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Diet and diseases of Zion Canyon mule deer, Zion National Park, Utah

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DIET AND DISEASES OF ZION CANYON MULE DEER, ZION NATIONAL PARK, UTAH

by
Brenda Cunningham

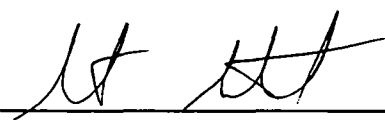
A thesis submitted in partial fulfillment
of the requirements for the degree of Master of Science in

Biology

Department of Biological Sciences
University of Nevada, Las Vegas
May, 1992

The thesis of Brenda Cunningham for the degree of Master of Science in Biology is approved.

Chairperson, Charles L. Douglas, Ph.D.



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ABSTRACT

Many mule deer (*Odocoileus hemionus*) in Zion Canyon, Zion National Park appear to be in poor condition. In this study diet composition, nutritional value of the diet, prevalences of diseases and parasites, and herd composition were examined for further evidence of poor condition. Analysis of forage plants indicated a nutritionally adequate diet. This conclusion was also supported by serum chemistry results. Serum titer levels did not reveal any current infections, however, high eosinophil levels in 84 % of animals tested were likely due to parasitism. Cysticeri of two species of *Taenia*, adult *Elaeophora schneideri*, and *Sarcocystis hemionilatrantis* were isolated in necropsies of two deer. Recruitment rates in Zion Canyon mule deer are indicative of healthy animals, however data presented here suggest the population has a greater proportion of older animals than other herds. Succession of canyon vegetation is presented here as the probable cause of historical changes in herd size.

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INTRODUCTION

This study examines the current physiological status and historical changes in the population and habitat of mule deer (*Odocoileus hemionus*) in Zion Canyon, Zion National Park, Utah. Many deer in the canyon appear to be in poor condition and emaciated adults and small fawns are common sights. Blood chemistry and nutrition of the herd have been analyzed here to evaluate the health of the deer and several aspects of their natural history have been examined for indications of poor health.

In 1909 President Howard Taft, by proclamation, created Mukuntuweap National Monument. This act was the first step in setting aside the area that is now Zion National Park. Zion Canyon, the central canyon of the park, has been the site of human activity for many centuries. It is well established that prehistoric cultures farmed and gathered food in the canyon (Conner and Vetter, 1986). At the time of pioneer settlement in 1862, Paiute Indians resided there and utilized the area for farming and food gathering (Woodbury, 1950). Until 1909 the upper end of Zion Canyon was grazed by the cattle and sheep of Western pioneers (Woodbury, 1950). It was not until 1933, however, that the land at the mouth of the canyon came under protection of the National Park Service. Until that time, the area was farmed extensively and grazed by sheep and cattle (Naturalist Report to the Superintendent, 1936, Zion National Park archives).

As in other regions of the Southwest, we can only speculate about species composition of the canyon's vegetation before farming and grazing. There are no relict plant populations on the floor of the canyon, and the slopes are areas of natural disturbance susceptible to opportunistic species such as brome grasses. The National Park Service planted cottonwood and ash trees in areas that require irrigation for such species and also continued to irrigate fruit trees planted by pioneer settlers. Large areas of lawn occur near the mouth of the canyon in employee housing areas and in the middle of the canyon in front of Zion Lodge. Deer use these areas extensively.

Although deer can move between both rims and the canyon floor and through the

Narrows at the upper end, canyon topography has restricted their movements, which made hunting deer easy for Paiutes and pioneers. According to the accounts of settlers, sightings of deer were rare in the 1920's (J.L. Crawford, personal communication). Park reports in the mid-1920's also indicated that sightings of deer in the canyon occurred infrequently (Naturalist Report to the Supt., 1928, ZNP archives). By 1935 deer sightings were common and managers became concerned about growth of the deer population (Naturalist Report to the Supt., 1935, ZNP archives).

The condition of the deer was considered good in 1933 (Naturalist Report to the Supt., 1933, ZNP archives), but had deteriorated to poor by 1937 (Presnall report on deer problem in Zion, 1937, ZNP archives). In 1938 C.C. Presnall, Park Naturalist, wrote of his concern for the vegetation of the canyon: "A pronounced deer line exists on all trees on the river bottoms..." and "...the range has approached a critical condition" (Presnall, 1938). The deer population was estimated at 300, and vegetation in the canyon appeared to be heavily impacted. Presnall (1938) proposed that the deer population was growing unchecked because of the extirpation of large predators, such as mountain lions. In an effort to improve the condition of the deer and the vegetation, in 1938 the Park began randomly culling the herd. Between 1938 and 1942, under direction of the Park Service, the Civilian Conservation Corps (CCC) trapped 271 deer and moved them to Forest Service and Bureau of Land Management sites. The herd continued to increase, and was estimated at 600 in 1942 (Naturalist Report to the Supt., 1942, ZNP archives). In the summer of 1943 the local hunters were hired to reduce the herd by 300 animals. The deer carcasses were dressed and donated to charitable organizations (Smith, 1943).

From 1966 to 1968 Bruce Moorhead studied movements of deer inhabiting the east rim of the canyon. These deer are part of Utah deer unit number 58 and are exposed to hunting outside the park. In addition to marking deer on the rim, Moorhead tagged and collared 20 deer in the canyon. He was able to document seasonal movements of animals in and out of the canyon and north-south movements within the canyon. Using a pellet group count method he

estimated the herd to be at least 320 animals residing all year in the canyon and 400 in the winter. This estimate translates to a density of 223 deer per square mile in the canyon in the summer, compared to 35 to 62 deer per square mile in other areas of the park (Moorhead, 1976).

In 1970, prompted by the high density of animals in the canyon, the park entered an agreement with the Utah Division of Wildlife Resources and the Bureau of Land Management (BLM) for the removal and translocation of Zion Canyon deer. In March, 1970, 40 deer were removed from the canyon by immobilization and trapping. Utah Division of Wildlife Resources transported the surviving deer to a BLM site (Deer translocation file, 1970, Resource Management, ZNP).

In 1990 the status of canyon deer was unknown. Roadside winter censuses had been conducted sporadically. In December, 1982, 54 deer were counted in the canyon by Mitchell and Anglin (Deer census file, 1982, Resource Management, ZNP). In December, 1986, 101 deer were counted in the canyon. In January and February of 1988, 56 and 86 deer were counted (Deer census file, 1988, Resource Management, ZNP).

In this study the physiological condition of the deer herd was evaluated. Blood and fecal samples were collected to analyze for indications of poor nutrition and diseases. Diet composition was determined through microhistological examination of deer feces and samples of important forage species were analyzed for nutritional value. Possible effects of vegetational succession and weather patterns on the condition of the deer were also examined. Historical records and recent population surveys were used to evaluate herd size and composition for evidence of poor condition.

LITERATURE REVIEW

Serum chemistry

Chemical constituents of blood samples are used to evaluate the nutritional status of ungulates. Correlations have been found between quality of diet and serum chemistry (Card et al., 1985; deCalesta et al., 1975; DelGuidice et al., 1987 and 1990b; Kie et al., 1983; Seal et al., 1972;). A minimum dietary protein requirement of 7% for deer maintenance and growth has been determined in controlled experiments (Dietz, 1965). The most consistent blood sample indicator of dietary protein levels is serum urea nitrogen (SUN) (Brown, 1984). Seal et al. (1978) examined the blood of 40 deer captured on sites that differed in vegetational succession and found lower SUN levels in deer from the site dominated by mature pine forests. This site was presumed to have lower quality and quantity of forage. In contrast, deer fed on alfalfa and deer from sites with earlier successional stages had higher SUN levels (Seal et al., 1978). Bahnak et al. (1979) found a low-protein diet (6.6%) resulted in low SUN levels. However, SUN levels should be interpreted with caution. High SUN levels also may occur in starvation states due to catabolism of muscle tissue (Bahnak et al., 1979; deCalesta et al., 1975).

The relationship of total serum protein (TSP) to dietary protein is not as clear as that of SUN. Bahnak et al. (1979) found TSP levels on low-protein diets (6.6%) to be consistently lower, but not always significantly different, than those of deer on high-protein diets (16.2%). Although Seal et al. (1978) found differences in SUN levels between habitats, they did not find significant differences in serum protein levels.

Serum cholesterol, most of which is produced in the liver, may be related to caloric intake. Coblentz (1975) reported a downward trend in cholesterol levels from October through January in deer. Although a concurrent study of the diet was not conducted, Coblentz suggested serum cholesterol levels may be used as an indicator of nutritional conditions. Other studies also have found seasonal variations in cholesterol (Waid and Warren, 1984; Warren et al., 1981). Testing the hypothesis that cholesterol reflected dietary energy, Card et al. (1985) compared

serum cholesterol levels in deer on low energy diets with those on high energy diets and found no significant difference. It has been suggested that cholesterol is affected more by seasonal changes in thyroid hormone production than by dietary changes (Card et al., 1985; DelGuidice et al., 1987; Seal et al., 1972).

