Several studies have concluded that deer are reluctant to move far into clearings from wooded areas (Reynolds 1962a, Clary and Larson 1971, Leopold and Barrett 1972, Terrel 1973). Taber and Dasmann (1958), Reynolds (1966b), and McCaffery and Creed (1969) suggested various opening sizes and shrub-forest mixtures for black-tailed deer (O. h. columbianus), mule deer, and white-tailed deer respectively.

Migration routes

Mule deer have distinct local home ranges (White 1960, Robinette 1966), yet usually exhibit seasonal migration between suitable winter and summer ranges (Richens 1967, Franzen 1968). When habitat requirements are satisfied year-round, deer are non-migratory (Mackie 1970, Dusek 1975). Migration corridors are influenced by topography. In areas of low relief, there is little orientation due to mountains or watersheds (Gruell and Papez 1963, Verme 1973). In areas of bold relief, topographic structure may limit migrations (Gilbert et al. 1970). However, Richens (1967) noted migrations over ridges and canyons in northeastern Utah. The proximity of winter and summer ranges and the routes between them seem critical because a suitable summer or winter range has no value if it is topographically isolated. However, no part of the study area in the present study appeared to be topographically isolated.

Forage

Forage is the major factor influencing summer deer distribution and one of the major factors affecting winter distribution in western North America (Loveless 1964, Julander 1966, Mackie 1970). Because no one forage species contains the correct balance of nutritive elements to sustain health over a long period of time, deer are broad spectrum feeders (Hill 1956, Loveless 1967). After reviewing 99 quantitative food habits studies, Kufeld et al. (1973) listed 788 plant species utilized by mule deer. Utilization of a given species varies with availability and season (Smith 1952, Hill 1956, White 1960, Martinka 1968, Goodwin 1973, Dusek 1975).

Big sagebrush (_Artemesia tridentata_) is the most commonly listed browse species. Other important species over most mule deer range include mountain mahogany (_Cercocarpus_ spp.), cliffrose (_Cowania Mexicana_), bitterbrush (_Pursia tridentata_), and serviceberry (_Amelanchier alnifolia_). Juniper (_Juniperus_ spp.) and pinion pine (_Pinus edulis_) supply emergency forage during severe winter periods (Julander 1966). However, the relative importance of species varies for different parts of the range. Highly palatable species in one area may have low utilization in other areas (Hill 1956, Martinka 1968, Kufeld et al. 1973). Therefore, the findings of food habits studies may have limited applicability (Smith 1952).

Presence of palatable forage does not insure good habitat _a priori_. Plant height and range productivity affect the quantity and quality of available forage. Because snow is present on many parts of mule deer winter range, a food plant with a low, horizontal life form will have no forage value after a snowfall. Robinette et al. (1952) and Julander et al. (1961) found correlations between herd condition and range condition on winter and summer range areas, respectively.

Plant community type

Although plant community types do not provide the detailed information contained in species lists, they are more easily determined and provide more flexibility than species lists when used in habitat evaluation. Several studies furnish evidence of the utility of plant community types. Smith (1952), Martinka (1968), and Dusek (1975) detected preferences for community types. Martinka (1968) concluded that

seasonal differences in elevation reflected preferences for community types rather than climatic variables. The ponderosa pine–Rocky Mountain juniper (Juniperus scopulorum) and douglas fir (Pseudotsuga menziesii)–Rocky Mountain juniper habitat types received the most use of eight cover types in the Missouri River Breaks, Montana (Mackie 1970). Thirteen subdivisions within South Dakota ponderosa pine forest significantly affected the distribution and density of pellet groups (Thilenius 1972). Stocker and Gilbert (1977) described different biological uses for the community types of Stocker et al. (1977).

## Optical density of vegetation

Vegetation structure affects the ability of an area to serve several of its major functions. Moen (1973) defined optical, mechanical, and thermal density of cover. Structure affects the concealing qualities of a stand and determines the mobility of an animal within a stand. One of its major influences, however, may be its effect upon the thermal insulation qualities of a stand, because thermoregulation is a major physiological requirement during summer heat and winter cold. Protection from wind chill and reduction of radiation heat loss have been widely noted (Lindsdale and Tomich 1953, Richens 1967, Mackie 1970, Miller 1970, Verma and Ozoga 1971, Ozoga and Gysel 1972, Terrel 1973, Verme 1973). Indeed, protective cover is often more critical than food (Hamerstrom and Blake 1939, Webb 1948, Krefting and Phillips 1970, Ozoga and Gysel 1972). Densely vegetated areas may also serve as refugia from summer heat (Lindsdale and Tomich 1953, Mackie 1970).

Climate

The importance of microclimatic parameters of snow depth and hardness, temperature, solar radiation, and wind was stressed by Loveless (1967) in his extensive analysis of winter range and by others (Porter and Gates 1969, Moen 1973). These factors influence heat balance, thermoregulation, available forage, and movement.

Snow depth and hardness are commonly mentioned as major influences; they initiate summer and winter migrations, cover forage, and impede or prohibit movement even at shallow depths (Smith 1942, Aldous 1945, Robinette et al. 1952, Hill 1956, Dalke and Presby 1964, Loveless 1967, Franzen 1968, Martinka 1968, Patton 1969, Gilbert et al. 1970, Miller 1970, Constan 1972, Terrel 1973, Verme 1973). Wallmo et al. (1977) concluded that winter mortality is governed by snow conditions and winter duration rather than total potential forage of a winter range.

Most studies citing snow as influential in deer habitat also considered temperature, solar radiation, and wind important. Lindsdale and Tomich (1953) noted an inverse relationship between activity and decreasing temperature, and an increased use of shade with increased temperature. Desert mule deer (Odocoileus hemionus crooki) became nocturnal during the hot-dry season in southeastern Arizona (Anthony and Smith 1977). Verme and Ozoga (1971) concluded that sharp drops in temperature are more important than snow in prompting white-tailed deer to seek physical comfort in sheltered yarding areas. Wind is a source of convective heat loss and also blows snow from some areas, thus making those areas available for use. Loveless (1967), Mackie (1970), Terrel (1973), and others have reported avoidance of exposed areas during

high winds. Stocker and Gilbert (1977) considered protection from wind chill an important biological use of habitats.

## Topographic effects

Slope (gradient), aspect (exposure), and elevation are fundamental determinants of microclimatic conditions; and, therefore, the effects of these parameters are difficult to distinguish from microclimate effects. Topography also influences the type, size and arrangement of plant communities. White (1960) stated that range use was influenced most by a combination of topography and vegetation.

Effects of aspect vary with geographic location, season of use, and plant community type. Harris (1959), Loveless (1967), and Mackie (1970) measured the greatest deer use on southerly exposures; whereas in New Mexico, Reynolds (1964) noted a 40-100 percent greater use of northeasterly exposures than other aspects. Pellet groups counted by Julander and Jeffery (1964) in Utah indicated preferences for southwestern slopes in summer and northwestern slopes later in the season. Reynolds (1962b) found equal pellet groups per amount of forage per hectare on north and south aspects in Arizona ponderosa pine communities. Utah piñon-juniper conversions increased use of south exposures and decreased use of north exposures; effects varied on east and west exposures (Terrel 1973).

Responses to slope and elevation are also varied. Studies by Julander and Jeffery (1964), Mackie (1970), and Terrel (1973) indicated slope preferences of greater than 11°, greater than 16°, and greater than 15° respectively. Elevation can indicate preferences for valleys,

mid-slopes areas, and ridgetops (Julander and Jeffery 1964, Loveless 1967).

STUDY AREA

## Location

Field research was conducted during the summers of 1976 and 1977
on the 13,000 ha ECOSYM study strip west of Price, Utah (Figure 1).
The strip includes portions of Sanpete, Carbon, and Emery counties.
The western area of the strip lies within the Price Ranger District,
Manti-LaSal National Forest.  Land in the eastern sections is managed
by private individuals, the State of Utah, and the Bureau of Land Man-
agement.

## Physiography

The entire strip lies within the Colorado Plateau geomorphic re-
gion (Thornbury 1965).  The strip west of Castle Valley Ridge is on the
Wasatch Plateau, the northernmost part of the High Plateau section, and
will be designated the mountain area.  The strip east of Castle Valley
Ridge lies in the Canyonlands section and will be designated as the
desert area.

Elevation varies from 3100 m near Skyline Drive in the west,
through 2960 m along Castle Valley Ridge, to 1700 m near Price in the
east.  The terrain west of Castle Valley Ridge is of two types:  (1)
glacial cirques with associated moraines (Figure 2a); and (2) rolling
hills and valleys dissected by a few major streams (Figure 2b).
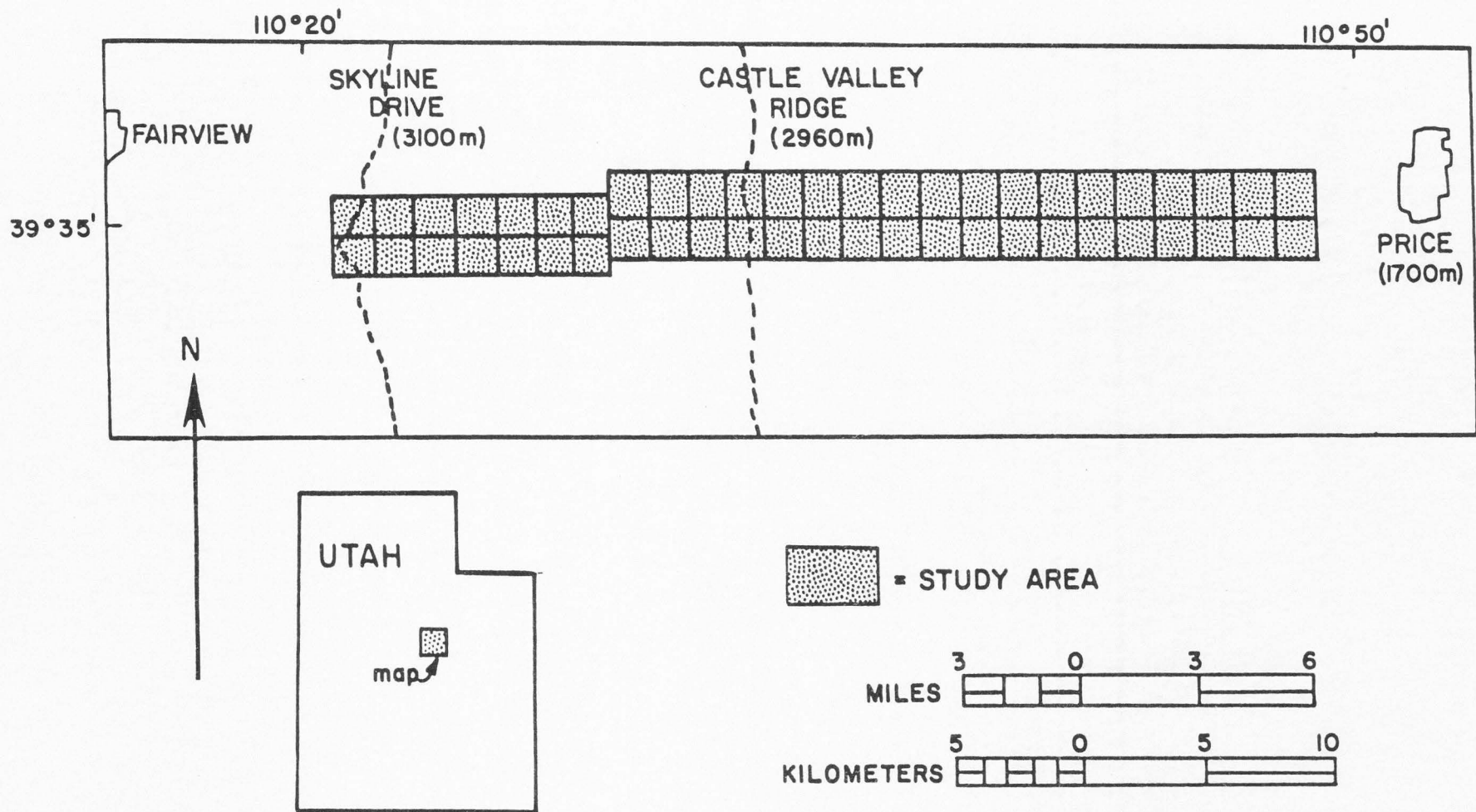
Figure 1. Location of study area in central Utah.
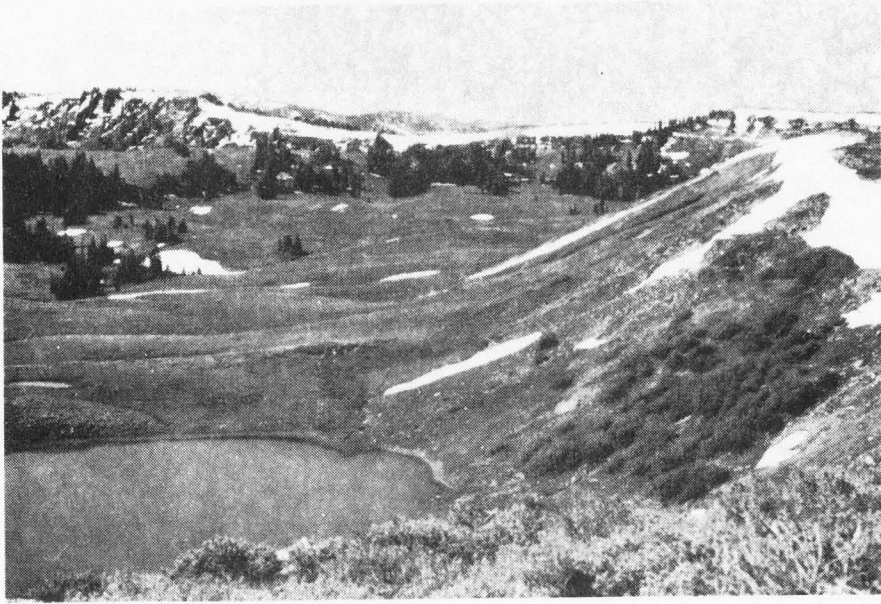
a. Glacial cirques and moraines.



b. Rolling hills and valleys.