The serum concentrations of several essential minerals have been studied as indicators of dietary quality. Serum potassium, calcium, and phosphorus are affected by dietary intake (DelGuidice et al., 1987; Simeson, 1970). Anderson et al. (1972a) reported a decrease in potassium concentrations in mule deer blood during autumn and winter. This corresponded to a decrease in potassium concentration of the forage. DelGuidice et al. (1987) found a lower potassium concentration in the blood of deer that were starved for two weeks. Potassium levels increased again with feeding.

DelGuidice et al. (1990b) reported elevated calcium levels in deer that were undernourished and a return to pre-experimental calcium levels when deer were placed on an adequate diet. An opposite trend was observed for phosphorus levels, which decreased until resumption of an adequate diet (DelGuidice et al., 1990b). DelGuidice et al. (1987) starved deer for two weeks and observed an increase in phosphorus levels. They hypothesized that this increase was due to a secondary hyperparathyroidism caused by nutritional deprivation.

In their study of the effects of habitat differences on blood values, Seal et al. (1978) found no significant difference between phosphorus and calcium levels of deer from four different successional habitats. Kie et al. (1983) compared nutritional parameters of a high density captive deer herd with those of deer in a natural herd. Although many physical indices, including average weight, and numerous blood values differed between the two herds, there were no differences in calcium and phosphorus levels (Kie et al., 1983).

Hematology

Hematological values are used as indicators of nutritional health (DelGuidice et al.,

1987; 1990a; DeLiberto et al., 1989; Kie et al., 1983; Rosen and Bischoff, 1952; Seal et al., 1972;). Hematocrit, hemoglobin, and red blood cell (RBC) counts are affected by nutritional deficiencies (LeResche et al., 1974). Research on captive animals indicates poor nutrition elevates RBC counts, hematocrits, and hemoglobin concentrations (DelGuidice et al., 1987; 1990a), however, research on wild populations has not yielded such consistent results (DeLiberto et al., 1989; Kie et al., 1983; Seal et al., 1978). Seal et al. (1978) examined blood samples taken from deer inhabiting four successional habitats. Deer from habitats with the oldest vegetation, considered the poorest habitat, had the lowest RBC counts. Other factors, such as hormone levels and sampling techniques, may complicate hematological studies (Card et al., 1985).

Diseases and parasites

Susceptibility of wild ungulates to livestock diseases is difficult to ascertain. In some cases, deer may act as reservoirs of infections for livestock. Antibody activity in reaction to bovine viral diarrhea (BVD), infectious bovine rhinotracheitis (IBR), and parainfluenza type 3 (PI-3) viruses has been detected in mule deer (Couvillion et al., 1980; Hampy et al., 1979; Stauber et al., 1977; Wallmo, 1981). BVD causes inflammation of mucous membranes in the gastrointestinal and upper respiratory tracts (Wallmo, 1981) that can result in emaciation and dehydration. IBR infects the upper respiratory and genital tracts of ungulates and has caused anemia and depression in deer (Karstad, 1970). PI-3 is known to infect sheep and cattle, causing pneumonia and death (Clark et al., 1985). Although Stauber et al. (1977) found a high prevalence of exposure to PI-3 among mule deer, little is known about the effects of PI-3 on these animals.

Antibody activity in reaction to respiratory syncytial virus (RSV) has been found in wild cervids (Clark et al., 1985; Giovannini et al., 1988; Johnson et al., 1986). RSV antibodies have been found in mule deer in Nebraska (Johnson et al., 1986) and in fallow deer in Italy (Giovannini et al., 1988)

Anaplasmosis is caused by a red blood cell parasite, *Anaplasma marginale* and may result in anemia and weight loss. Rapid card agglutination and complement fixation tests for antibodies to *A. marginale* have been shown to produce false positive results for mule deer (Peterson et al., 1973). Despite this problem, few studies using these methods have reported anything but small percentages of deer with antibodies to *A. marginale* (Hampy et al., 1979; Johnson et al., 1986; Merrell and Wright, 1978; Morley and Hugh-Jones, 1989; Stauber et al., 1977; Waldrup et al., 1989).

Toxoplasmosis is caused by a protozoan, *Toxoplasma gondii* that infects felids in the sexual stage of its life cycle. In deer, the protozoan forms cysts in muscle tissue (Franti et al., 1975). Although little is known about the effects of *T. gondii* on wild deer populations, experimentally infected deer suffer from decreased appetite, inactivity, and diarrhea (Thorne et al., 1982).

Many species of macroparasites have evolved life cycles that utilize the predator-prey relationships of carnivores and herbivores. Cysticeri of *Taenia* spp. have been found in the mesentery and on the liver of mule deer (Jensen et al., 1982; Kie et al., 1984; Stubblefield et al., 1987; Thorne, 1975; Worley and Eustace, 1972). *Sarcocystis hemionilatrantis* is very common in mule deer populations (Dubey and Kistner, 1985; Dubey and Speer, 1985; Emnett and Hugghins, 1982). Sarcocysts have been found in tongue, heart, diaphragm, and skeletal muscles and in esophageal tissue. Although heavy infestations of sarcocysts have been known to cause death in young deer (Dubey and Kistner, 1985), many populations sustain moderate infestations without apparent harm (Dubey and Speer, 1985; Emnett and Hugghins, 1982).

Several species of nematodes have been identified in mule deer (Hoberg et al., 1989; Pederson et al., 1985; Platt and Samuel, 1978; Walker and Becklund, 1970). Gastrointestinal nematodes have been reported in mule deer populations throughout the west (Hoberg et al., 1989; Platt and Samuel, 1978; Thorne et al., 1982; Walker and Becklund, 1970). Mule deer are the natural hosts to an arterial worm, *Elaeophora schneideri* (Pederson et al., 1985; Thorne et al.,

1982). Although *E. schneideri* can cause necrosis and death in elk, it has not been found harmful to mule deer.

A high prevalence of bot fly larvae (*Cephenemyia* spp.) has been reported in Utah mule deer (McMahon and Bunch, 1989). Bot fly larvae can cause death in deer, however, healthy deer have recovered naturally from infestations (Cogley, 1987).

Ticks, mites and lice are the common ectoparasites of deer. Species found on both North American deer species are listed in Walker and Becklund (1970). Biting parasites are vectors for many diseases affecting livestock and wildlife (Eads, 1981) and blood sucking parasites, such as ticks and lice, can cause anemia (Jellison and Kohls, 1938).

Fecal indices

Dietary quality is a difficult parameter to measure. In most cases the best estimators of dietary quality are dietary nitrogen (%) and dietary digestibility (%) (Van Soest, 1982). These indices require knowledge of the composition of the study animals' diets. In cases where the dietary composition is difficult or too costly to obtain, a fecal index is an acceptable alternative. Fecal nitrogen is one index of particular value as it is inexpensive to measure and can be used to compare the quality of individuals' diets or those of entire populations (Leslie and Starkey, 1987).

Many researchers have examined diet and fecal samples from captive animals on controlled diets to evaluate the use of fecal nitrogen as an index of diet quality (Holechek et al., 1982; Mubanga et al., 1985; Wofford et al., 1985). Studies have shown a relationship between diet *in vitro* digestibility and fecal nitrogen (Leslie and Starkey, 1985; Mubanga et al., 1985; Wofford et al., 1985). Leslie and Starkey (1985) found a high correlation ($r=.91$) between fecal nitrogen and diet *in vitro* digestibility in mule deer and Mubanga et al. (1985) found a high correlation ($r=.94$) between fecal *in vitro* and diet *in vitro* digestibility in mule deer. Jenks et al. (1989) tested the use of composite samples for fecal nitrogen values in white-tailed deer and found no significant difference in fecal nitrogen values between individual and composite samples.

Although these studies show a high correlation between fecal nitrogen and other indices of dietary quality, one must use the fecal nitrogen index with caution. Mason (1969) has shown that nearly all nitrogen in ruminant feces is of microbial origin and as dietary quality increases, the concentration of rumen microbes increases. However, phenolics and other secondary metabolites in plants may elevate fecal nitrogen independent of dietary nitrogen (McLeod, 1974). These factors may vary from site to site and must be considered when using fecal nitrogen as an index of dietary quality. Leslie and Starkey (1987) recommended the fecal nitrogen index be limited to assessing: "...(1) relative changes in inter-seasonal diet quality of a single population, (2) single-season comparisons of a population between years, and (3) within-season comparison of different populations that occupy similar habitats."

Diet composition

The need for quantitative methods for determining diets of wild ruminants and the difficulties inherent in estimating diets from feeding behavior have led to the development of standardized microhistological procedures for examination of fecal material. Microhistological analysis was developed by Baumgartner and Martin (1939) for the identification of plant fragments in squirrel stomachs. Their technique has since been modified and used frequently for the identification of plant material in feces of ruminants (Hansen et al., 1977; Holechek, 1982; Sparks and Malechek, 1968; Storr, 1961; Williams, 1969).