Figure 2. Views of mountain portion of study area.

The eastern half of the strip is a descending series of benches deeply
dissected by large canyons (Figure 3a). The east end of the strip is
on the nearly level floor of Castle Valley (Figure 3b). The topography
of the strip has been described and mapped by DeGraff (1977a).

## Geology and Soils

Horizontal strata of Cretaceous and Tertiary shales and sandstone
comprise most of the formation on the plateau. Bedrock in Castle Valley
is horizontal to gently dipping Mancos shale, a marine shale which
usually produces clayey soils, characterized by large sediment and salt
production (Thomas 1976). DeGraff and Oaks (1978) and Oaks (1978)
classified and mapped the regolith and bedrock of the strip.

Soils of the plateau include Cryoborolls, Cryoboralfs, and Cryo-
chrepts. Calciorthids, Torriorthents, Agriborolls, and Haploborolls
are the primary soils in the desert area (Southard et al. 1978).

## Climate

Due to substantial differences in the geomorphology of the eastern
and western halves of the study strip, the respective climatic condi-
tions differ significantly. Zsiray and Wooldridge (1978a) studied the
climate of the area in detail. Mean annual precipitation declines from
100 cm at Skyline Drive to 25 cm near Price. Maximum precipitation in
the mountains usually occurs as snow during winter. Summertime convec-
tive storms provide the maximum precipitation in the desert.

In both mountain and desert areas, January is the coldest month
and July is the warmest. The mean maximum temperature in January ranges
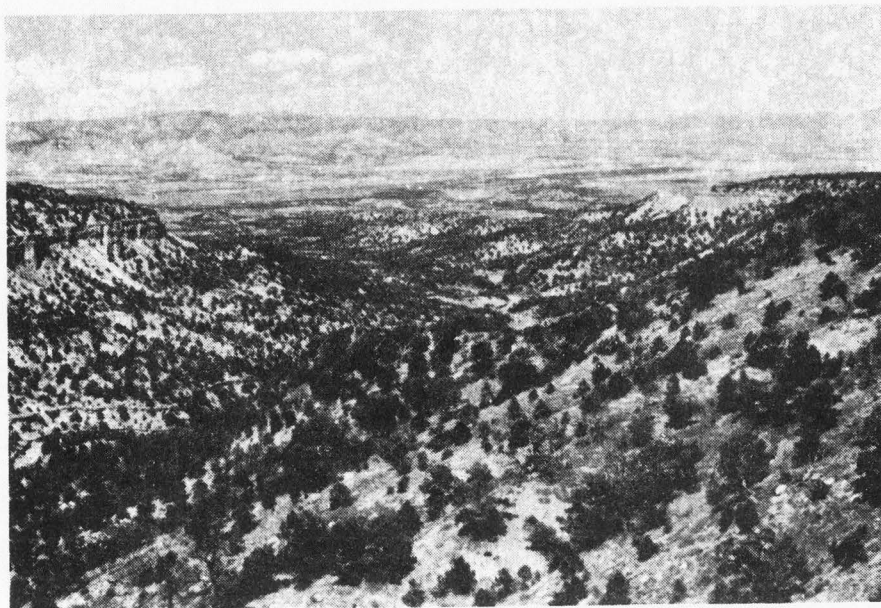
a. Benchlands dissected by steep canyons.
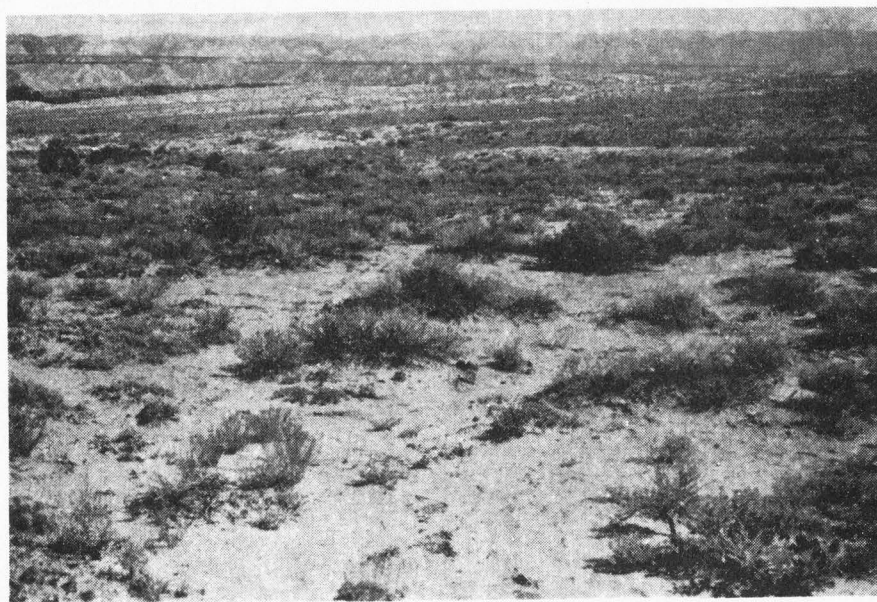


b. Level floor of Castle Valley.

Figure 3. Views of desert portion of study area.

from -6 to 3°C, and the mean minimum temperature ranges from -18 to -10°C. The mean maximum July temperature varies from 18 to 32°C, and the mean minimum temperature varies from 5 to 14°C. Thermal inversions cause wide daily temperature variations in canyons and valleys.

Snowfall is quite variable and ranges from 36 cm in the desert to 540 cm in the mountains. The lower elevations do not maintain a persistent snowpack during the winter. Snowfall in the higher elevations reaches maximum depth by 1 March and may persist into July.

## Vegetation

The western portion of the strip is characterized by three major plant communities: (1) aspen (Populus tremuloides), (2) Englemann Spruce (Picea englemanii)-subalpine fir (Abies Lasiocarpa), and (3) big sagebrush. Less dominant species include elderberry (Sambucus racemosa), false hellbore (Veratrum californicum), rabbitbrush (Chrysothamnus vicidiflorus), Douglas fir, wildryes (Elymus spp.), and bluegrasses (Poa spp.) (Kerr and Henderson 1978b).

On the eastern portion of the strip, the mountain brush zones, benches, canyons, and floor of Castle Valley are respectively dominated by gambel oak (Quercus gambelii) and serviceberry (Amelanchier utahensis), big sagebrush and various grasses, piñon pine- Utah juniper (Juniperus osteosperma) woodlands, and shadscale (Atriplex confertifolia). Minor species include mountain mahogany (Cercocarpus montanus), Indian rice-grass (Oryzopsis hymenoides), and blue grama (Bouteloua gracilis) (Shute and West 1978).

## METHODS

### Location of Study Plots

During the summer of 1976, data were collected from 86 study plots (43 mountain, 43 desert). The deer study plots surrounded the 500 $m^2$ circular ECOSYM vegetation inventory plots (Kerr and Henderson  1978). Mountain plots were located according to a twice stratified random sampling procedure. The mountain region was stratified into three equal parts and then stratified by cover type (aspen, conifer, or non-forest). Plot locations were first determined on U. S. Department of Agriculture Timber Survey Maps and later transferred onto 1:31,680 color infrared aerial photographs. Desert plots were systematically located. U. S. Geological Survey 1:24,000 topographic maps were overlayed with grids; plot sites comprised the center of the southwest quarter of each quarter section (Shute and West 1978).

During the summer of 1977, data were collected from 46 study plots (23 mountain, 23 desert). Three mountain sections were overlayed with grids of 100 points each. Plots were located by selection of two random numbers for each plot. The first number determined in which section the plot would be located; the second number determined the plot's site within that section. Eighteen desert sections were similarly overlayed with grids to locate desert plots. Plots were found in the field with the aid of aerial photographs and topographic maps.

## Deer Utilization and Habitat Parameters

During the first field season, data on plant community types, vegetation height, and topographic parameters were collected by ECOSYM vegetation inventory crews. I collected these data during the second field season.

### Pellet group counts

An index of deer utilization was derived from fecal pellet group counts (Bennett et al. 1940, Ferguson 1955, Neff 1968, Overton 1971). Twenty 0.001 ha circular pellet plots were semi-randomly located at each study plot (Figure 4a); relative positions of pellet plots to the ECOSYM plot were consistent during all data collection. The radii of the pellet plots were measured by a 1.78 m length of nylon cord. Only groups with over 50 percent of the pellets within the plot were counted (Ryel and Burgoyne 1976). Size, shape, color, and relative weathering of groups were used to discriminate between two or more overlapping or closely deposited groups.

Pellet counts have been widely used to index or census ungulates, lagomorphs, small mammals, and gallinaceous birds (Overton 1971). Robinette et al. (1952) considered pellet group counts particularly well adapted for censusing deer in Utah, and the Utah Division of Wildlife Resources has employed pellet group counts to gather management data since 1953 (Utah State Division of Wildlife Resources 1976). Julander (1966) stated that pellet group counts were the most reliable means for determination of relative deer use intensity.
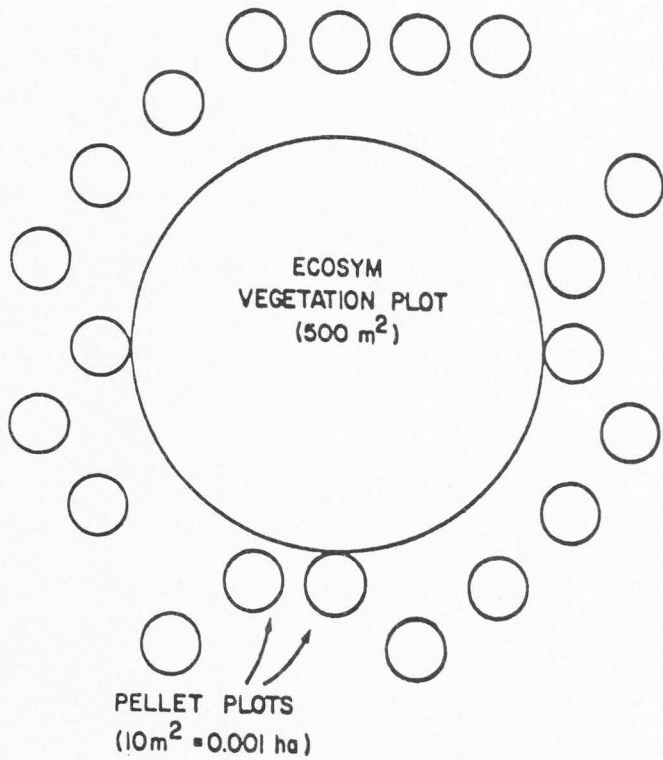
a. Location of pellet plots.
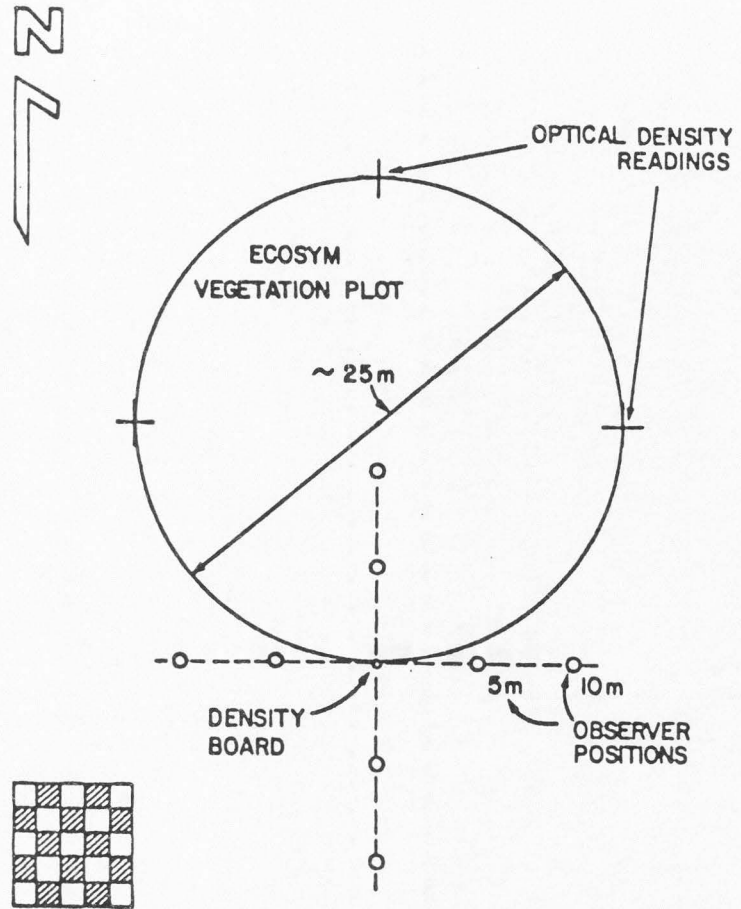
b. Location and method for optical density of vegetation readings.

Figure 4. ECOSYM vegetation plot

It is assumed that pellet groups are deposited most heavily in those places where deer feed (Bennett et al. 1940, Julander 1975) and in places in which deer spend the greater part of their time (Neff 1968). McCain and Taylor (1956:439) stated, "It is obvious that the amount [of pellets] on the ground is directly proportional to the number of deer, the amount of forage they consume, and the length of time they have occupied the area."

Bennett et al. (1940) compared habitat utilization as measured by pellet group counts and direct observations. Direct observations from airplanes and ground spotters substantiated the pellet group count data which detected not only differences in movements and utilization by deer between different plant community types, but also seasonal differences in utilization within community types. Harris (1959) detected an increase in deer population, and found a significant ($P<0.01$) difference between deer use of south and north exposures. White (1960) found agreement between results from pellet group counts, observations, and the Lincoln Index. After comparing pellet group results with results from radio telemetry, track counts, and deer counts, Terrel (1973) concluded the pellet group counts were a valid indicator of deer use of a site.