Fracker and Brischle (1944) reported a frequency sampling method for plant distributions, which has been applied to microscope slides of stomach, esophageal, rumen and fecal material (Anthony and Smith, 1974; Gill et al., 1983; Green, 1987; Johnson and Pearson, 1981; McInnis et al., 1983; Sparks and Malechek, 1968). The use of Fracker and Brischle's frequency sampling method is based on several assumptions: (1) plant fragments are randomly distributed on the microscope slides, (2) plant fragments of different taxa are the same average size, (3) for a given relative density the dry weights of different plant taxa are the same, and (4)

the percentage of identifiable fragments is the same for different taxa (Havstad and Donart, 1978; Johnson, 1982). The first two assumptions are met by grinding sample material over a screen to reduce plant fragments to a uniform size and thoroughly mixing the sample. The third assumption may be a weakness in this method if the study animal consumes plants that vary significantly in bulk. The fourth assumption has been difficult to test and may contribute to inaccuracies. Gill et al. (1983) estimated diets of captive deer on three known diets. They found inaccuracies in the estimations and hypothesized that errors were due to differences in the ratios of identifiable to unidentifiable fragments of plant species. Some plant species are easy to identify because of unusual characteristics that retain their integrity through digestion. These species may be overestimated and cause the underestimation of less discernible species (Dearden et al., 1972; 1975).

Differential digestion of plant species is also known to affect estimations of relative frequencies of taxa (Baker and Hansen, 1985; Holechek and Vavra, 1981; Leslie, et al., 1983; Vavra and Holechek, 1980). Anthony and Smith (1974) analyzed rumen content and feces of mule deer and white-tailed deer in southeastern Arizona, and found a higher frequency for *Juniperus* spp. by fecal analysis than by rumen analysis. Large numbers of species were found exclusively in fecal samples and others were found exclusively in rumen samples. They suggested that some of these discrepancies may be the result of rumen samples representing food eaten by deer in one or two feeding bouts before collection, whereas fecal samples may represent food eaten over a longer period of time.

Despite these inaccuracies there are many advantages to using fecal analysis for the estimation of ungulate diets. As outlined by Anthony and Smith (1974) the collection of fecal samples is noninvasive to the population, requires a smaller sample size than rumen samples, and may be the most accurate method available when compared to field observations.

Diet overlap

Dietary overlap is used as a measure of niche similarity. The coefficient of community, also known as percent similarity measure, is simply the sum of minimum overlapping percentages of each food item found in two diets. Unfortunately, it cannot be used to test a hypothesis, such as the other common similarity measures. (Linton et al., 1981; Morisita, 1959; Smith and Zaret, 1982).

In addition to measuring similarities between species, dietary overlap can be used to measure similarities between individuals or populations of the same species and to express changes in resource use over time (Alcoze and Zimmerman, 1973; Anthony and Smith, 1977; Krausman, 1978; Medcraft and Clark, 1986; Miller and Gaud, 1989; Schwartz and Ellis, 1981; Singer, 1979).

Forage preference (selectivity)

Several methods for evaluating habitat preference can be used to determine forage species preference. Robel's preference index, percent use divided by percent availability, ranges from 0 to infinity. Preference is indicated by values higher than 1 and avoidance by values between 1 and 0 (Robel et al., 1970). Chi-squared goodness-of-fit tests have been used extensively for use-availability comparisons, however, they are appropriate only when availability of a resource is known, not estimated. Neu et al. (1974) introduced the use of "family" confidence intervals around resource use values. If availability of a forage species falls outside 95% confidence intervals for use, then the species is either avoided or preferred. This method has been used quite often, but error increases with increasing numbers of habitat types or forage species tested (Alldredge and Ratti, 1986). The Neu et al. (1974) method cannot be used when zero values occur in resource use. In this case two-sample binomial tests can be used to develop confidence intervals around the differences between use and availability of resources (Krausman et al., 1989; McClave and Dietrich, 1988).

Nutrition

Ruminants have the unique ability to utilize plant tissues that are indigestible to other animals. Microorganisms present in the digestive tract of ruminants metabolize plant tissue anaerobically, resulting in the production of reduced organic substances, enriched in carbon and hydrogen. Products of microbial fermentation are catabolized aerobically by ruminants. Foods low in carbon and hydrogen content degrade quickly and cannot be retained long enough for fermentation and absorption to occur. At the other extreme, foods that are very high in carbon and hydrogen content cannot be degraded within the holding time for rumen material in most ruminants. These foods are either avoided or are eaten and excreted without complete degradation. Some components of plant cells, such as lignin and cutin, are not only high in carbon and hydrogen, but are also low in oxygen, making them resistant to anaerobic degradation (Van Soest, 1982).

The field of ungulate nutrition has been dominated by studies estimating diet quality through measurements of nutritional components of plant species (Holechek et al., 1982; Robbins et al., 1987a; Van Soest, 1982). The cell walls of plants are composed of some materials that are resistant to digestive enzymes. These substances are collectively called the dietary fiber complex. Some of these, such as cellulose and hemicellulose, can be degraded by microorganisms found in digestive tracts of ruminants. Lignin, also present in the cell wall, cannot be digested by microorganisms within the retention time of ruminants. Lignin binds with carbohydrates and limits their availability for metabolism. Tannins, present in the cells of many plants, precipitate and inactivate proteins. Measurements of the relative abundances of these substances are used as indicators of the nutritional quality of forage species (Holechek et al., 1982; Van Soest, 1982).

Measurements of plant components are used to compare same species diets in different habitats (Robbins et al., 1987b) and to compare feeding strategies of different ungulate species (Hobbs et al., 1983; LeResche et al., 1974). The most commonly measured components are: crude protein, crude fat, ash, acid detergent lignin, acid detergent fiber, and neutral detergent

fiber. Recently developed techniques for measuring *in vitro* digestibility as an estimate of *in vivo* digestibility are in use, but are still quite expensive. All of these estimations require chemical analyses of plant samples. Studies of forage clipping techniques have shown that study animals consistently select plant parts of higher quality than that available on the plants overall (Van Dyne et al., 1980) and conclusions from such analyses must be drawn with caution.

In controlled studies it has been estimated that a minimum of 7% dietary protein is required to meet the metabolic needs of deer, and 12-18% is needed for growth and reproduction (Dietz, 1965; Sowell et al., 1985). Although Reynolds (1967) found selection of forage by deer in Arizona favored high crude protein and low crude fiber content, the relationship between crude protein and digestibility of a forage species is not well established. A low correlation between protein and digestibility when browse consumption has been found in several habitats (Rosiere et al., 1975). The low correlations of protein with digestibility when a significant level of browse is in the diet is likely due to the higher level of protein binding tannins in browse species. Robbins et al. (1987a) found a reduction in digestibility of cell solubles, such as protein, with plants of high tannin content compared to those with low tannin levels.

Although available protein is reduced by the presence of plant phenolics in browse species (Robbins et al., 1987a), Robbins et al. (1987b) found that mule deer produce at least 4 different salivary proteins that bind with tannins and limit the reduction in cell wall digestion expected from high levels of phenolics. Mule deer diets high in tannins had reduced digestion of cell contents as compared with that of low tannin diets, but there was not a reduction in the digestion of cell wall materials (Robbins et al., 1987b). It also has been found that deer can limit their intake of phenolics by diet selection (Personius et al., 1987) and populations of rumen microorganisms can adjust to higher levels of chemicals over time, increasing digestibility of browse species (Freeland and Janzen, 1974).

As should be apparent from this discussion, the nutrition of ruminants is very complex. It cannot be assumed that all of the protein in a forage species is available to the animal.

Grazers and browsers have evolved different strategies for combating the defense chemicals of plants. These strategies and their limitations must be considered in an evaluation of dietary protein.

Mineral content of the diet is thought to play a significant role in the health and reproduction of ungulates. In western rangelands phosphorus and calcium levels are the most likely limiting minerals (Dietz, 1965; Scrivner et al., 1988). Both phosphorus and calcium are essential to the development of the skeleton and the utilization of energy (Dietz, 1972). It has been suggested that dietary phosphorus levels below the 0.25% minimum requirement for deer (French et al., 1956) have been a significant factor in causing low population densities in California (Scrivner et al., 1988) and the reason for deer's use of mineral blocks set out for livestock (Payton and Garner, 1980).

DESCRIPTION OF STUDY SITE

Zion National Park is located in Washington County in southwestern Utah (Figure 1) and protects 57,690 hectares of land. The area of Zion Canyon under investigation (Fig. 2) extends from the entrance to the Zion Narrows, 1.6 kilometers up the Virgin River from the end of the canyon road, to the south entrance of the Park at Springdale. The North Fork of the Virgin River has cut through the massive Navajo Sandstone and underlying thinner formations to form Zion Canyon, more than 600 meters deep and the park's largest canyon. Zion Canyon is widening through fracturing and collapse of adjacent cliffs and erosion by Virgin River tributaries. The study area includes the floor of the canyon and its tributaries and the slopes between the floor and the cliffs.