Dasmann and Taber (1955) compared results of total counts, sample area counts, Lincoln Index, and pellet group counts. Their data, although showing approximate agreement between the methods, indicated that census figures derived from pellet group counts are susceptible to error from variations in defecation rate. Higher defecation rates may be caused by a seasonal high percentage of herbaceous species in

the diet, range condition and age of the individual deer (Dasmann and Taber 1955, Smith 1964, Neff 1968). Similarly, Franzmann and Arneson (1976) detected a difference in defecation rates between male and female moose (Alces alces). However, problems and bias from differences in defecation rate need not be considered in this study because pellet group counts were used as an indicator of trends between areas, not as a method of census (Neff 1968).

Observations of tame elk by Collins (1977) indicated that elk defecate only when walking or feeding. Distribution of pellet groups was, therefore, significantly different from the distribution of actual habitat use by elk. Data for deer (Collins unpublished data) showed similar distributional differences; however, the rank of habitat use as ordered by pellet group counts was the same as that ordered by direct observation of the animals.

Ferguson (1955) and Eberhardt and Van Etten (1956) investigated persistance of pellet groups. Deer pellet groups withstand weathering better than lagomorph pellets. In their studies of cottontails (Sylvilagus auduboni) and black-tailed jackrabbits (Lepus californicus) Flinders and Crawford (1977) measured decreases of approximately 10 percent in pellet density after 8 days. Comparable deterioration of deer pellets under similar climatic conditions required 10 months (Ferguson 1955). Deer pellets may persist 2 years in swampy areas (Eberhardt and Van Etten 1956), and 5 years or more in dry areas (Robinette et al. 1958). Ferguson (1955) also found groups remaining intact on 60-80 percent slopes if there were herbaceous cover to hold them. Because the present study investigated long-term utilization patterns, persistence of pellets from previous years was not detrimental to the data.

Pellet plots of 0.001 ha are a good compromise to minimize observer and sampling bias, and to maximize sampling and time efficiency (Robinette et al. 1958, Smith 1968). Larger plots are prone to underestimation from missed groups, and smaller plots are easily biased by slight inaccuracies in location of plot centers or incorrect decisions on borderline groups (Batcheler 1975).

Although susceptible to the biases previously mentioned, pellet groups provide as reasonable an index of habitat utilization as is presently practicable considering the time and financial constraints of this study. Alternate methods are also prone to bias or are untested. Potential methods involve track counts (McCaffery 1976), track-pellet group counts (Lautenschalger and Hennessey 1975), remote sensing (Graves et al. 1972), and a distance to nearest group method (Bacheler 1975). Bowden et al. (1969) and McConnell and Smith (1970) fitted pellet group frequency distributions to Poisson, Newman-type A, and negative binomial distributions for clues to behavioral patterns and possible refinements in statistical analysis.

## Optical density of vegetation

Density boards have been employed in numerous studies to obtain indices of the horizontal density or visual obscuring qualities of vegetation (DeVos and Mosby 1971, Nudds 1977, Wilson and Hirst 1977). Measurements in this study were made using a density checkerboard similar to that used by Jones (1968) to evaluate sharp-tailed grouse (Pediocetes phasianellus columbianus) habitat. The board was 63.5 X 63.5 cm and was marked off into twenty five 12.7 X 12.7 cm squares.

The percent unobstructed squares was recorded. The board was placed 12.6 m due north, east, south, and west of the vegetation plot center. At each of these points, readings were taken at 5 and 10 m from the board in each cardinal compass direction (Figure 4b). Readings were originally made with both the board and observer at breast height. After collection of data from 52 plots during the first summer, a reading with the board and observer at waist height was added. It was felt that the lower reading might more accurately reflect the average height of a deer's head. Loveless (1964:417) called 86 cm above the ground "deer height." Readings at both heights were taken for the remainder of the study.

Because it was suspected that the average visibility of the vegetation on a plot might mask some of the variability in density, an additional quantity was calculated. Variation of visibility was the standard deviation of the visibility readings. This parameter was calculated for all distances and heights.

## Plant community interspersion

Several techniques for the evaluation of edge have been developed. Schuerholz (1974), using line transect sampling procedures, superimposed detailed grids over aerial photographs; the intersections of vegetation edges with the grid lines were counted. Similarly, Baxter and Wolfe (1972) evaluated bobwhite quail (Colinus virginianus) habitat by drawing diagonal lines across each quarter section on maps of the study area and counting the edges between vegetation types intersecting the diagonals. Patton (1975) developed a formula which compared edge

lengths with included areas. Taylor (1977) compared the methods of
Baxter and Wolfe (1972) and Patton (1975) and found little difference
in the evaluation of ring-necked pheasant (Phasianus colchicus)
habitat. Hudson et al. (1976) simply counted the number of discrete
plant communities in adjacent study cells.

In this study, plot centers were located on 1:12,000 color infra-
red aerial photographs. Two sets of perpendicular lines were super-
imposed on the plot centers. The number of changes in plant community
type intersected by the diagonals was counted. Lines of one set were
3.35 cm; lines of the other set were 6.71 cm. Line length corresponded
to 0.4 and 0.8 km of ground distance respectively.

## Plant community types

Plant community types on the strip were determined using the method
described in Henderson and West (1978). Communities were usually the
dominant overstory species and the characteristic understory species.
Community types were condensed into 11 cover types: (1) mountain grass,
(2) mountain sagebrush, (3) spruce--fir, (4) aspen, (5) aspen-conifer
(6) piñon pine, (7) piñon-juniper, (8) desert sagebrush, (9) desert
grass, (10) low desert shrubs, and (11) gambel oak or serviceberry.
Low desert shrub communities were characterized by halophytic shrubs
and were usually dominated by Atriplex spp. Russian thistle (Salsola
kali) was common in some of these areas. Gambel oak and serviceberry
dominated only one plot each; therefore, they were combined during
analysis as tall shrubs.

## Height of grass, forb, and shrub layers

Heights of grass, forb, and shrub layers were estimated to the nearest decimeter. Estimates were average layer heights for the 500 $m^2$ ECOSYM vegetation plots.

## Topographic features

Percent slope and aspect were measured by a Suunto clinometer and a Silva Ranger compass respectively. Aspect was recoded into five qualitative classes. If a plot had slope less than 10 percent, it was said to have no aspect. Plots with slope greater than 10 percent were assigned to north, east, south, or west categories. Elevation was read from U. S. Geological Survey 1:24,000 topographic maps.

## Climatic variables

Within the climate sub-project of ECOSYM, Zsiray and Wooldridge (1978b) developed complex regression models to predict mean, maximum, and minimum temperatures for annual and monthly periods. Independent variables for these models were slope, aspect, elevation, topographic ratio, and some interaction terms. Topographic ratio indicated positions of plots with respect to ridge and valley elevations. $R^2$ values during model development were 0.95, 0.98, and 0.92 for annual mean, maximum, and minimum temperatures, and 0.99, 0.99, and 0.96 for January mean, maximum, and minimum temperatures. Zsiray and Wooldridge (1978b) concluded that an adequate data base did not exist to develop models for solar radiation, wind direction and speed, or snow cover; however, estimates of snow cover were generated as a function of elevation.

### Rule Construction and Validation

Data from the first summer's work were analyzed to develop a habitat rule. Habitat parameter data from the second summer were then used in the habitat rule to calculate expected deer utilization. The expected deer utilization was compared to deer utilization data measured during the second summer to test the validity of the rule.

Utilization and habitat parameter data were coded on computer cards and analyzed using the Statistical Package for the Social Sciences (APSS) (Nie et al. 1975). For input into SPSS, each variable was assigned a mneomonic variable name (Table 1). A nominal scale variable CVRTYP was created with values from 1-11 corresponding to the 11 cover types. However, because the values of CVRTYP could not be ordered and had no unit of measurement, they could not be treated as scores, as they would normally be treated in regression analysis. Therefore, the cover types were recoded as 11 dummy or indicator variables (Neter and Wasserman 1974, Kim and Kohout 1975). In this way, the nominal scale cover type variable could be incorporated into regression analysis. A set of dummy variables is created by treating each category of a nominal scale variable (e.g. CVRTYP) as a separate variable and assigning arbitrary scores (-1, 0, 1) for cases depending upon presence or absence.

SPSS subprograms PEARSON CORR, SCATTERGRAM, and REGRESSION calculated means, standard deviations, Pearson product-moment correlation coefficients (r), significance of correlations, and multiple regression equations. Output from the REGRESSION subprogram also included

Table 1.  Variable names, mnemonic variable names, and units of
          measurement

| Variable name | Mnemonic name | Unit of measurement |
|---|---|---|
| Pellets per study plot | PELLETS | sum of pellet plots at a study plot |
| Frequency of pellets | FREQPEL | percent of pellet plots at a study plot with pellets |
| Optical density of vegetation chest height, 10 m from density board | VISUP10 | percent unobstructed squares; mean of 16 readings |
| Optical density of vegetation chest height, 5 m from density board | VISUP5 | same as VISUP10 |
| Optical density of vegetation, waist height, 10 m from density board | VISDN10 | same as VISUP10 |
| Optical density of vegetation, waist height, 5 m from density board | VISDN5 | same as VISUP10 |
| Variation of optical density of vegetation, chest height, 10 m from density board | VARUP10 | standard deviation of 16 optical density readings |
| Variation of optical density of vegetation, chest height, 5 m from density board | VARUP5 | same as VARUP10 |
| Variation of optical density of vegetation, waist height, 10 m from density board | VARDN10 | same as VARUP10 |
| Variation of optical density of vegetation, waist height, 5 m from density board | VARDN5 | same as VARUP10 |
| Elevation of plot | ELEV | meters |
| Aspect | ASPECT | degrees from north |
| Slope | SLOPE | percent slope |
| Aspect when slope is greater than 10% | ASPSLP | |
| Mean annual precipitation | PPT | centimeters |
| Mean annual maximum temperature | TMAX | degrees C |
| Mean annual minimum temperature | TMIN | degrees C |

Table 1.  Continued

| Variable name | Mnemonic name | Unit of measurement |
|---|---|---|
| Mean annual mean temperature | TMEAN | degrees C |
| Snow depth in January | SNOWJAN | centimenters |
| Mean January temperature | TJANMEAN | degrees C |
| Mean minimum January temperature | TJANMIN | degrees C |
| Mean maximum January temperature | TJANMAX | degrees C |
| Height of grass layer | GRASSHT | decimeters |
| Height of forb layer | FORBHT | decimeters |
| Height of shrub layer | SHRUBHT | decimeters |
| Plant community interspersion 0.8 km ground distance | EDGE2 | intersection of plant community edges with perpendicular lines |
| Plant community interspersion, 0.8 km ground distance | EDGE4 | same as EDGE2 |
| Plant cover types | CVRTYP | |
| Mountain grass cover | GRASSUP | |
| Mountain sagebrush cover | SAGEUP | |
| Spruce--fir mixture cover | SPRFR | |
| Aspen cover | ASPEN | |
| Aspen--conifer mixture cover | CONPOTR | |
| Piñon pine cover | PINON | |
| Piñon--juniper mixture cover | PJ | |
| Desert sagebrush cover | SAGEDN | |
| Desert grass cover | GRASSDN | |
| Low desert shrub cover | SHRUBDN | |
| Gambel oak or serviceberry cover | OAKSERV | |

regression coefficients (b), standard error and significance tests (F statistic) for the regression coefficients, multiple correlation coefficients (r), coefficients of multiple determination ($R^2$), and a significance test (F statistic) for the regression equation. Subprogram ONEWAY used a oneway analysis of variance to measure the effects of the qualitative variables ASPSLP and CVRTYP. ONEWAY provided an F statistic for significance of the effect of the independent variable on the dependent variable. Additionally, ONEWAY calculated least significant difference a posteriori multiple mean comparisons (Steel and Torrie 1960). SPSS analysis was run on the Burroughs B6700 computer at Utah State University.

Calculation of confidence interval estimates and hypothesis tests using the Student t distribution (Lapin 1975) were done on a hand calculator. Significant levels for F statistics were calculated by an F distribution program (ST1-18) on a Texas Instruments SR-52 programmable calculator.

In this study, a probability level of 0.2 or better in the statistical analysis was usually considered significant. Because of the complicated nature and inherent variability of biological systems, it may be unreasonable to expect higher levels of significance. Julander and Jeffery (1965) expressed concern that the commonly used significance level of 0.05 may eliminate variables which are actually significant.

Multiple regression fits a linear combination of independent variables to a measured dependent variable by the least squares method. The model or response function takes the form:

$$E(Y) = B_o + B_1 X_1 + B_2 X_2 + \ldots + B_k X_k$$

where:

E(Y) = expected value for the dependent variable Y

$B_o$ = a constant

$B_1$, $B_2$, ...., $B_k$ = regression coefficients

$X_1$, $X_2$, ...., $X_k$ = values of independent variables

(Neter and Wasserman 1974, Nie et al. 1975). Regression coefficients ($B_i$) indicate the change in the dependent variable Y for a unit increase in the dependent variable $X_i$, when all other independent variables are held constant. When there is only one independent variable, the function is simply the equation for a line; $B_o$ is the Y axis intercept, $B_1$ is the slope of the line. If $B_i$ is near zero, the effect of variable $X_i$ on Y is insignificant. The standard error of $B_i$ can be used to test if $B_i$ is significantly different from zero. Similarly, the significance of $B_i$ can be measured with the F statistic using the formula given by Nie et al. (1975:326).

Correlation coefficients provide a measure of the strength of the linear association between the independent and dependent variables. Pearson's product-moment correlation coefficient (r) for one independent variable and the multiple correlation coefficient (R) for several independent variables vary from 1 to -1, with 0 denoting absence of a relationship. The squares of r and R are the coefficient of determination ($r^2$) and the coefficient of multiple determination ($R^2$). The meaning of these coefficients is easily interpreted. They represent the proportion of variation in the dependent variable Y that can be explained by the regression equation of Y on the independent variables $X_1$, $X_2$, ...., $X_k$ (Lapin 1975). Nie et al. (1975) give a detailed

discussion of regression analysis which includes calculation formulas and numerous additional references.

RESULTS AND DISCUSSION

## Correlation of Habitat Parameters with Utilization

Means, standard deviations, and sample sizes for the basic data
used in rule development are listed in Table 2. Desert sections, which
are equivalent to winter range on the strip, had a significantly higher
(t = 6.38, df = 42, P < 0.001) pellet group density than mountain sec-
tions. Several factors probably contributed to this result. Most
important was the greater persistance of pellet groups in the desert
(Ferguson 1955, Eberhardt and Van Etten 1956, Robinette et al. 1958).
Pellet groups which appeared to have weathered several years were com-
monly found in the desert; indeed, fresh pellets were rarely observed.
However, the forceful impact of raindrops from summer thunderstorms
on the sandy soil may have covered some groups with dust, giving them
a weathered appearance. In the mountains, old pellet groups were sel-
dom observed, indicating a more rapid rate of disintegration. In con-
trast to the desert however, summer storms in the mountains tended to
make pellet groups appear fresher. Another factor contributing to the
difference between mountain and desert results was increased observa-
bility of desert pellet groups. The desert understory was very sparse;
bare ground and rock often accounted for a majority of percent ground
cover. Sagebrush and blue grama grass caused only minor difficulties
in location of pellet groups. Pellet groups in the mountains were
much more difficult to find. Aspen and grass communities usually had

Table 2.  Variable means and standard deviations; rule development
          data--1976[a]

| Variable | Strip (n=86) $\bar{x}$ | s | Mountains (n=43) $\bar{x}$ | s | Desert (n=43) $\bar{x}$ | s |
|---|---|---|---|---|---|---|
| PELLETS | 24.7 | 27.43 | 5.4 | 5.25 | 43.9 | 27.13 |
| FREQPEL | 53.0 | 33.95 | 26.5 | 19.66 | 79.5 | 22.59 |
| VISUP10 | 64.6 | 32.17 | 57.3 | 32.62 | 72.1 | 30.29 |
| VISUP5 | 76.0 | 23.55 | 71.2 | 24.77 | 80.7 | 21.50 |
| VISDN10[b] | 42.2 | 34.82 | 28.5 | 33.17 | 64.2 | 25.46 |
| VISDN5[b] | 56.1 | 29.11 | 44.4 | 28.89 | 74.9 | 17.85 |
| VARUP10 | 25.2 | 18.33 | 26.8 | 16.75 | 23.7 | 19.87 |
| VARUP5 | 25.4 | 19.06 | 27.2 | 18.16 | 23.6 | 19.96 |
| VARDN10[b] | 22.3 | 15.15 | 18.6 | 14.06 | 28.2 | 15.54 |
| VARDN5[b] | 27.0 | 15.00 | 26.8 | 14.68 | 27.2 | 16.13 |
| ELEV | 810.5 | 128.24 | 934.1 | 29.89 | 687.0 | 133.98 |
| ASPECT | 174.5 | 113.70 | 183.2 | 99.74 | 165.7 | 126.72 |
| SLOPE | 27.4 | 20.53 | 32.2 | 15.26 | 22.6 | 23.93 |
| GRASSHT | 0.3 | 0.26 | 0.3 | 0.33 | 0.3 | 0.15 |
| FORBHT | 0.5 | 0.53 | 0.4 | 0.39 | 0.7 | 0.61 |
| SHRUBHT | 0.6 | 0.85 | 0.6 | 0.51 | 0.6 | 1.09 |
| EDGE2 | 11.9 | 6.07 | 15.8 | 4.96 | 8.1 | 4.35 |
| EDGE4 | 6.2 | 3.92 | 8.4 | 3.67 | 4.0 | 2.73 |
| TJANMEAN | -7.5 | 1.89 | -9.0 | 0.19 | -5.9 | 1.48 |

[a] Variable names from Table 1

[b] n = 34 for strip, 21 for mountains, 13 for desert

lush understory vegetation which had to be searched carefully to avoid overlooking groups. Conifer communities, although usually lacking a lush understory, had a high amount of down woody material and shrubs. The magnitude of the effect of these biases is unknown. Numerous lagomorph pellets were noted in areas of difficult observation; therefore, a high percentage of deposited deer pellets were probably counted. Another probable cause of higher desert pellet group counts was higher deer density on the winter range. Winter snowpack in the higher elevations excludes deer during winter months.

The simple correlation coefficients and significance of the correlations of habitat variables with PELLETS are given in Table 3. Most of the measured habitat parameters had highly significant correlations when data for the entire strip were analyzed together; however, inspection of scatterplots of individual parameters against PELLETS indicated that the strong correlations were mostly the result of the large difference between mean mountain and desert pellet densities. Mountain data points were clumped close to the origin when graphed on the same axes with desert data. Therefore, all correlation, rule construction, and rule validation analyses were run separately for mountain and desert sections. This approach is reasonable considering the different thermal, forage, and cover requirements of deer on winter and summer ranges (Stocker and Gilbert 1977).

Several variables were recoded or calculated in an attempt to increase the predictive power of the statistical methods employed. VISUP10, EDGE2, EDGE4, and SLOPE were recoded into several interval categories as follows:

Table 3.  Simple correlation coefficients and significance of corre-
lation of habitat variables with PELLETS; rule development
data--1976[a]

| Variable | Strip | | Mountains | | Desert | |
|---|---|---|---|---|---|---|
| | r | (sig.)[b] | r | (sig.) | r | (sig.) |
| VISUP10 | 0.261 | (.008) | 0.063 | (.344) | 0.200 | (.100) |
| VISUP5 | 0.251 | (.010) | 0.012 | (.470) | 0.240 | (.060) |
| VISDN10 | 0.425 | (.006) | 0.419 | (.029) | -0.184 | (.273) |
| VISDN5 | 0.463 | (.003) | 0.452 | (.020) | -0.080 | (.397) |
| VARUP10 | -0.208 | (.028) | -0.291 | (.029) | -0.228 | (.070) |
| VARUP5 | -0.206 | (.029) | -0.153 | (.163) | -0.242 | (.059) |
| VARDN10 | 0.170 | (.168) | -0.025 | (.457) | -0.303 | (.157) |
| VARDN5 | -0.097 | (.292) | -0.065 | (.389) | -0.321 | (.143) |
| ELEV | -0.651 | (.001) | 0.603 | (.001) | 0.153 | (.164) |
| SLOPE | -0.378 | (.001) | 0.033 | (.416) | -0.375 | (.007) |
| TJANMEAN | 0.708 | (.001) | -0.614 | (.001) | 0.333 | (.015) |
| EDGE2 | -0.534 | (.001) | 0.112 | (.237) | -0.249 | (.054) |
| EDGE4 | -0.446 | (.001) | 0.062 | (.347) | -0.138 | (.189) |
| GRASSHT | -0.202 | (.031) | 0.019 | (.452) | -0.428 | (.002) |
| FORBHT | 0.021 | (.425) | -0.113 | (.235) | -0.277 | (.036) |
| SHRUBHT | -0.092 | (.199) | -0.142 | (.182) | -0.158 | (.155) |
| CVISUP10 | 0.254 | (.009) | 0.078 | (.310) | 0.163 | (.147) |
| SPEDGE2 | -0.514 | (.001) | 0.110 | (.241) | -0.254 | (.050) |
| SPEDGE4 | -0.420 | (.001) | 0.089 | (.286) | -0.081 | (.304) |
| SPSLOPE | -0.393 | (.001) | 0.031 | (.423) | -0.339 | (.013) |

[a]Variable names from Table 1.

[b]Significance of correlation coefficient.

| (1) | VISUP10: | 0-10 | 10-35 | 35-65 | 65-90 | 90-100 | | |
|-----|----------|------|-------|-------|-------|--------|---|---|
|     | CVISUP10: | 1 | 2 | 3 | 4 | 5 | | |
| (2) | EDGE2: | 0-4 | 5-8 | 9-12 | 13-16 | 17-20 | 21-23 | 24+ |
|     | SPEDGE2: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| (3) | EDGE4: | 0-2 | 3-5 | 6-8 | 9-11 | 12-15 | 16+ | |
|     | SPEDGE4: | 1 | 2 | 3 | 4 | 5 | 6 | |
| (4) | SLOPE: | 0-15 | 15-25 | 25-35 | 35-45 | 45-55 | 55+ | |
|     | SPSLOPE: | 1 | 2 | 3 | 4 | 5 | 6 | |

A comparison between the correlation coefficients of the raw and re-
coded variables with PELLETS (Table 3) indicated no increase in pre-
dictability; therefore, the raw variables were used in subsequent
analysis. "SEE" variables were computed as the product of correspond-
ing visibility and variation of visibility variables (e.g. SEEUP10 =
VISUP10 X VARUP10); however, these variables did not exhibit any in-
creased or unique contribution to predictive power of the original
variables, and were discarded.

## Optical density of vegetation

VISDN10 and VISDN5 had strong significant positive correlations
and VARUP10 and VARUP5 had significant negative correlations with
PELLETS in the mountains. VISUP10, VISUP5, VARDN10, and VARDN5 had
no significant effect. The positive sign of r for VISDN10 and VISDN5
indicates that more pellets were found in areas of greater visibility
(less optical density). These results are unexpected because density
readings at waist height could indicate presence within a stand thermal
cover, escape cover, and forage. Protective cover is especially im-
portant during fawning, forage is a chief factor affecting summer dis-
tribution, and succulent vegetation is critical for lactation

(Julander 1966, Black et al. 1976). In the desert, the chest height measurements rather than the waist height measurements were significantly correlated to PELLETS; however, the r is again positive. These correlations probably reflect the higher use of sagebrush areas which are more open at check height than tall brush or piñon-juniper communities.

## Elevation and slope

Results of mountain pellet group counts were very strongly correlated with ELEV (r = 0.603). Correlation of desert pellet group counts with ELEV, although significant at the 0.2 level, indicated a much smaller influence of elevation on this winter range. The high correlation in the mountains indicated increased use of upper slopes and decreased use of valleys and canyon bottoms. Einarsen (1956) stated that bucks moved to higher elevations during the summer. Because domestic cattle and sheep were grazed in the mountains, deer may have used higher, more rugged parts of the range to avoid contact with livestock (Julander and Robinette 1950, Julander and Jeffery 1964, Cook 1966, Dusek 1975). Mountain valleys may have been avoided because of low temperatures from thermal inversions. Decreasing pellet group density with decreasing elevation on the winter range may have reflected reaction to decreasing palatable forage and increased human activity near Price and the floor of Castle Valley.

Slope had a highly significant negative correlation in the desert, but lacked any effect in the mountains. Most of the slopes in the desert were the very steep walls of the canyons which dissect the benchlands. These slopes were usually very rocky and supported

piñon-juniper plant communities. However, both in the mountains and desert, pellet groups were observed on slopes with such a steep gradient that standing was difficult. Julander (1964) stated that effects of slope are indirect and varied; some slopes receive little use due to lack of forage, whereas other steep slopes receive heavy use due to better forage availability and lack of competition with livestock. These variations in effect could account for the lack of correlation in the mountains. Black et al. (1976) stated that fawning sites were usually located on slopes greater than 15 percent. Results from this study conflict with those of Julander and Jeffery (1964), Mackie (1970), and Terrel (1973) who respectively measured greatest deer use of slopes of 30, 20, and 27 percent. Hudson et al. (1976) found a significant ($P < 0.05$) positive correlation ($r = 0.11$) with slope on winter range and no significant correlation on spring range.

## Plant community interspersion

No effect of edge as measured in this study was detected in the mountains. Although the importance of edge is universally cited, lack of responses to edge have been reported (Reynolds 1962a, 1966a). The lines superimposed on the aerial photographs to determine EDGE2 and EDGE4 were not corrected for differences in ground distance due to topographic variation. Therefore, because the lines covered varying ground distances, the measured edge values may not have accurately reflected actual interspersion. Edge correlations for the desert plots, although significant, showed negative rather than positive relationships. The highest desert pellet density was in sagebrush cover which was usually located on broad, flat benchlands of fairly uniform plant

community composition.  These results indicate that preference for some
group of characteristics of sagebrush communities outweighs edge
effects.

### Height of grass, forb
### and shrub layers

The height of grasses, forbs, and shrubs all showed significant
negative correlations with pellet density in the desert.  In the moun-
tains, SHRUBHT showed the only significant correlation, again negative.
Grasses and forbs in the mountains exhibited considerable growth during
the course of the summer field season.  This growth likely contributed
to the lack of significance of GRASSHT and FORBHT correlations.  Nega-
tive correlations could indicate greater forage utilization in areas of
high deer density.  If this conclusion is true, it would be inappropri-
ate to include these variables in a regression on PELLETS because both
X (plant height) and Y (PELLETS) would be some function of the same
parameter, namely presence of deer.

Inspection of the individual scatterplots of GRASSHT, FORBHT, and
SHRUBHT against PELLETS indicated that the correlations, although sig-
nificant in four cases, resulted from data variations less than the
precision of the data measurements.  Data entries for layer heights
were necessarily subjective averages for the 500 $m^2$ ECOSYM vegetation
plots.  Therefore, because use of these correlations in a rule would
require data precision not possible from these averages, and because
grass, forb, and shrub heights may have been functions of deer pre-
sence (as is PELLETS), GRASSHT, FORBHT, and SHRUBHT were not included
in any further analysis.