The highest and lowest elevations in the study site both occur near the park's south entrance, ranging from the river at 1173 meters to the base of the Navajo Sandstone cliffs at 1829 meters. The canyon floor rises gradually from the park entrance at 1207 meters to 1356 m at the entrance to Zion Narrows at the north end of the canyon. The width of the study area varies from 4.1 km at the south end to 0.05 km at the north end of the Gateway to the Narrows Trail. The study area encompasses 64.8 hectares.

The geological strata of Zion National Park dip toward the northeast. At the northern end of Zion Canyon a single slope covered by material eroded from the cliffs connects the Virgin River to the base of the 600 meter high principal cliffs of Navajo Sandstone. About one kilometer north of Zion Lodge, a narrow sandstone cliff emerges from the tilted strata and divides the region below the principal Navajo Sandstone into two slopes. In the southern part of the canyon, a similar situation has been created due to the presence and exposure of the cliff-forming Springdale member of the Moenave Formation (Hamilton, 1984). In some places the upper slopes are quite large and benches have formed. Intermediate cliffs are broken in places or ramped by scree, giving access between the lower and upper slopes.

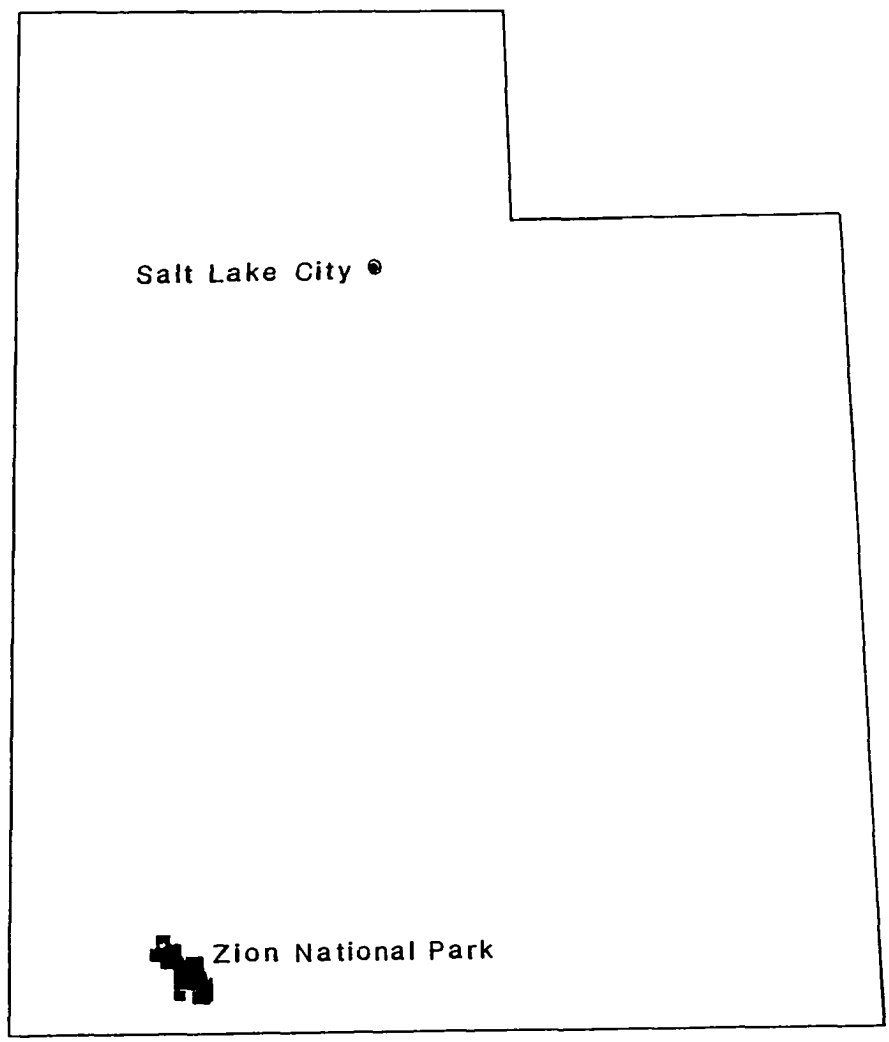

Figure 1. Location of Zion National Park, UT.

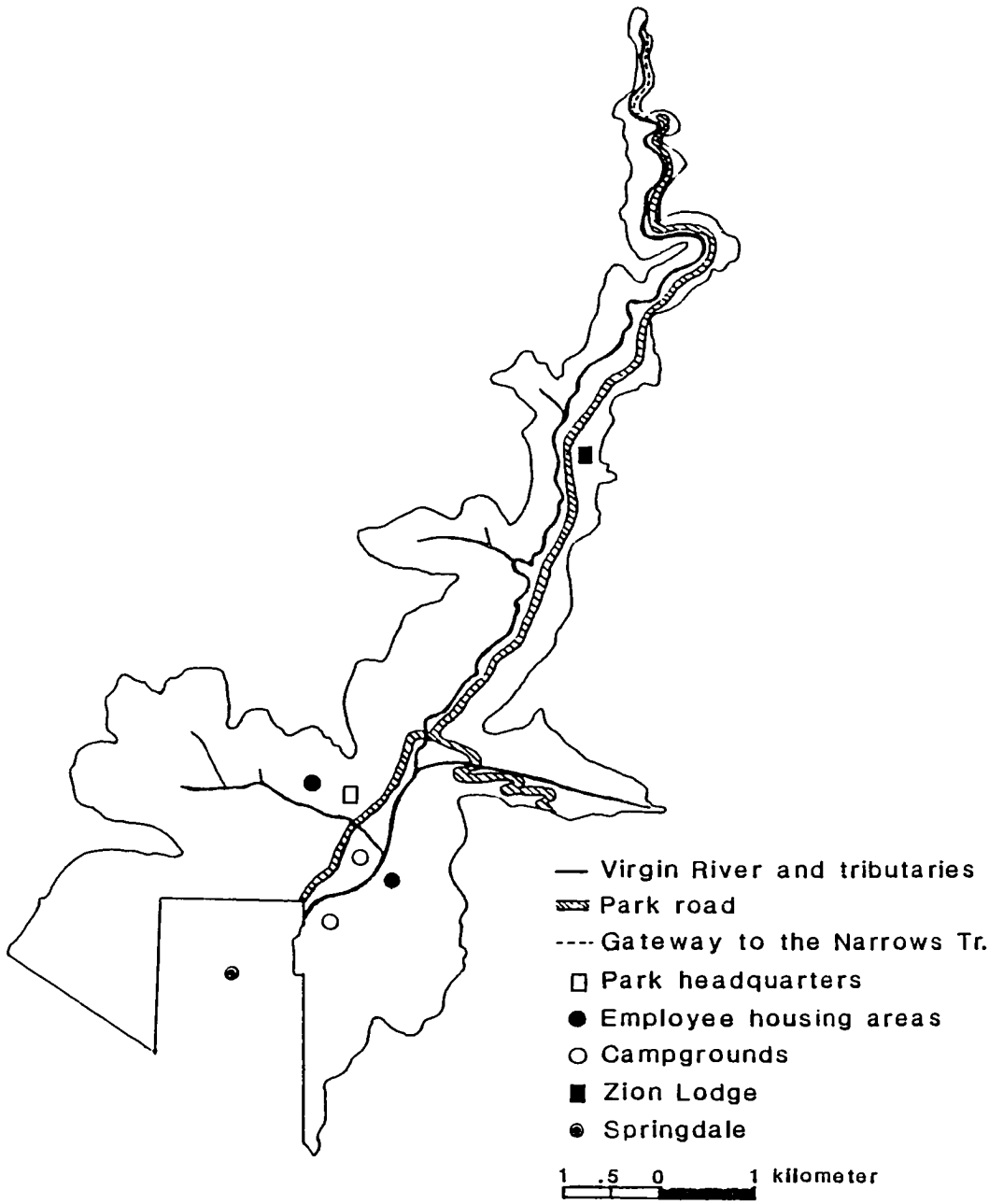

Figure 2. Zion Canyon, Zion National Park, UT.

Although the river is the primary canyon carving force, it only occasionally presents a barrier to movement of deer. Rainstorms may cause the river to swell enough to make the river impassable for several hours at a time.

Zion Canyon and the area south and west along the Virgin River have been the focus of human development at least since the time of the Anasazi, commencing in 265 AD (Conner and Vetter, 1986). The canyon's scenic beauty, relatively easy access, and fertile bottomlands have contributed to humans of many cultures inhabiting, utilizing, and enjoying the canyon. Natural disturbances, such as flash floods and rockslides, are an integral part of the canyon ecosystem. Zion Canyon also has been subject to many anthropogenic disturbances: livestock grazing, cultivated agriculture, and development for visitor services (campgrounds, buildings, roads, parking lots, etc.).