## Climatic variables

Because snow depth parameters were simple functions of elevation, they were not included in the regression analysis. The temperature parameters were complex functions of elevation, slope, aspect, and topographic ratio. The temperature parameter which showed the best correlation to pellet density, TJANMEAN, was selected for use in rule development. However, in attempting to generate temperature predictions for the rule validation plots using the climate rule of Zsiray and Wooldridge (1978b), many unrealistic or grossly inaccurate temperatures were calculated. Manipulation of topographic ratios failed to improve results to a useful level. Zsiray and Wooldridge (1978b) stated coefficients in the climate rule calculations would need to be regenerated for areas other than the ECOSYM strip. Therefore, climatic parameters were not used in further rule construction for three reasons: (1) most of the predictive ability of the climate variables were contained in slope, aspect, and elevation, especially the latter; (2) a separate climatic study would be necessary to apply a habitat rule containing predicted climate variables at a site other than the ECOSYM strip; and (3) excessive data manipulation was required for input into the climate rule to provide acceptable output.

## Effects of Cover Types and Aspect

Sample sizes, means, standard deviations, and standard errors of the various aspects and flat categories of ASPSLP, and of the various cover types of CVRTYP are presented in Table 4. Figures 5 and 6 graphically display the 95, 90, and 80 percent confidence interval

Table 4.   ASPSLP and CVRTYP:  Sample size, mean, and standard deviation
           of PELLETS for categories; rule development data--1976[a]

| Variable | Plot location | Category[a] | n | $\bar{x}$ | s |
|----------|---------------|-------------|---|-----------|---|
| ASPSLP | Mountains | none | 2 | 3.1 | 4.38 |
| | | north | 9 | 6.4 | 5.77 |
| | | east | 8 | 3.6 | 2.87 |
| | | south | 10 | 7.4 | 7.66 |
| | | west | 14 | 4.7 | 3.92 |
| | Desert | none | 11 | 49.4 | 26.96 |
| | | north | 12 | 43.4 | 30.09 |
| | | east | 5 | 39.5 | 18.25 |
| | | south | 8 | 45.5 | 35.45 |
| | | west | 7 | 37.6 | 28.01 |
| CVRTYP | Mountain | ASPEN | 13 | 3.1 | 2.53 |
| | | SPRFR | 10 | 5.2 | 4.79 |
| | | CONPOTR | 7 | 6.0 | 4.23 |
| | | GRASSUP | 8 | 7.3 | 5.97 |
| | | SAGEUP | 5 | 7.9 | 9.86 |
| | Desert | GRASSDN | 4 | 23.0 | 18.17 |
| | | PJ | 12 | 27.8 | 16.15 |
| | | OAKSERV | 2 | 31.3 | 26.45 |
| | | PIÑON | 7 | 47.5 | 35.83 |
| | | SHRUBDN | 3 | 50.1 | 8.95 |
| | | SAGEDN | 15 | 61.2 | 24.85 |

[a]Variable and category names from Table 1.
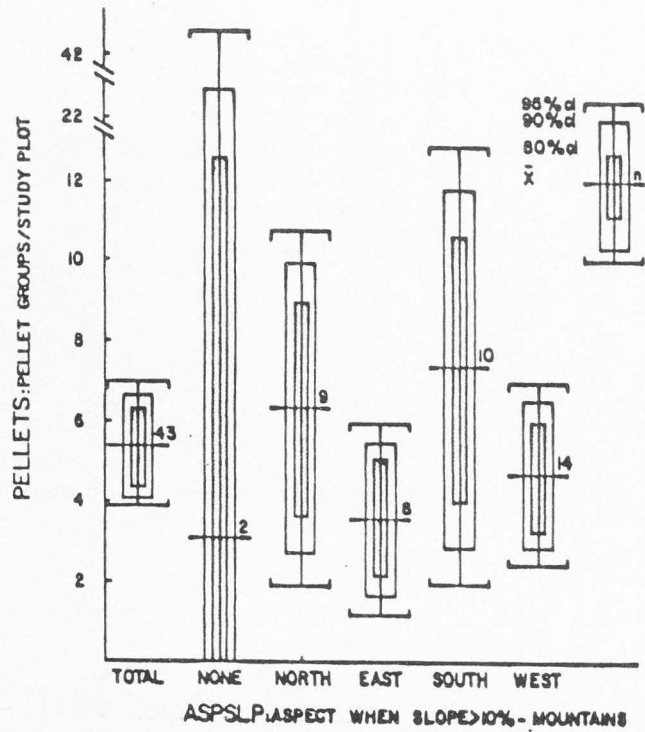
a.  Mountain sections.
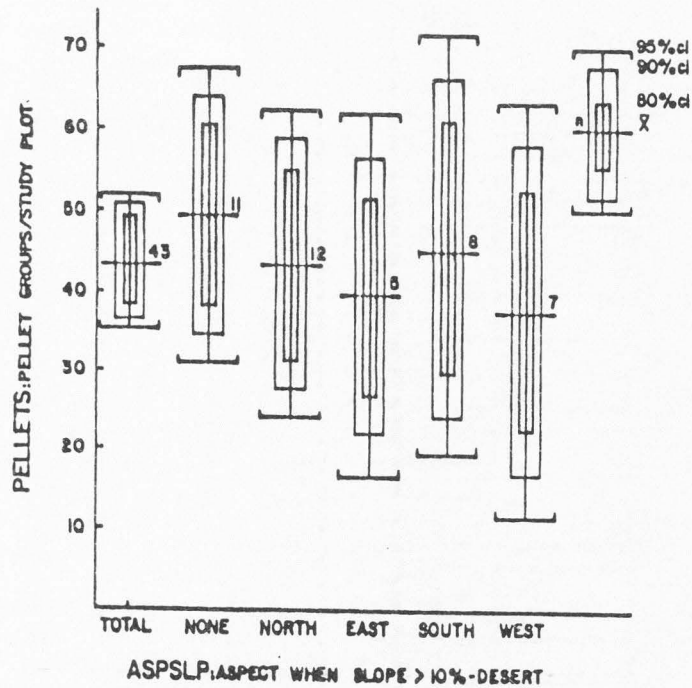
b.  Desert sections.

Figure 5.   Confidence interval estimates for aspects; rule development data--1976.
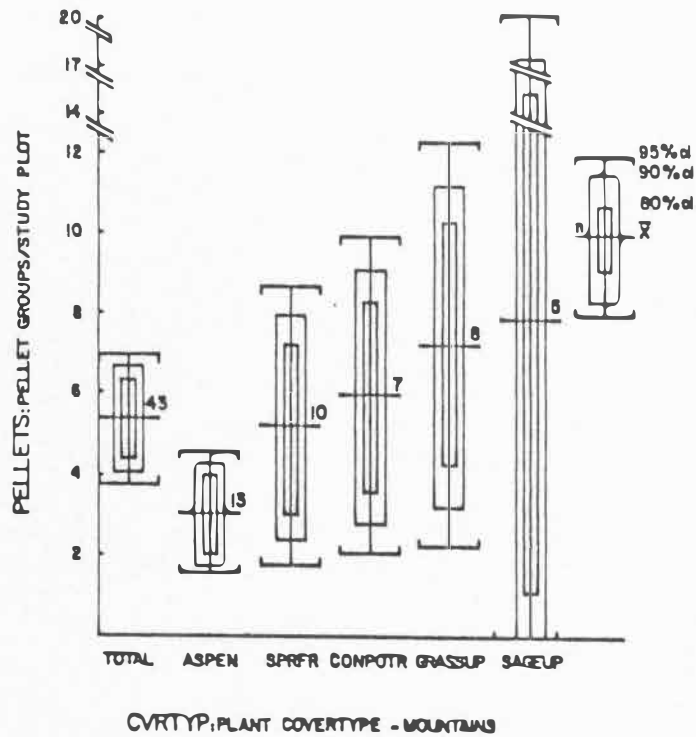
a. Mountain sections.
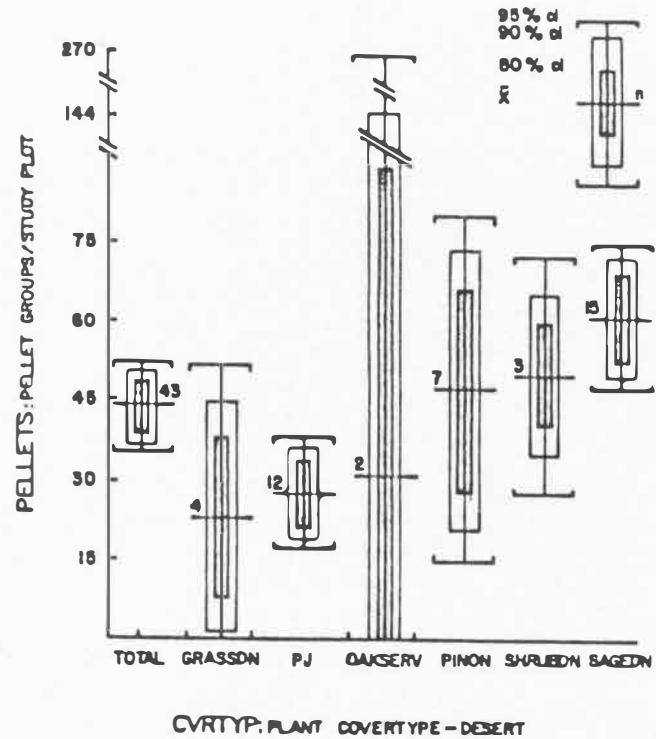
b. Desert sections.

Figure 6. Confidence interval estimates for cover types; rule development data--1976.

estimates for these categories.  Analyses of variance (AOV) to test

the effects of ASPSLP and CVRTYP are in Table 5.

Table 5.  Analysis of variance:  effect of ASPSLP and CVRTYP on
PELLETS; rule development data--1976[a]

| Variable | Plot location | Groups | df[b] | Mean squares | F | Probability of F |
|----------|---------------|--------|-----|--------------|---|------------------|
| ASPSLP | Mountains | between | 4 | 22.38 | 0.79 | 0.538 |
|  |  | within | 38 | 28.18 |  |  |
|  | Desert | between | 4 | 182.02 | 0.23 | 0.919 |
|  |  | within | 38 | 794.50 |  |  |
| CVRTYP | Mountains | between | 4 | 32.78 | 1.21 | 0.322 |
|  |  | within | 38 | 27.08 |  |  |
|  | Desert | between | 5 | 1969.90 | 3.46 | 0.012* |
|  |  | within | 37 | 569.45 |  |  |

*Significant at given probability level.
[a]Variable names from Table 1.
[b]Degrees of freedom.

Inspection of Figure 5 indicates a lack of significant effect of

ASPSLP which is confirmed by the low F statistic values in the AOV.

Although the north and south exposures had higher mean pellet densities

than east and west exposures in the mountains, the differences are not

significant even at the 0.2 probability level.  The very small sample

size (n = 2) contributed to the wide confidence interval estimate in

mountain "none" (no aspect) plots.  In the desert, the very low F sta-

tistic confirms the lack of effect of ASPSLP shown in Figure 5b.

The absence of significant ASPSLP effect in the mountains probably reflects movement of the animals to different exposures in response to the phenology of forage plants. Early summer foraging occurs on those exposures which support early plant growth; as early plants mature and dry out, foraging shifts to exposures which support green forage longer (Julander 1966). Exposures in the desert showed only very slight differences in pellet density. Because the winter range does not have a persistent, deep snowpack, deer would not be excluded from or concentrated on certain exposures for long periods. Hudson et al. (1976) found no significant influence by aspect. Terrel's (1973) results were inconclusive.

AOV tests of the effects of plant cover types (CVRTYP) detected a significant (P = 0.012) effect in desert sections, but no significant effect in mountain sections. Figure 6a shows that the mountain cover with the lowest mean PELLETS value, ASPEN, is significantly different from only one other cover, GRASSUP, and then only at the 0.2 probability level. In addition, ASPEN is the only cover type with a PELLET value significantly different (P < 0.2) from the overall mean for mountain sections. Three desert cover types, GRASSDN, PJ, and SAGEDN, had means significantly different from the overall desert mean. These differences, in addition to the significant differences between several cover types, contributed to the significant effect of CVRTYP in the desert. An AOV for the effects of CVRTYP on elevation was run to determine if the significant effects of CVRTYP on PELLETS were merely a result of elevational differences in desert cover types. The lack of significance (Table 6) indicated that CVRTYP effects were not due

Table 6.  Analysis of variance:  effect of ELEV on CVRTYP; rule development data--1976[a]

| Plot location | Groups | df[b] | Mean squares | F | Probability of F |
|---|---|---|---|---|---|
| Mountains | between | 4 | 925.12 | 1.04 | 0.40 |
| | within | 38 | 489.09 | | |
| Desert | between | 5 | 1511.37 | 1.37 | 0.259 |
| | within | 37 | 1106.76 | | |

[a]Variable names from Table 1.
[b]Degrees of freedom

to elevation.  The wide confidence intervals on OAKSERV resulted from the wide difference between the pellet group counts on the two plots. Elimination of OAKSERV from the AOV (Table 7) raised the F statistic to 4.20 (P = 0.007).

The low ASPEN value is unexpected, as aspen communities usually supported good understories; however, the higher understory density may have made pellet groups more difficult to find.  Utilization of most of a summer range from deer following maturing plants as discussed earlier for ASPSLP could account for the absence of a significant mountain CVRTYP effect.  Julander and Jeffery (1964) found significant (P < 0.1)  summer range preferences; the order of preference for their communities and deer-days use per acre were:  (1) mixed shrub (6.4), (2) oak (5.3), (3) aspen (4.2), (4) conifer-shrub (3.1), (5) aspen-conifer (2.1), and grass-forb (0.7).  Also unexpected in this study is the higher pellet density (although not significantly different) in piñon cover than in piñon-juniper cover.

Table 7. Analysis of variance: effect of CVRTYP (without OAKSERV) on PELLETS; rule development data--1976[a]

| Plot location | Groups | df[b] | Mean squares | F | Probability of F |
|---|---|---|---|---|---|
| Desert | within | 4 | 2378.84 | 4.20 | 0.007* |
| | between | 36 | 565.84 | | |

*Significant at given probability level.
[a]Variable names from Table 1.
[b]Degrees of freedom.