A road runs parallel to the Virgin River from the south entrance station to the northern end of Zion Canyon, at the Temple of Sinawava. Present human development along the road consists of two campgrounds, with a total of 274 sites, a National Park visitor center, government housing areas, Zion Lodge with 121 rooms, and numerous parking lots, pullouts, and hiking and horseback trails. Visitation increased significantly during the study. Zion National Park received 2.3 million visitors in 1990 and 2.5 million in 1991.

Although the elevation change within the study site is less than 700 meters, the deep and narrow canyon, along with the north-south orientation, affect available moisture and result in many vegetation communities.

The topography of the canyon floor also differs from one end to the other. Approximately 4,000 years ago a landslide formed a dam on the Virgin River 3 km north of the canyon mouth (Fig. 2). As a result, water backed up, forming a 1.8 km^2 lake behind the dam and depositing sediments on the canyon floor. It has been estimated that this lake existed for approximately 400 years. The Virgin River eventually cut through the dam and released the reservoir of water (Hamilton, 1984). The canyon floor above the landslide for 4.5 km up canyon

is fairly flat bottomed and sandy. Sand dunes, debris from rockfalls, and dry channels of the Virgin River add some relief to the lake bottom sediments. Above the level of the lake and below the landslide, the canyon floor topography reflects it's longer history of rockslides and flash floods.

The canyon weather station is located behind the Visitor Center at the mouth of Oak Creek, a tributary of the Virgin River, at an elevation of 1235 m. The station receives an average of 432 mm of precipitation per year. Historical information about the weather of the area will be presented in the Results section, along with possible correlations with deer populations.

Movement by deer between upper and lower parts of the canyon is evident from numerous deer trails on slopes and benches above the landslide area. However, because of the vegetation differences and consistent observations of the same animals in the same locations, two study areas were described and the data from each area treated separately. This does not imply that the two populations are isolated, but rather that their diets and the forage available to them may differ. Study site one, referred to as "upper canyon" is the area from the landslide region north to the start of the Zion Narrows hiking trail. Study site two, referred to as "lower canyon", is the area south of the landslide to the south entrance of the park. When possible, data from the two sites were compared before combining. Mean values of diet composition, nutrition, and fecal nitrogen are presented here.

METHODS

Blood chemistry

Blood samples from 26 mule deer were collected between January 1990 and December 1991 from both study areas. Deer were immobilized with a 3 cc pneudart containing 600 mg ketamine and 120 mg xylazine (DelGiudice et al., 1989; Jessup et al., 1983). Some animals required additional doses of immobilizing drugs, either because of poor placement of the first dart or due to individual responses to the drugs. Other animals needed an extra 1 to 2 cc of drugs once they were down, to insure the safety of both the animals and the researchers. Once down, a blindfold was placed on the face of the animal and straps around the legs.

Blood was drawn, within 15 minutes after immobilization, from vessels in the neck. Two serum separator tubes (red tops) and one EDTA tube (lavender top) were filled. Two blood smears also were made with the fresh sample. Blood was placed on ice in the field, then centrifuged for 15 minutes at the end of the day. The serum was drawn off and refrigerated until it could be delivered within two days to a laboratory. Half was divided into 2-3 ml aliquots and stored frozen until sent to the Veterinary Pathology Lab at Washington State University for disease testing and half was delivered to Associated Pathologists Laboratories (APL) in Las Vegas for analysis. The unclotted blood (EDTA tube) and blood smears also were taken to APL for analysis.

Immobilized animals also were examined for external parasites, which if found, were collected and frozen for identification. The estimated age and condition of the animal (good, fair, poor, lactating, etc.) also were noted.

Immobilization darts were removed with minimal tissue damage, and antiseptic spray was applied to the wound. Leg straps were removed, and 6 to 10 cc of the reversal drug Yohimbine (2 mg/ml) was injected into the bloodstream, and the blindfold was removed. In most cases the deer were alert and even mobile within 10 minutes.

Diseases

Sera from 16 blood samples were sent to Washington Animal Disease Diagnostic Laboratory in Pullman, Washington, and tested for antibodies for the following viruses by serum neutralization of cattle viruses: infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, and respiratory syncytial virus. Sera also were tested for exposure to the bacterial disease anaplasmosis by two methods: latex agglutination and complement fixation. A negative response for anaplasmosis was a 1:5 titer. Exposure to the protozoan that causes toxoplasmosis was measured by indirect hemagglutination, using sensitized sheep erythrocytes. A negative response for toxoplasmosis was a 1:64 titer.

Parasites

Fresh fecal samples were collected from immobilized animals. Samples were fixed in one vial each of formalin and PVA, and examined by APL for evidence of internal parasites. A composite sample from 10 fresh pellet groups was collected from the lower canyon area in August, 1991 and sent to the veterinary pathology laboratory at the Washington State University in Pullman. No evidence of parasites was found in this sample.

High eosinophil levels in Zion Canyon deer prompted an examination for internal parasites. Necropsies were performed in October, 1991, on two euthanized does, 12 and 16 years of age. Animals were immobilized in the same manner as previously sampled deer. Blood and fecal samples were collected before euthanasia drugs were injected. Tissue samples were collected from all major organs and transported on dry ice to Oregon State University, where they were sectioned and examined microscopically for signs of disease. Walls of the digestive tracts and contents of the large and small intestines were washed and examined for parasites. Lungs were cut open along the bronchial tubes and examined for lungworms.

Fecal nitrogen

Fecal nitrogen was measured at Habitat Analysis Laboratory (HAL) at Washington State University, Pullman, Washington on composite samples collected monthly from both study sites. Original and duplicate samples were analyzed.

Diet composition and nutrition

The diet of the Zion Canyon mule deer herd was determined by observations of feeding animals and by microscopic examination of fecal pellets. Observations were conducted biweekly at different times of the day and at a variety of locations. These observations were made to determine kinds of forage plants being selected and were not quantitative. The habitat types and feeding behavior of the deer did not permit quantitative analysis of diet via direct observations.

In the second year of study, samples of plants that deer were observed eating were collected for nutritional analyses. Monthly samples of leaves and new growth of a minimum of ten plants of each species consumed by deer during that month were composited and dried. Dried plant samples were ground in a Wiley mill through a 2 mm screen in preparation for nutrient analyses. Samples of major dietary species were sent to HAL. Analyses for organic matter, crude fat, Kjeldahl crude protein, neutral detergent fiber, acid detergent fiber, and acid detergent lignin were conducted on original and duplicate samples.

The diet of deer was quantified by microhistological examination of fecal material. Fecal samples were collected monthly from January 1990 through December 1991 from the two study areas. Three pellets were selected from a minimum of ten fresh pellet groups each from upper and lower canyon areas. These were oven dried for at least 72 hours at 40 C. After drying, the pellets were ground to a 2 mm fragment size using a Wiley mill. The ground fecal material was stored in glass jars until analyzed.

Fecal material was prepared for microhistological examination according to Holechek (1982). Approximately one gram of ground fecal material was cleared with bleach, then washed

with hot water over a 0.1 mm screen. The cleared material was placed on prelabelled microscope slides, along with several drops of Hertwig's clearing solution (Baumgartner and Martin, 1935). Slides were heated on a hot plate to dissolve starches and to clear the plant tissue. When the Hertwig's solution had evaporated, the slides were removed from the hot plate and allowed to cool. As they were cooling, the material was mounted with Hoyer's mounting medium (Baker and Wharten, 1952).

Reference slides of known plant material were prepared in a fashion identical to the fecal material slides. Plant samples were collected while conducting plant transects in the canyon. These were identified, dried and ground to uniform fragment size. After clearing and mounting, the plant slides were maintained as references for the identification of plant fragments in fecal material. Notes were taken as to stomatal size and shape, descriptions of epidermal features, such as trichomes, druses, raphides, and other distinguishing characteristics (Mauseth, 1988; Storr, 1961).

Fecal slides were examined under 100X using an Olympus Vanox phase contrast microscope equipped with Nomarsky interference. The species represented and numbers of plant fragments were tallied in twenty views taken along transects on each slide. Ten slides were analyzed for each month, five from each study area. Relative densities of plant fragments were calculated according to Fraeker and Brischle (1944).

Samples of fecal material from each study area were sent to HAL for analysis of fecal nitrogen. Results were used to compare relative quality of diets in the two study areas with results of nutritional analyses of plant samples.

Forage availability

Vegetation types were defined by hiking to high points along the rim of the canyon and mapping distinct boundaries manually onto a USGS 7.5 minute topographic map. Questionable boundaries were determined by hiking in the areas. The surface areas of the vegetation types

were measured with the mapping program PMAP and a digitizer. Vegetation cover was measured along 50 meter line transects, 2-3 placed randomly within each vegetation type. Percent cover of shrubs was measured by line intercept. Diameters at breast height (dbh) of trees within 2 meters of the line were measured, yielding percent dbh over a 4 meter wide belt transect. Herbaceous material was estimated using the Braun-Blanquet method at five meter intervals with a 0.25 meter quadrat (Barbour et al., 1987). Total cover of shrubs and dbh of trees in the canyon was estimated by summing the values for each species in each vegetation type times percent of canyon in that vegetation type. Although cover is not equivalent to biomass, as a fast, noninvasive measure of occurrence, it was used to estimate relative availability within forage classes for use in diet preference analysis.

Herd composition and reproduction

Roadside counts were conducted in winter, when deer were concentrated in the canyon. Data for surveys conducted in the course of this study were collected by two people, one passenger and one driver, driving a car through the canyon, slower than 15 miles per hour, and stopping when necessary to classify individuals. The same procedures were used for previous surveys, however, occasionally more than two people participated. All surveys were conducted in clear weather, starting a few hours before nightfall. Counts were not attempted in other seasons because deer were scattered and visibility was decreased by dense foliage. Dates on which first fawns of the year were observed were noted and compared to other populations.

Data analysis

Variances of serum chemistry and hematology mean values for seasons, gender, and lapse of time from collection to laboratory testing (1 or 2 days) were tested for equality using Bartlett's variance test ($p<.05$). Those values with equal variances were compared by one-way analysis of variance tests in Statgraphics 5.0 software program ($p<.05$). Those with unequal

variances were tested with the H-test (McClave and Dietrich, 1988). When many similar ANOVA tests were conducted p-values were adjusted for table-wide significance using the method recommended by Rice (1989).

Seasonality and low availability of annuals and forbs prevented the analysis of preference for these species. Diet composition and availability of trees and shrubs were compared monthly, on two sites, for two years, using the two-sample binomial test for differences (McClave and Dietrich, 1988). Data were analyzed excluding species that were not consumed.

Similarities in species composition of the two study site diets were measured using Spearman's rank correlation. Varying unknown browse and grass components in feces made comparisons by overlap indices invalid. However, dietary overlap by forage class was measured between the two study sites every month and between monthly averages of the two sites using the coefficient of community. Values for forage classes were determined by adding unknown grass values to grass components and adding unknown browse values proportionally to tree, shrub, and perennial forb components.

Mean monthly fecal nitrogen values were compared between sites and years with Friedman's randomized block test using Statgraphics 5.0.

RESULTS

Serum chemistry

Serum chemistry values of Zion Canyon mule deer are presented in Table 1. Serum chemistry means that are significantly different by season, gender, or lapse of time to laboratory testing are presented in Figures 3 through 6. Analysis of variance (ANOVA) p-values were tested for table-wide significance at an adjusted α level of $.05/1+k\text{-}i$ as suggested by Rice (1989). Serum sodium, calcium, and iron concentrations were lower than those found in other mule deer populations. Serum glucose, alkaline phosphatase, and creatine phosphokinase levels varied widely between individual samples and serum carbon dioxide levels were higher than those found in other studies. Other serum chemistry values were in agreement with results from studies of other mule deer populations.

Hematology

Hematological values for Zion Canyon mule deer are presented in Table 2. Hematological means that are significantly different by season, gender, or lapse of time to laboratory testing are presented in Figures 7 through 9. ANOVA p-values were tested for table-wide significance at an adjusted α level of $.05/1+k\text{-}i$ as suggested by Rice (1989). Eosinophil levels were very high in 21 out of 25 samples measured. Red blood cell and hemoglobin concentrations were lower than those found in other mule deer populations, yet mean corpuscular hemoglobin concentration was normal. All other hematological values were within normal ranges.

Diseases and Parasites

Results of serological tests on samples from 16 mule deer in Zion Canyon are summarized in Table 3. Tests were conducted on sera collected from deer between March, 1990 and April, 1991. Virus titers were determined by serum neutralization of infected cattle tissue.

Table 1. Serum chemistry values of Zion Canyon mule deer, 1990-1991.

Parameter (units)	n	mean	s.e.	range	other populations**
Glucose (mg/dl)	26	165.0	9.9	78-272	105.7-165.0
Urea nitrogen[a] (mg/dl)	26	19.0	0.9	8-31	10.21-29.82
Creatinine (mg/dl)	26	1.2	0.03	0.8-1.4	1.27-2.60
Sodium (mEq/l)	26	142.1	0.5	134-149	148.5-149.0
Potassium (mEq/l)	26	5.0	0.1	4.0-6.5	4.4-11.2
Chloride (mEq/l)	26	103.6	0.3	100-107	101.0-110.1
CO_2 (mEq/l)	26	31.2	0.4	26-35	21.1-22.0
Anion gap (mEq/l)	26	12.3	0.4	7-18	7-18
Osmolality (mos/kg)	26	289.4	1.1	270-301	282-300
Phosphorus (mg/dl)	26	5.4	0.3	1.9-8.1	4.96-12.54
Calcium (mg/dl)	26	8.6	0.1	7.6-9.6	9.37-12.50
Protein (g/dl)	26	6.2	0.1	5.4-6.8	5.18-7.59
Albumin (g/dl)	26	3.0	0.03	2.6-3.2	1.28-4.42
Globulin (g/dl)	26	3.3	0.1	2.7-4.0	1.20-5.13
Total bilirubin (mg/dl)	26	0.2	0.01	0.1-0.3	0.21-0.72
Direct bilirubin (mg/dl)	26	0.1	0.01	0.0-0.1	
Indirect bilirubin (mg/dl)	26	0.2	0.01	0.1-0.3	
Alkaline phosphatase[b] (IU/l)	26	31.4	5.5	5-139	37-247
AST (IU/l)*	26	59.3	4.2	9-93	58-581
CPK (IU/l)*	26	198.9	40.9	21-811	38-513
GGT (IU/l)*	26	57.7	2.6	39-92	62.8-67.2
Amylase (units)	26	53.0	7.0	9-162	
Lipase[a] (units)	26	0.3	0.03	0.1-0.8	
Cholesterol (mg/dl)	26	43.5	1.2	2-24	37.8-96.9
Triglycerides (mg/dl)	26	9.9	1.2	2-24	18.2-82
Magnesium[a] (mg/dl)	26	2.4	0.1	1.9-3.3	1.90-3.34
Iron (IU/l)	26	150.5	15.8	59-435	228-234

*AST = aspartate aminotransferase; CPK = creatine phosphokinase; GGT = gamma-glutamyl transferase

**Anderson et al. (1972a, b); deCalesta et al. (1977); DelGuidice et al. (1987, 1990a, b); DeLiberto et al. (1989); Hunter (1973); Kaplan and Pesce (1984); Kie et al. (1983); Pederson (1970); Rohwer (1970); Seal and Erickson (1969); Seal et al. (1972, 1978); Smith (1976); Waid and Warren (1984); Wilber and Robinson (1958)

[a]significantly different by season ($p<.05/1\text{-}k+i$) [b]significantly different by gender ($p<.05/1\text{-}k+i$)

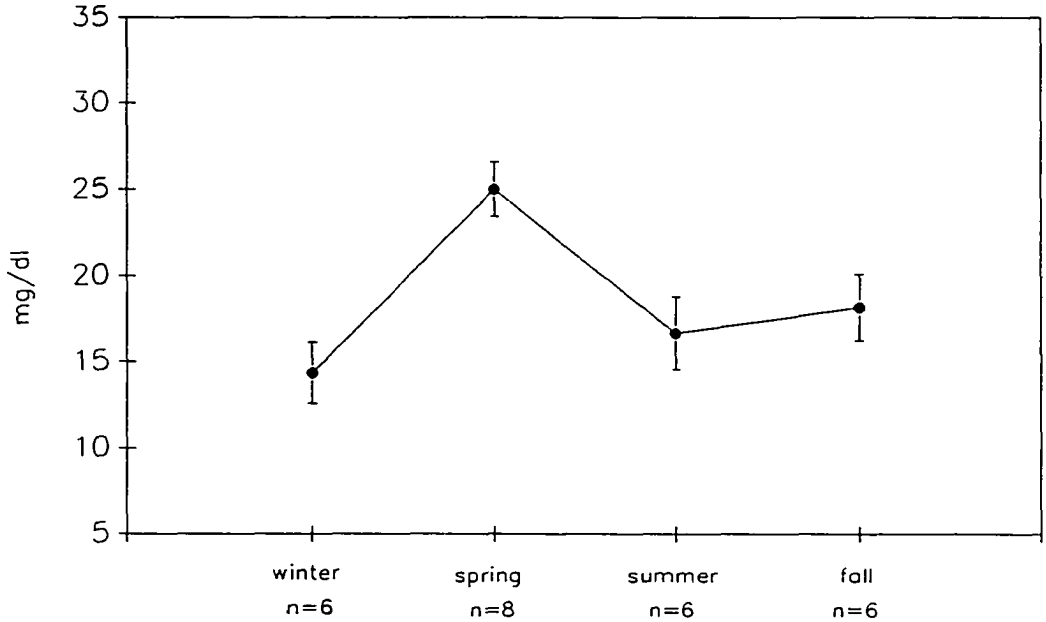

Figure 3. Seasonal means and standard errors in mule deer serum urea nitrogen, Zion Canyon, UT, 1990-1991, p(F) = .0019.