## Rule Construction and Validation

### Construction

Stepwise multiple regression was used to construct the habitat rule. The complete correlation matrices for PELLETS, cover type dummy variables, and habitat variables for mountain and desert sections are given in Appendices 1 and 2. In this study, only variables which contributed significantly ($P < 0.2$) when added to the regression equation were used in the final regression model. An attempt was also made to minimize both the number of and intercorrelations between independent variables used in the equation.

The dummy variables for plant cover types were regressed against PELLETS for mountain and desert sections (Table 8). PJ and ASPEN were coded with a value of -1; other cover types took the value of 1. One cover type in each area was not added to the regressions because the last cover type was completely described by the first n-1 variables; i.e., plots in the last cover type were identified as such because they

Table 8.  Stepwise regression of plant cover types on PELLETS; rule development data--1976[a]

| Plot Location | Step | Variables | $F_{var}$ [b] | Prob. of $F_{var}$ [c] | Mult. R | $R^2$ | $R^2$ Change | $F_{reg}$ [b] | Prob. of $F_{reg}$ [c] |
|---|---|---|---|---|---|---|---|---|---|
| Mountains | 1 | ASPEN | 3.851 | 0.057 | 0.293 | 0.086 | - | 3.851 | 0.057 |
| | 2 | ASPEN | 4.603 | 0.038 | 0.322 | 0.103 | 0.017 | 2.308 | 0.112 |
| | | SPRFR | 0.785 | 0.381 | | | | | |
| | 3 | ASPEN | 4.797 | 0.035 | 0.334 | 0.112 | 0.009 | 1.640 | 0.196 |
| | | SPRFR | 1.100 | 0.300 | | | | | |
| | | CONPOTR | 0.377 | 0.543 | | | | | |
| | 4 | ASPEN | 3.056 | 0.089 | 0.336 | 0.113 | 0.001 | 1.210 | 0.322 |
| | | SPRFR | 0.858 | 0.300 | | | | | |
| | | CONPOTR | 0.369 | 0.547 | | | | | |
| | | GRASSUP | 0.042 | 0.839 | | | | | |
| Desert | 1 | PJ | 6.653 | 0.014 | 0.374 | 0.140 | - | 6.653 | 0.014 |
| | 2 | PJ | 1.714 | 0.198 | 0.504 | 0.254 | 0.114 | 6.800 | 0.003 |
| | | SAGEDN | 6.117 | 0.018 | | | | | |
| | 3 | PJ | 3.368 | 0.074 | 0.550 | 0.303 | 0.049 | 5.640 | 0.003 |
| | | SAGEDN | 2.987 | 0.092 | | | | | |
| | | GRASSDN | 2.731 | 0.106 | | | | | |
| | 4 | PJ | 4.108 | 0.050 | 0.564 | 0.318 | 0.015 | 4.431 | 0.005 |
| | | SAGEDN | 1.803 | 0.187 | | | | | |
| | | GRASSDN | 3.286 | 0.078 | | | | | |
| | | OAKSERV | 0.864 | 0.358 | | | | | |
| | 5 | PJ | 2.995 | 0.092 | 0.564 | 0.319 | 0.001 | 3.459 | 0.012 |
| | | SAGEDN | 1.577 | 0.217 | | | | | |
| | | GRASSDN | 2.674 | 0.110 | | | | | |
| | | OAKSERV | 0.713 | 0.404 | | | | | |
| | | SHRUBDN | 0.026 | 0.872 | | | | | |

[a] Variable names from Table 1

[b] $F_{var}$ = F test for significance of contribution of variable to regression; $F_{reg}$ = F test for significance of regression equation.

[c] Significance of F statistic

were not included in any of the other cover types.  The F test for significant contribution of a variable ($F_{var}$) supported the results from the confidence interval estimates.  Because only ASPEN in the mountains and PJ, SAGEDN, and GRASSDN in the desert differed significantly ($P < 0.2$) from the overall mean for the respective areas, these were the only cover type variables which contributed significantly to the regressions.  Although the overall significance of the regression equation, as tested by an F test statistic ($F_{reg}$), remained significant for

two more regression steps in both the mountains and desert, it would have been incorrect to add those extra variables because their contribution was insignificant as indicated by both $F_{var}$ and the small increase in predictive ability of the regression equation ($R^2$). ASPEN, PJ, SAGEDN, and GRASSDN were, therefore, retained as significant plant cover types for further regression analysis.

To determine which group of significant habitat variables, along with significant cover type dummy variables, provided the best prediction of pellet density, a series of regressions were run (Table 9). The various regressions included the following variables: (1) significant plant cover types, (2) ELEV, (3) SLOPE, (4) EDGE2, and (5) one or two optical density variables. Only EDGE2 was included because it was highly correlated (r = 0.9) with EDGE4 and it was more strongly correlated with pellet density than EDGE4. Optical density variables included in the regressions summarized in Table 9 are: mountain sections--(regression 1) VISDN5, (regression 2) VISDN10, (regression 3) VARUP10, (regression 4) VARDN5; desert sections--(regression 1) VISUP10 and VARDN10, (regression 2) VISUP10 and VARDN5, (regression 3) VISUP5 and VARDN10, (regression 4) VISUP5 and VARDN5. EDGE2 and SLOPE were automatically not added by SPSS into mountain regressions 3 and 4 respectively because of their extremely small contributions to the regression.

Because mountain regression 1 and desert regression 2 resulted in the highest $R^2$ values (0.556 and 0.440 respectively), the variables in those regressions were selected for rule construction. Table 10 shows complete stepwise regression results using the selected variables.

Table 9. Summary of regressions of habitat variables on PELLETS; rule development data--1976[a]

| Plot location | Variable | Regression[b] | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Mountains | ASPEN | 0.086 | 0.086 | 0.086 | 0.086 |
| | ELEV | 0.456 | 0.456 | 0.456 | 0.456 |
| | SLOPE | 0.555 | 0.508 | 0.511 | - |
| | EDGE2 | 0.556 | 0.509 | - | - |
| | VISDN5 | 0.531 | - | - | - |
| | VISDN10 | - | 0.497 | - | - |
| | VARUP10 | - | - | 0.494 | |
| | VARDN5 | - | - | - | 0.460 |
| Desert | PJ SAGEDN GRASSDN | 0.303 | 0.303 | 0.303 | 0.303 |
| | SLOPE | 0.348 | 0.348 | 0.348 | 0.348 |
| | ELEV | 0.411 | 0.440 | 0.386 | 0.419 |
| | EDGE2 | 0.413 | 0.440 | 0.360 | 0.420 |
| | VISUP5 | - | - | 0.368 | 0.406 |
| | VISUP10 | 0.392 | 0.392 | - | - |
| | VARDN5 | - | 0.433 | - | 0.375 |
| | VARDN10 | 0.409 | - | 0.379 | |

[a]Variable names from Table 1.

[b]$R^2$ values.

Table 10. Stepwise regression of significant plant cover types and habitat variables on PELLETS; rule development data--1976[a]

| Plot Location | Step | Variables | $F_{var}$[b] | Prob. of $F_{var}$[c] | Mult. R | $R^2$ | $R^2$ Change | $F_{reg}$[b] | Prob. of $F_{reg}$[c] |
|---|---|---|---|---|---|---|---|---|---|
| Mountains | 1 | ELEV | 23.392 | <0.001 | 0.603 | 0.363 | - | 23.392 | <0.001 |
| | 2 | ELEV | 23.761 | <0.001 | 0.708 | 0.501 | 0.138 | 20.058 | <0.001 |
| | | VISDN5 | 11.912 | 0.002 | | | | | |
| | 3 | ELEV | 25.734 | <0.001 | 0.728 | 0.531 | 0.030 | 14.700 | <0.001 |
| | | VISDN5 | 6.241 | 0.017 | | | | | |
| | | ASPEN | 2.490 | 0.123 | | | | | |
| | 4 | ELEV | 21.377 | <0.001 | 0.745 | 0.554 | 0.023 | 11.821 | <0.001 |
| | | VISDN5 | 8.382 | 0.006 | | | | | |
| | | ASPEN | 3.114 | 0.086 | | | | | |
| | | SLOPE | 2.024 | 0.163 | | | | | |
| | 5 | ELEV | 20.355 | <0.001 | 0.746 | 0.556 | 0.002 | 9.267 | <0.001 |
| | | VISDN5 | 8.273 | 0.007 | | | | | |
| | | ASPEN | 2.878 | 0.098 | | | | | |
| | | SLOPE | 1.792 | 0.189 | | | | | |
| | | EDGE2 | 0.132 | 0.718 | | | | | |
| Desert | 1 | PJ | 3.368 | 0.074 | 0.550 | 0.303 | - | 5.640 | 0.003 |
| | | SAGEDN | 2.987 | 0.092 | | | | | |
| | | GRASSDN | 2.731 | 0.107 | | | | | |
| | 2 | PJ | 2.722 | 0.107 | 0.591 | 0.348 | 0.045 | 5.076 | 0.002 |
| | | SAGEDN | 0.712 | 0.404 | | | | | |
| | | GRASSDN | 4.503 | 0.040 | | | | | |
| | | SLOPE | 2.663 | 0.111 | | | | | |
| | 3 | PJ | 3.558 | 0.067 | 0.626 | 0.392 | 0.044 | 4.776 | 0.002 |
| | | SAGEDN | 2.681 | 0.110 | | | | | |
| | | GRASSDN | 1.542 | 0.222 | | | | | |
| | | SLOPE | 4.769 | 0.036 | | | | | |
| | | VISUP10 | 2.678 | 0.110 | | | | | |
| | 4 | PJ | 4.022 | 0.052 | 0.658 | 0.433 | 0.041 | 4.588 | 0.001 |
| | | SAGEDN | 1.473 | 0.232 | | | | | |
| | | GRASSDN | 2.456 | 0.126 | | | | | |
| | | SLOPE | 4.731 | 0.036 | | | | | |
| | | VISUP10 | 3.716 | 0.062 | | | | | |
| | | VARDN5 | 2.611 | 0.115 | | | | | |
| | 5 | PJ | 2.806 | 0.103 | 0.663 | 0.440 | 0.007 | 3.928 | 0.003 |
| | | SAGEDN | 1.266 | 0.268 | | | | | |
| | | GRASSDN | 2.487 | 0.124 | | | | | |
| | | SLOPE | 3.939 | 0.055 | | | | | |
| | | VISUP10 | 2.921 | 0.097 | | | | | |
| | | VARDN5 | 2.984 | 0.093 | | | | | |
| | | ELEV | 0.416 | 0.523 | | | | | |
| | 6 | PJ | 2.637 | 0.114 | 0.664 | 0.440 | 0.000 | 3.346 | 0.006 |
| | | SAGEDN | 0.882 | 0.354 | | | | | |
| | | GRASSDN | 2.449 | 0.127 | | | | | |
| | | SLOPE | 3.472 | 0.071 | | | | | |
| | | VISUP10 | 2.555 | 0.119 | | | | | |
| | | VARDN5 | 2.609 | 0.116 | | | | | |
| | | ELEV | 0.413 | 0.525 | | | | | |
| | | EDGE2 | 0.031 | 0.861 | | | | | |

[a] Variable names from Table 1

[b] $F_{var}$ = F test for significance of contribution of variable to regression; $F_{reg}$ = F test for significance of regression equation.

[c] Significance of F statistic

SLOPE had a statistically significant (P = 0.163) contribution to
the mountain regression in step 4; but because its correlation coef-
ficient was very low (r = 0.033), it was concluded that its inclusion
would be incorrect. $F_{var}$ for EDGE2 in step 5 indicated a non-signifi-
cant contribution. Therefore, because the contributions of SLOPE and
EDGE2 were insignificant and added only 0.025 to the $R^2$, the regres-
sion equation from step 3 was selected as the mountain rule. This rule,
including regression coefficients $B_i$, is:

PELLETS = (0.099 x ELEV) + (0.055 x VISDN5) + (2.126 x ASPEN)

   - 88.896                          $R^2$ = 0.531

The correlation matrix for this regression is given in Table 11.

Table 11.  Correlation matrix; mountain habitat rule[a]

|        | PELLETS | ASPEN  | ELEV  | SLOPE  | VISDN5 |
|--------|---------|--------|-------|--------|--------|
| ASPEN  | −0.293  |        |       |        |        |
| ELEV   | 0.603   | 0.018  |       |        |        |
| SLOPE  | 0.033   | 0.290  | 0.163 |        |        |
| VISDN5 | 0.452   | −0.383 | 0.141 | −0.452 |        |
| EDGE2  | 0.112   | −0.040 | 0.119 | 0.178  | −0.077 |

[a]Variable names from Table 1.

In the desert regression, ELEV and EDGE2, which were added in steps 5 and 6 respectively, had non-significant $F_{var}$ values and contributed only 0.007 to the $R^2$. Therefore, the regression equation from step 4 was selected as the desert rule. This rule, including regression coefficients $B_i$, is:

$$\text{PELLETS} = (18.293 \times \text{PJ}) + (14.550 \times \text{SAGEDN}) + (-23.887 \times \text{GRASSDN})$$
$$+ (-9.419 \times \text{SLOPE}) + (-0.388 \times \text{VISUP10}) + (0.419 \times \text{VARDN5})$$
$$+ 94.099 \qquad\qquad R^2 = 0.433$$

The correlation matrix for this regression is given in Table 12.