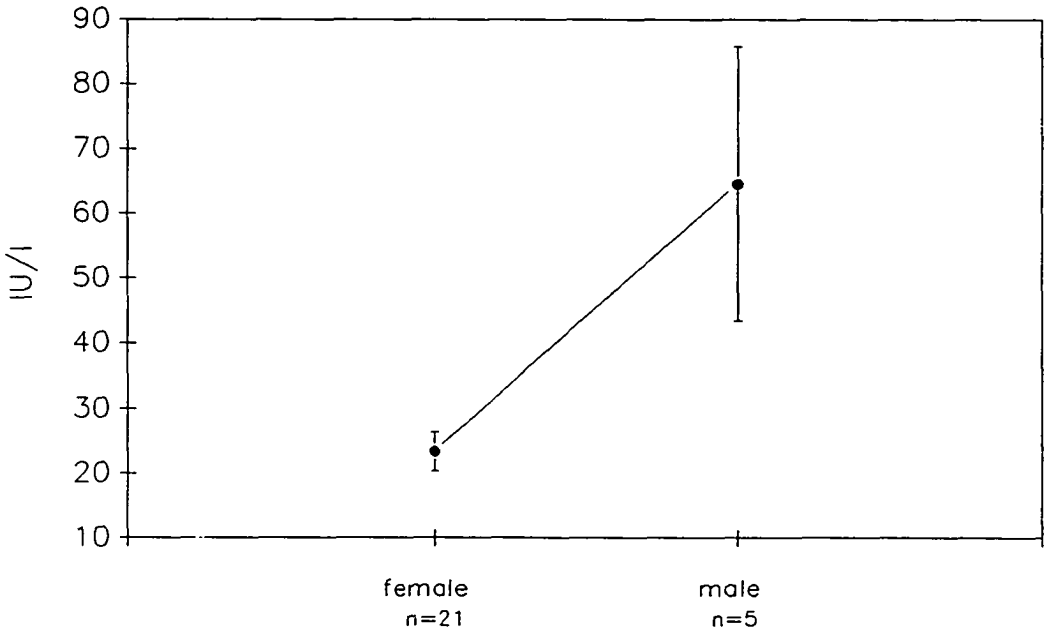

Figure 4. Gender means and standard errors in mule deer serum alkaline phosphatase, Zion Canyon, UT, 1990-1991, p(F) = .0015.

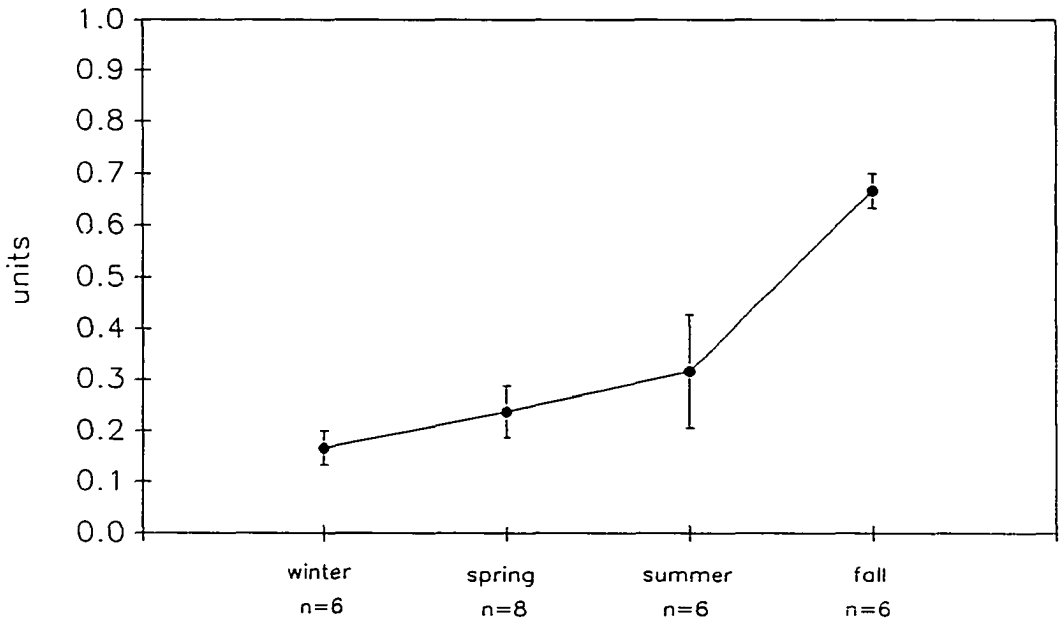

Figure 5. Seasonal means and standard errors in mule deer serum lipase, Zion Canyon, UT, 1990-1991, p(F) = .0001.

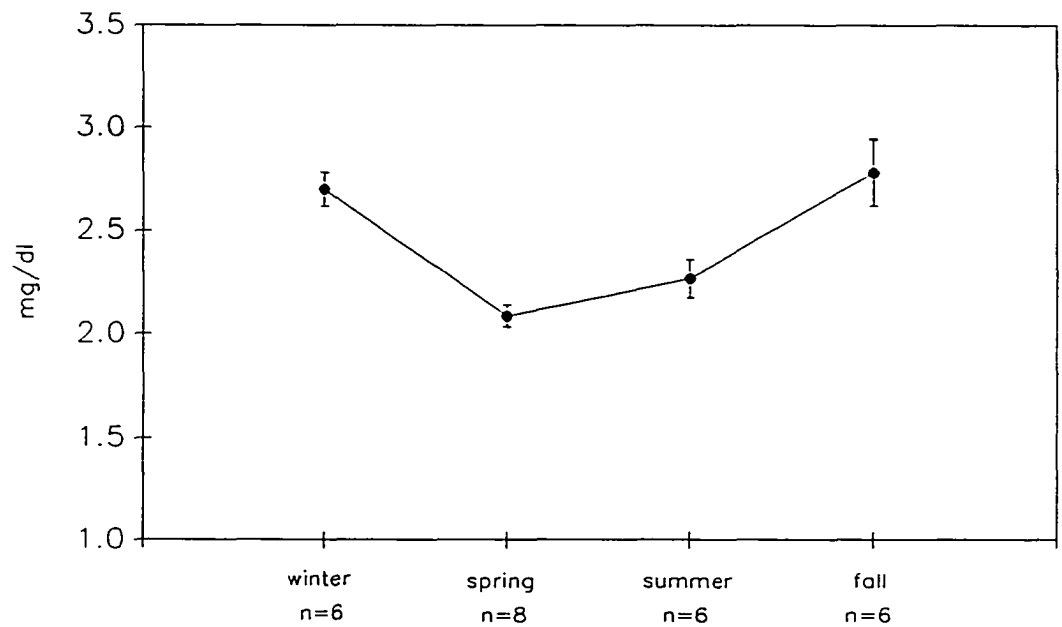

Figure 6. Seasonal means and standard errors in mule deer serum magnesium, Zion Canyon, UT, 1990-1991, p(F) = .0001.

Table 2. Hematological values of Zion canyon mule deer, 1990-1991.

Parameter (units)	n	mean	s.e.	range	other populations**
WBC ($10^3/\mu l$)*	25	3.5	0.4	1.52-10.75	3.0-3.9
Neutrophils[a] (%)	25	38.2	2.3	3.1-67.0	40.6-65.3
Lymphocytes[a] (%)	25	38.9	2.5	12.0-92.9	29.2-43.4
Eosinophils (%)	25	21.0	2.6	0.9-49.0	2.6-8.3
RBC ($10^6/\mu l$)*	25	7.0	0.2	4.94-8.86	8.7-13.0
Hemoglobin (g/dl)	25	11.3	0.3	8.3-13.2	12.8-21.1
Hematocrit (%)	25	30.6	0.8	21.9-35.9	30.0-52.7
MCV (fl)*	25	43.1	0.7	34.6-50.7	30.5-52.8
MCH (pg)*	25	16.2	0.2	12.9-18.0	11.5-14.0
MCHC[a] (g/dl)*	25	37.0	0.2	33.0-40.5	33.6-38.0
Fibrinogen (mg/dl)	25	256.1	24.4	<100-625	166-325

*WBC = white blood cells; RBC = red blood cells; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration

**Anderson et al. (1970); Browman and Sears (1955); Bubenik and Brownlee (1987); DelGuidice et al. (1990a, b); Rohwer (1970); Rosen and Bischoff (1952); Seal and Erickson (1969); Seal et al. (1972, 1978)

[a]significantly different by season ($p<.05/1\text{-}k+i$)