Table 12. Correlation matrix; desert habitat rule[a]

| | PELLETS | PJ | SAGEDN | GRASSDN | SLOPE | VISUP10 | VARDN5 | ELEV |
|---|---|---|---|---|---|---|---|---|
| PJ | 0.374 | | | | | | | |
| SAGEDN | 0.471 | 0.455 | | | | | | |
| GRASSDN | −0.250 | 0.199 | −0.234 | | | | | |
| SLOPE | −0.375 | −0.408 | −0.477 | −0.211 | | | | |
| VISUP10 | 0.200 | 0.523 | 0.642 | 0.277 | −0.664 | | | |
| VARDN5 | −0.321 | −0,298 | −0.455 | −0.202 | 0.396 | −0.535 | | |
| ELEV | 0.153 | 0.221 | 0.005 | −0.060 | −0.062 | −0.128 | 0.323 | |
| EDGE2 | −0.249 | 0.043 | −0.439 | 0.071 | 0.305 | −0.214 | 0.381 | 0.139 |

[a]Variable names from Table 1

Comparison of what might seem unusually low predictive capabilities

in this study's regressions to results of other studies shows that low

$R^2$ values have been widely reported. In a study by Cook (1966), only

11 of 21 habitat variables in a multiple regression significantly

affected cattle utilization of slopes. The $R^2$ with all 21 variables in

the multiple regression was only 0.375. Anderson et al. (1972) calcu-

lated $R^2$'s of 0.40, 0.37, and 0.45 for deer use of three Colorado win-

ter range sites; however, the set of significant variables was differ-

ent for each area, and no one variable was significant in all three

areas. Further, several of the included variables may have had high

intercorrelations or have been functions of deer presence. The high-

est $R^2$ calculated by Terrel (1973) in Utah piñon-juniper communities

was 0.526; however, 22 variables were included in this regression, and

most of the other regressions had much lower $R^2$ values (e.g. 0.360,

0.215, 0.119). Hudson (1977) could describe only 23 and 25 percent of

the variation in winter and spring spatial distribution of white-tailed

deer, mule deer, elk, and bighorn sheep (Ovis canadensis). Taken indi-

vidually, 16 percent of winter and 12 percent of the variation in

spring mule deer distribution could be explained. Schijf (1978) ex-

plained only 23-35 percent of the variation in springbok (Antidorcas

marsupialis) distribution, of which 17-33 percent was from a measure of

gregariousness.

Several studies have reported higher $R^2$ values than those from

this study; however, results from some of these other studies may suf-

fer from one or more statistical problems. Two major problems are

high inter-correlations between the independent variables

(multicollinearity) and inclusion of an inappropriately large number of often insignificant variables; either problem may cause unreasonably high $R^2$ values. Nie et al. (1975) cautioned users of the SPSS REGRESSION program against multicollinearity. Regressions by Slough and Sadlier (1977) which had $R^2$ values of 0.926 and 0.805 for prediction of lake and stream beaver den density included some highly intercorrelated variables. In addition, an important parameter in their analysis was shoreline length or some function thereof; thus, the regression simply stated that more beaver colonies occurred in areas with more space for beaver colonies. Although this conlusion may be satisfactory for prediction of colony density and use for land management, it contributes little to the understanding of habitat quality or habitat selection. Hirst (1971) reported $R^2$ values from 0.427 to 0.908 when analyzing habitat selection by seven African ungulates. However, 16 to 42 often highly intercorrelated variables were included in the calculations. That multicollonearity and numerous independent variables can produce spurious results can be documented in this study. A mountain section regression which included ASPEN, ELEV, six optical density variables, SLOPE, TJANMEAN, EDGE2, and EDGE4 produced an $R^2$ of 0.988. A desert section regression which included the significant cover types, SLOPE, three optical density variables, and EDGE4 produced an $R^2$ of 0.977. Although both regression equations had significant F statistics, the validity of the $R^2$ values is extremely questionable. A final common problem observed in Julander and Jeffrey (1964) and other previously cited studies is the use of independent variables which are functions either of the dependent variable or of some

parameter of which the dependent variable is also a function (e.g. forage utilization). Forage utilization is a function of deer use or presence. Julander and Jeffery (1964) reported $R^2$ values of 0.69, 0.49, and 0.77 for deer, elk, and cattle distributions respectively. However, inclusion of forage utilization in a regression with independent site factors may be inappropriate and artificially elevate $R^2$ values.

### Validation

Habitat parameter data from plots visited during the summer of 1977 were input into the habitat rules which calculated an expected pellet density. Predicted pellet density was plotted against field measured density in Figure 7. The figure and accompanying statistics show that the models accounted for only 8 and 0.02 percent of measured mountain and desert variation in PELLETS.

Means, summary statistics, and correlation coefficients with PELLETS for the habitat variables in 1977 are presented in Table 13-15. Several variables had significantly different ($P < 0.05$) mean values during 1977 when compared to 1976. Of variables included in the mountain rule, ELEV decreased and VISDN5 increased significantly. In the desert rule, SAGEDN was the only variable to significantly change, with mean pellet density decreasing to 14.6. Overall 1977 desert pellet density was only 27 percent of the 1976 density. However, if pellet groups had merely been of lower density but with the same relative distribution in 1977 as 1976, the percentage of explained variation would have been higher, and the lower density would have been expressed
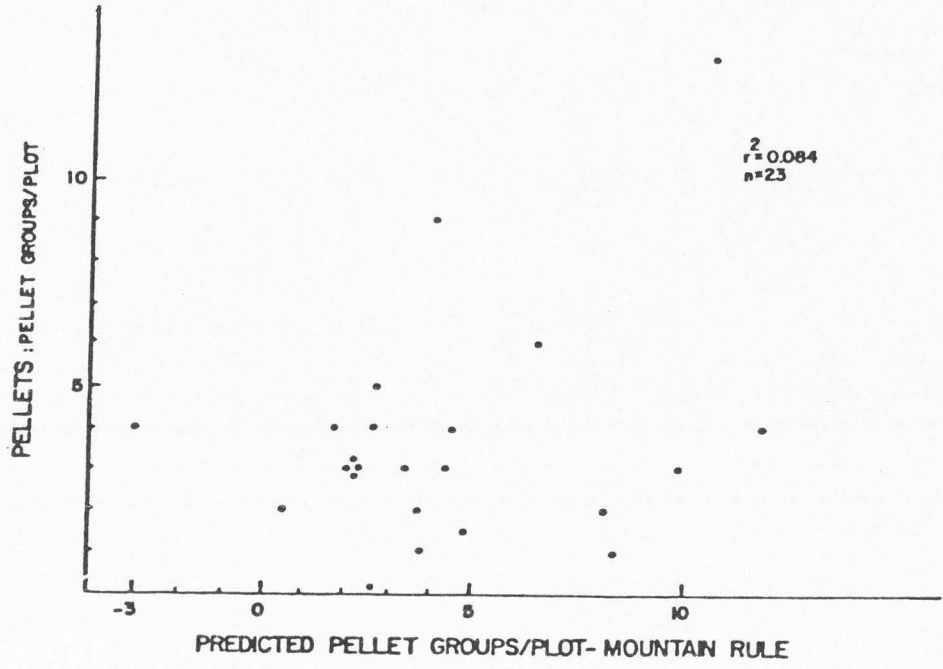
a.  Mountain sections.
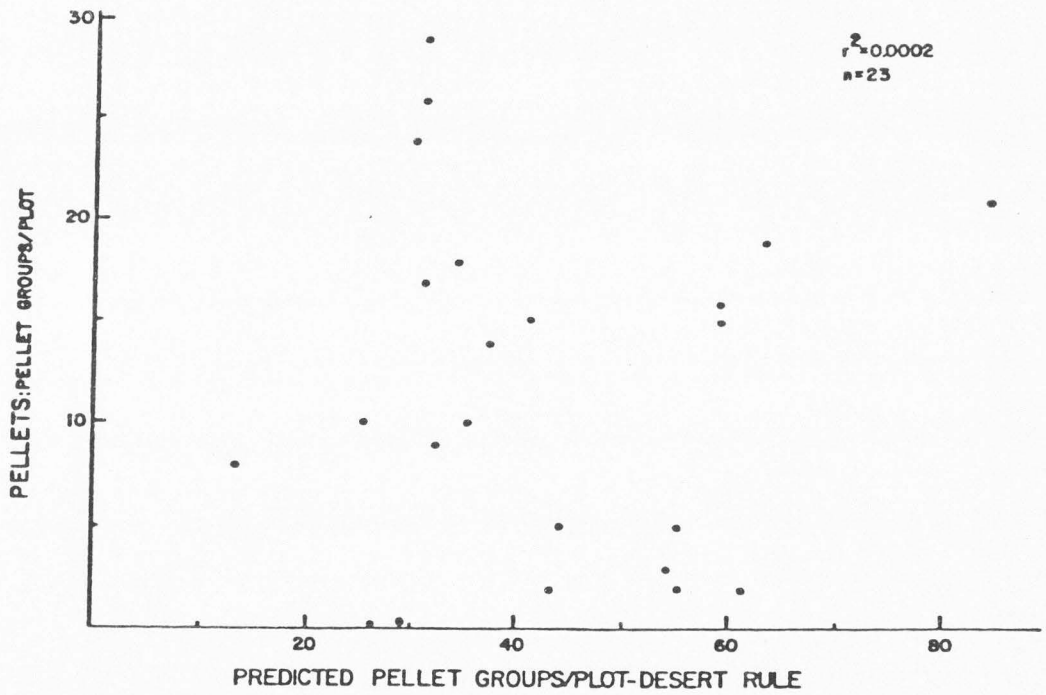


b.  Desert sections.

Figure 7.   Relationship of predicted and field measured pellet group
            density.

Table 13. Variable means and standard deviations; rule validation
data--1977[a]

| Variable | Mountains (n-23) | | Desert (n=23) | |
|---|---|---|---|---|
| | $\bar{x}$ | s | $\bar{x}$ | s |
| PELLETS | 3.7 | 2.74 | 11.8* | 8.66 |
| VISUP10 | 66.9 | 27.07 | 83.0 | 21.55 |
| VISUP5 | 78.0 | 21.27 | 89.1 | 16.27 |
| VISDN10 | 51.3* | 29.03 | 75.8 | 23.94 |
| VISDN5 | 62.9* | 24.62 | 83.1 | 23.61 |
| VARUP10 | 28.9 | 17.41 | 19.6 | 19.92 |
| VARUP5 | 26.3 | 16.92 | 15.0 | 20.38 |
| VARDN10 | 33.3* | 13.56 | 25.6 | 14.95 |
| VARDN5 | 32.7 | 12.95 | 18.7 | 17.53 |
| ELEV | 913.8* | 27.58 | 643.1 | 44.21 |
| SLOPE | 23.4 | 21.10 | 12.8 | 18.29 |
| GRASSHT | 0.5 | 0.36 | 0.2* | 0.13 |
| FORBHT | 0.5 | 0.36 | 0.1* | 0.06 |
| SHRUBHT | 0.3 | 0.43 | 0.6 | 0.47 |
| EDGE2 | 12.3* | 4.22 | 5.1* | 4.45 |
| EDGE4 | 6.3* | 3.14 | 2.3* | 2.65 |

[a]Significantly different ($P < .05$) from corresponding rule
development data (Table 2).
[a]Variable names from Table 1.

Table 14. Simple correlation coefficients and significance of correlation of habitat variables with PELLETS; rule validation data--1977[a]

| Variable | Mountains | | Desert | |
|----------|-----------|-----------|----------|-----------|
| | r | (sig.[b]) | r | (sig.[b]) |
| VISUP10 | 0.245 | (.129) | -0.276 | (.101) |
| VISUP5 | 0.196 | (.185) | -0.203 | (.177) |
| VISDN10 | 0.269 | (.107) | -0.216 | (.162) |
| VISDN5 | 0.227 | (.149) | -0.279 | (.098) |
| VARUP10 | -0.345 | (.054) | 0.228 | (.148) |
| VARUP5 | -0.291 | (.089) | 0.105 | (.317) |
| VARDN10 | -0.462 | (.013) | 0.460 | (.014) |
| VARDN5 | -0.432 | (.020) | 0.103 | (.319) |
| ELEV | 0.235 | (.140) | 0.230 | (.146) |
| SLOPE | -0.153 | (.243) | -0.201 | (.179) |
| GRASSHT | -0.022 | (.460) | 0.280 | (.098) |
| FORBHT | 0.065 | (.384) | 0.097 | (.330) |
| SHRUBHT | 0.296 | (.085) | 0.218 | (.159) |
| EDGE2 | -0.133 | (.273) | 0.202 | (.178) |
| EDGE4 | -0.091 | (.339) | 0.361 | (.045) |

[a] Variable names from Table 1.
[b] Significance of correlation coefficient (r).

Table 15. ASPSLP and CVRTYP: sample size, mean, and standard deviation of PELLETS for categories; rule validation data--1977[a]

| Variable | Plot location | Category[a] | n | $\bar{x}$ | s |
|---|---|---|---|---|---|
| ASPSLP | Mountains | none | 6 | 4.1 | 2.47 |
| | | north | 4 | 5.2 | 5.37 |
| | | east | 5 | 3.6 | 1.67 |
| | | south | 4 | 2.3 | 0.96 |
| | | west | 4 | 3.1 | 2.16 |
| | Desert | none | 13 | 12.0* | 7.99 |
| | | north | 2 | 26.5 | 3.54 |
| | | east | 4 | 2.6* | 3.73 |
| | | south | 2 | 16.5 | 2.12 |
| | | west | 2 | 9.5 | 0.70 |
| CVRTYP | Mountains | ASPEN | 7 | 3.5 | 2.76 |
| | | SPRFR | 4 | 2.7 | 1.25 |
| | | CONPOTR | 4 | 3.0 | 1.15 |
| | | GRASSUP | 6 | 4.9 | 4.30 |
| | | SAGEUP | 2 | 4.0 | 1.41 |
| | Desert | GRASSDN | 4 | 13.4 | 11.04 |
| | | PJ | 8 | 15.9 | 7.47 |
| | | SAGEDN | 5 | 14.6* | 7.35 |
| | | OAKSERV | 1 | 2.2 | - |
| | | PINON | 0 | - | - |
| | | SHRUBDN | 5 | 3.0* | 2.04 |

*Significantly different ($P < .05$) from corresponding rule development data (Table 4).
[a]Variable and category names from Table 1.

by a regression line slope differing from one. An AOV showed similar
ASPSLP and CVRTYP effects in 1977 as in 1976 (Table 16), except that
ASPSLP significantly affected desert pellet distribution. Differences
in variable means may have resulted from different percentages of
various cover types visited during 1976 and 1977.

Table 16. Analysis of variance: effect of ASPSLP and CVRTYP on
PELLETS; rule validation data--1977[a]

| Variable | Plot location | Groups | $df^b$ | Mean squares | F | Prob. of F |
|----------|---------------|--------|--------|--------------|------|------------|
| ASPSLP | Mountains | between | 4 | 4.87 | 0.60 | 0.667 |
| | | within | 18 | 8.07 | | |
| | Desert | between | 4 | 206.45 | 4.49 | 0.011* |
| | | within | 18 | 45.88 | | |
| CVRTYP | Mountains | between | 4 | 4.02 | 0.49 | ℃.748 |
| | | within | 18 | 8.26 | | |
| | Desert | between | 5 | 132.43 | 2.28 | 0.093* |
| | | within | 17 | 58.21 | | |

*Significant at given probability level.
[a] Variable names from Table 1.
[b] Degrees of freedom.

The winter of 1976-1977 was one of severe drought in Utah. How-
ever, because this study investigated traditional utilization trends
using pellet groups of more than one year, it is unlikely that the

effects of the drought could have caused the large differences between the 1976 and 1977 data.

The poor results of the rule validation can be explained by examination of the individual correlation coefficients. In the mountains, the 1977 r value for ELEV was approximately 40 percent of the 1976 value. In the desert, VISUP10 changed from r = 0.200 to r = -0.276, and VARDN5 went from r = -0.321 to r = 0.103.

The statistical analysis during rule development was susceptable to Type I (alpha) errors (Lapin 1975). In this study, a Type I error is the conclusion that a variable had a significant effect on pellet density when, in truth, it did not. Use of 0.2 as the critical probability level and an analysis of many independent variables increased the likelihood of such errors.

Only one previously cited study performed a model validation segment during data analysis. Slough and Sadlier (1977) tested their beaver land-capability rule for lakes with 34 additional data points. Actual colony density regressed against predicted colony density produced an $R^2$ of 0.53; $R^2$ during rule development was 0.93. Although the validation $R^2$ was significant, it was substantially smaller than what would have been expected from the rule development $R^2$.

CONCLUSIONS

## Deer Habitat Rule

The regression models developed from the first summer's data were
unable to predict pellet density for the independent set of data
gathered during the second summer.  Thus, using the techniques employed
in this study, a predictive rule of mule deer habitat cannot be con-
structed.  Shannon et al. (1975), Hudson et al. (1976), and Slough
and Sadlier (1977) gave several possible explanations for poor results
obtained when attempting to describe habitat selection.

To determine differences in habitat quality by measuring varying
levels of use, a habitat must be filled so that all areas of potential
habitat are being exploited and areas of equal preference are occupied.
Recent studies (Utah State Division of Wildlife Resources 1976) stated
that deer numbers were low on the herd unit encompassed by the desert
sections of the ECOSYM strip.

Secondly, distribution may not always be tightly related to the
environment.  The migratory and home range behavior of deer and other
species may reflect traditional responses which originated under dif-
ferent habitat conditions.  Herding and avoidance behavior could cause
different utilization of two adjacent habitats of equal quality.

The conceptual image of ECOSYM rules during the early stages of
this work was that each point in space had a habitat value based upon
parameters measured at that point and disregarding parameters in

surrounding areas. Deer habitat quality, however, because of the high mobility and migration of deer, cannot be measured as a point value. Therefore, habitat quality for deer and other mobile species must be evaluated by measuring components within cells of habitat, the size of which must correspond to daily or seasonal activity patterns. Stocker and Gilbert (1977) measured components in 1 km$^2$ cells of white-tailed deer habitat.

The most basic requirement for reliable results is precise measurement of habitat utilization and habitat parameters. The reliability of pellet group counts has been previously discussed; however, trend or census techniques for most species have many inherent biases or unrealistic assumptions. Further, it is unknown whether the methods used in this and other studies to measure habitat components (e.g. vegetation density boards) accurately measured those components.

Finally, it is unknown whether the habitat components which were measured were, in actuality, part of the functional environment of the animal (Moen 1973). Perception and selection of habitat may result from complex often non-linear reactions to numerous environmental stimuli either not measured or incorrectly analyzed by the techniques employed in this study.

### Potential of Habitat Rules

This study has not proven that a habitat rule cannot be constructed for mule deer. It has, however, suggested several limitations of the rule concept. Rules can probably be constructed for species which are limited by a single or a small set of resources such as winter cover

for snowshoe hares or nest trees for woodpeckers.  Notably, a rule for mule deer could probably be constructed where winter concentration areas (Gilbert et al. 1970) or some other factor was the weak link in sustaining the population.  Where no such clearcut relationship exists, many habitat components may govern distribution, any or all of which may vary in importance in time and space.  Whether such complex inter-actions can be quantified is unknown.

Rules will be of little utility if they are applicable only to a small area.  The adaptability and variability of deer as shown by Smith (1952), Miller (1970), Anthony and Smith (1977), and others indi-cate that deer rules, when developed, may be appropriate for very limited areas.  For some species, habitat utilization can vary between areas because of presence or absence of competitors, as shown for desert rodents by Larsen (1978).  Ideally, habitat rules will be con-structed on the basis of functional habitat components.  The use of vegetation structure rather than plant species and of nutritional re-quirements rather than forage species illustrate how rules might be structured to increase their applicability.

For habitat rules to be effective land management tools, mere correlation of activities to various parameters is necessary.  None-theless, for the rules to be defendable to land managers and the general public, it will be advantageous to demonstrate some biological or physical explanation for the results generated by statistical analysis. The search for cause and effect relationships will also generate the increased understanding of biological systems which was an original justification for development of the rule concept.

## Importance of Replication

The data from 1976 had virtually no relationship to the data from 1977. Had these two years of data been collected by separate studies, the results and conclusions from the data would have been very different. That both data sets were collected by the same personnel in the same area makes the results even more unexpected. Only one of the cited studies (Slough and Sadlier 1977) attempted validation of results from initial data analysis by use of an independent data set. If results of studies are to be accepted and applied to management plans in the field, results must be confirmed. This study illustrates how acceptance of conclusions from one set of data may be incorrect and is certainly unwise.

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APPENDICES

Appendix A

Correlation Matrix:  Mountain Habitat Variables

| | PELLETS | VISUP10 | VISUP5 | VISDN10 | VISDN5 | VARUP10 | VARUP5 | VARDN10 | VARDN5 | TJANMEAN | ELEV | SLOPE | EDGE2 | EDGE4 | GRASSUP | SAGEUP | SPRFR | ASPEN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VISUP10 | 0.063 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| VISUP5 | 0.012 | 0.946 | | | | | | | | | | | | | | | | |
| VISDN10 | 0.419 | 0.786 | 0.732 | | | | | | | | | | | | | | | |
| VISDN5 | 0.452 | 0.692 | 0.681 | 0.961 | | | | | | | | | | | | | | |
| VARUP10 | -0.291 | -0.707 | -0.611 | -0.849 | -0.787 | | | | | | | | | | | | | |
| VARUP5 | -0.153 | -0.863 | -0.841 | -0.881 | -0.811 | 0.899 | | | | | | | | | | | | |
| VARDN10 | -0.025 | -0.226 | -0.134 | -0.210 | -0.024 | 0.413 | 0.365 | | | | | | | | | | | |
| VARDN5 | -0.065 | -0.721 | -0.629 | -0.622 | -0.415 | 0.650 | 0.751 | 0.782 | | | | | | | | | | |
| TJANMEAN | -0.614 | 0.022 | 0.052 | -0.209 | -0.119 | 0.026 | -0.041 | 0.340 | 0.292 | | | | | | | | | |
| ELEV | 0.603 | 0.023 | -0.010 | 0.233 | 0.141 | -0.037 | 0.026 | -0.339 | -0.305 | -0.963 | | | | | | | | |
| SLOPE | 0.033 | -0.483 | -0.503 | -0.364 | -0.452 | 0.491 | 0.535 | -0.123 | 0.095 | -0.184 | 0.163 | | | | | | | |
| EDGE2 | 0.112 | -0.128 | -0.154 | -0.001 | -0.077 | 0.017 | 0.090 | -0.137 | -0.070 | -0.041 | 0.119 | 0.178 | | | | | | |
| EDGE4 | 0.062 | -0.218 | -0.255 | -0.130 | -0.187 | 0.064 | 0.184 | -0.159 | -0.042 | -0.006 | 0.070 | 0.121 | 0.876 | | | | | |
| GRASSUP | 0.172 | 0.507 | 0.493 | 0.794 | 0.749 | -0.440 | -0.546 | -0.403 | -0.628 | -0.214 | 0.165 | -0.312 | -0.106 | -0.108 | | | | |
| SAGEUP | 0.173 | 0.476 | 0.426 | 0.265 | 0.312 | -0.553 | -0.546 | 0.330 | 0.003 | 0.299 | -0.263 | -0.496 | -0.092 | -0.164 | -0.173 | | | |
| SPRFR | -0.017 | -0.480 | -0.376 | -0.209 | -0.031 | 0.321 | 0.450 | 0.249 | 0.528 | 0.055 | -0.072 | 0.087 | 0.041 | 0.206 | -0.263 | -0.200 | | |
| ASPEN | 0.293 | 0.035 | 0.028 | 0.289 | 0.383 | -0.258 | -0.167 | 0.205 | 0.184 | -0.033 | -0.018 | -0.290 | 0.040 | 0.066 | 0.315 | 0.239 | 0.362 | |
| CONPOTR | 0.053 | -0.356 | -0.424 | -0.346 | -0.393 | 0.256 | 0.326 | 0.142 | 0.248 | -0.138 | 0.114 | 0.299 | 0.195 | 0.103 | -0.211 | -0.160 | -0.243 | 0.290 |

Variable names from Table

Appendix B

Correlation Matrix:  Desert Habitat Variables

| | PELLETS | VISUP10 | VISUP5 | VISDN10 | VISDN5 | VARUP10 | VARUP5 | VARDN10 | VARDN5 | TJANMEAN | ELEV | SLOPE | EDGE2 | EDGE4 | PINON | PJ | SAGEDN | GRASSDN | SHRUBDN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VISUP10 | 0.120 | | | | | | | | | | | | | | | | | | |
| VISUP5 | 0.240 | 0.964 | | | | | | | | | | | | | | | | | |
| VISDN10 | -0.184 | 0.619 | 0.581 | | | | | | | | | | | | | | | | |
| VISDN5 | -0.080 | 0.518 | 0.605 | 0.920 | | | | | | | | | | | | | | | |
| VARUP10 | -0.228 | -0.788 | -0.741 | -0.627 | -0.564 | | | | | | | | | | | | | | |
| VARUP5 | -0.242 | -0.890 | -0.871 | -0.607 | -0.584 | 0.936 | | | | | | | | | | | | | |
| VARDN10 | -0.303 | -0.552 | -0.580 | -0.722 | -0.747 | 0.709 | 0.695 | | | | | | | | | | | | |
| VARDN5 | -0.321 | -0.535 | -0.617 | -0.749 | -0.849 | 0.667 | 0.675 | 0.934 | | | | | | | | | | | |
| TJANMEAN | 0.333 | 0.408 | 0.392 | 0.166 | 0.009 | -0.479 | -0.470 | -0.206 | -0.236 | | | | | | | | | | |
| ELEV | 0.153 | -0.128 | -0.135 | -0.518 | -0.470 | 0.085 | 0.169 | 0.230 | 0.323 | -0.289 | | | | | | | | | |
| SLOPE | -0.375 | -0.664 | -0.656 | 0.016 | -0.097 | 0.604 | 0.614 | 0.391 | 0.396 | -0.446 | -0.062 | | | | | | | | |
| EDGE2 | -0.249 | -0.214 | -0.229 | -0.199 | -0.213 | 0.408 | 0.348 | 0.334 | 0.381 | -0.375 | 0.139 | 0.305 | | | | | | | |
| EDGE4 | -0.138 | -0.247 | -0.242 | -0.219 | -0.269 | 0.502 | 0.447 | 0.340 | 0.409 | -0.287 | 0.098 | 0.393 | 0.865 | | | | | | |
| PINON | 0.058 | -0.381 | -0.388 | -0.538 | -0.548 | 0.406 | 0.378 | 0.249 | 0.422 | -0.185 | 0.169 | 0.291 | 0.274 | 0.377 | | | | | |
| PJ | 0.374 | 0.520 | 0.434 | 0.126 | 0.023 | -0.482 | -0.504 | -0.462 | -0.298 | 0.176 | 0.221 | -0.408 | 0.043 | -0.005 | 0.274 | | | | |
| SAGEDN | 0.471 | 0.642 | 0.618 | 0.149 | 0.126 | -0.707 | -0.729 | -0.485 | -0.455 | 0.437 | 0.005 | -0.477 | -0.439 | -0.482 | -0.323 | 0.455 | | | |
| GRASSDN | -0.250 | 0.277 | 0.233 | 0.460 | 0.409 | -0.259 | -0.169 | -0.217 | -0.202 | 0.057 | -0.060 | -0.211 | 0.071 | 0.032 | -0.141 | 0.199 | -0.234 | | |
| SHRUBDN | 0.063 | 0.125 | 0.140 | -0.003 | -0.156 | 0.013 | -0.101 | 0.238 | 0.149 | 0.037 | -0.052 | -0.134 | 0.167 | 0.172 | -0.121 | 0.170 | -0.200 | -0.088 | |
| OAKSERV | -0.104 | -0.210 | -0.284 | * | * | 0.204 | 0.266 | * | * | -0.412 | 0.310 | 0.154 | 0.306 | 0.166 | -0.097 | 0.137 | -0.162 | -0.071 | -0.060 |

* Correlation coefficient could not be computed

Variable names from Table