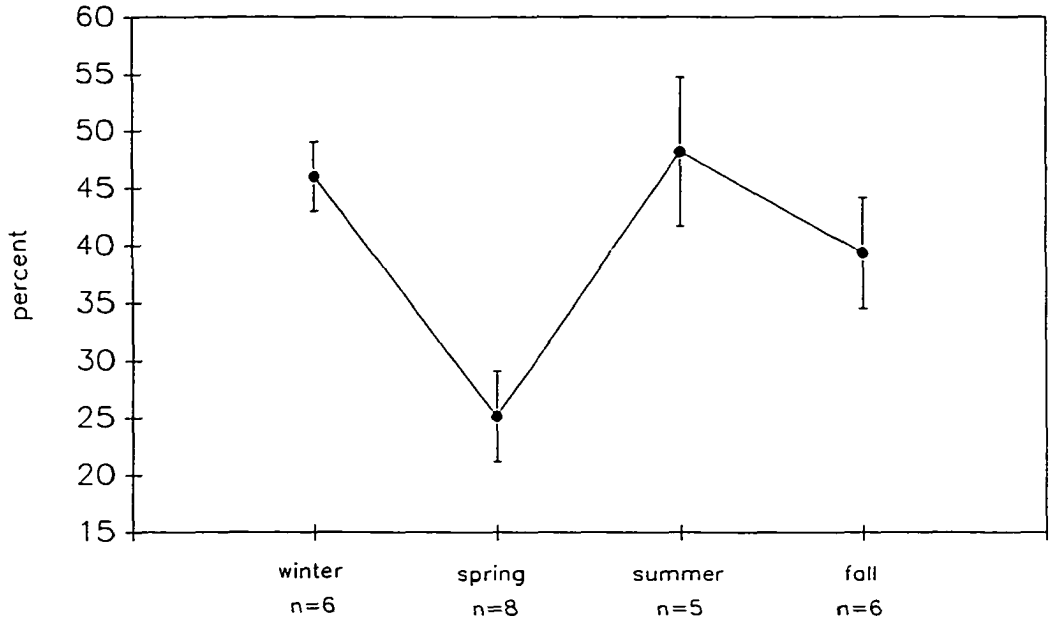

Figure 7. Seasonal means and standard errors in mule deer neutrophils, Zion Canyon, UT, 1990-1991, p(F) = .0047.

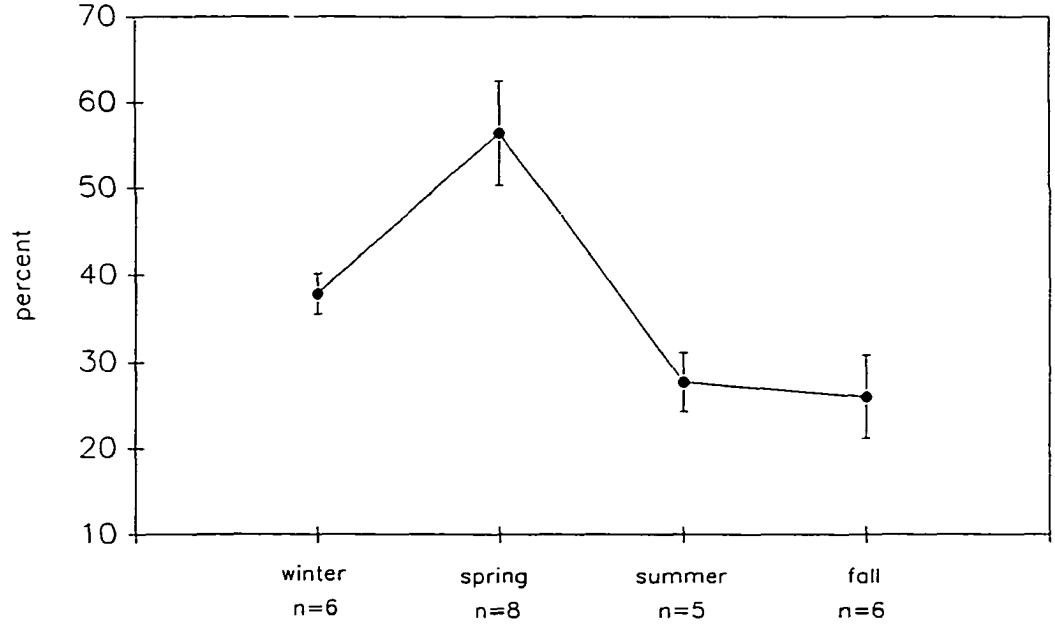

Figure 8. Seasonal means and standard errors in mule deer lymphocytes, Zion Canyon, UT, 1990-1991, p(F) = .0005.

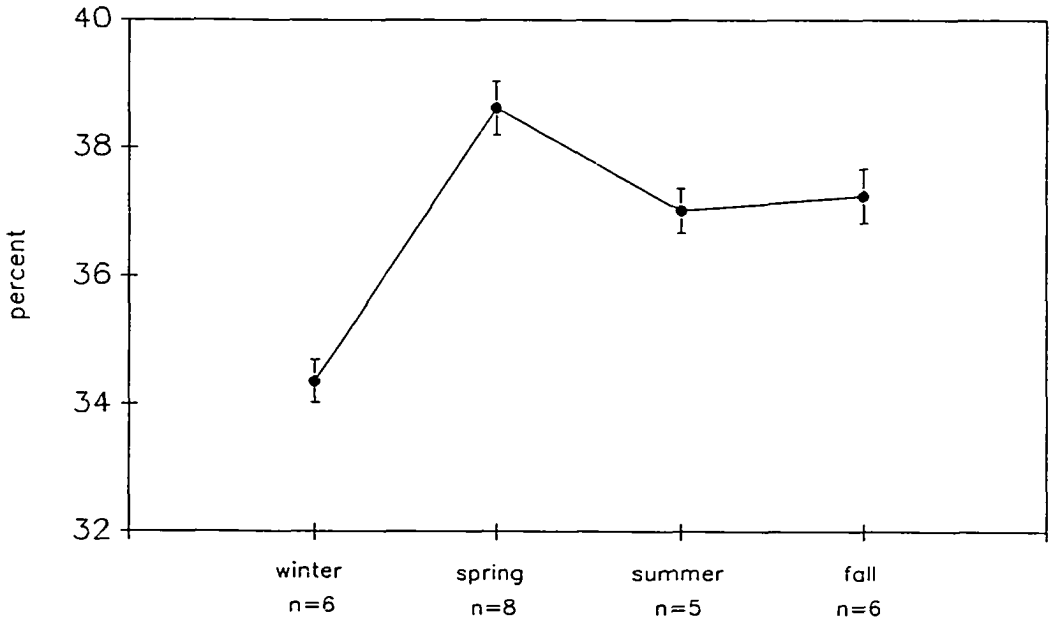

Figure 9. Seasonal means and standard errors in mule deer mean corpuscular hemoglobin concentration, Zion Canyon, UT, 1990-1991, p(F) <.0001.

In addition to virology, sera were tested for toxoplasmosis and anaplasmosis. All 16 deer tested negative for antibodies to *Toxoplasma gondii*, using indirect hemagglutination of sensitized sheep erythrocytes (negative at $\leq$ 1:64) and to *Anaplasma marginale*, using latex agglutination (negative at $\leq$1:5) and complement fixation. Both anaplasmosis tests used sensitized sheep erythrocytes.

Table 3. Mule deer serum titers to four common livestock viruses, Zion Canyon, 1990-1991. IBR = infectious bovine rhinotracheitis; BVD = bovine viral diarrhea; PI-3 = parainfluenza type 3; RSV = respiratory syncytial virus.

virus	<1:5	1:5	1:10	1:40	1:80	1:160
IBR	94*	6				
BVD	100					
PI-3	38		19	12	25	6
RSV	100					

*percentage of 16 animals

Necropsies were performed on two adult female mule deer from Zion Canyon in October, 1991. Six species of parasites were identified: cysticeri of *Taenia hydatigena* and *Taenia krabbei* (tapeworm cysts), *Elaeophora schneideri* (arterial worm), *Sarcocystis hemionilatrantis*, *Dermacentor albipictus* (winter tick), and lice. Adult parasites were not found in the digestive tracts of either animal. This observation supports the negative results of parasite examinations of fecal samples from 25 immobilized deer. Results of bacterial isolation tests of liver and lung tissue from necropsied deer were negative. Fluorescent antibody examinations of liver and lung tissues for antibodies to infectious bovine rhinotracheitis (IBR), parainfluenza type 3 (PI-3), bovine viral diarrhea (BVD), and respiratory syncytial virus (RSV) were negative for both animals.

Sixty-two percent of deer immobilized in Zion Canyon had winter ticks, *Dermacentor albipictus*. Infestations on individual deer varied from 0 to 12. One of the necropsied deer also had scabs in its ears, indicative of lice, but no lice were isolated.

Fecal nitrogen

Average nitrogen values of original and duplicate monthly fecal samples did not differ between years or sites ($Fr=5.4$, $p=.115$). Monthly means from the two sites in 1990 and 1991 are illustrated in Figure 10.

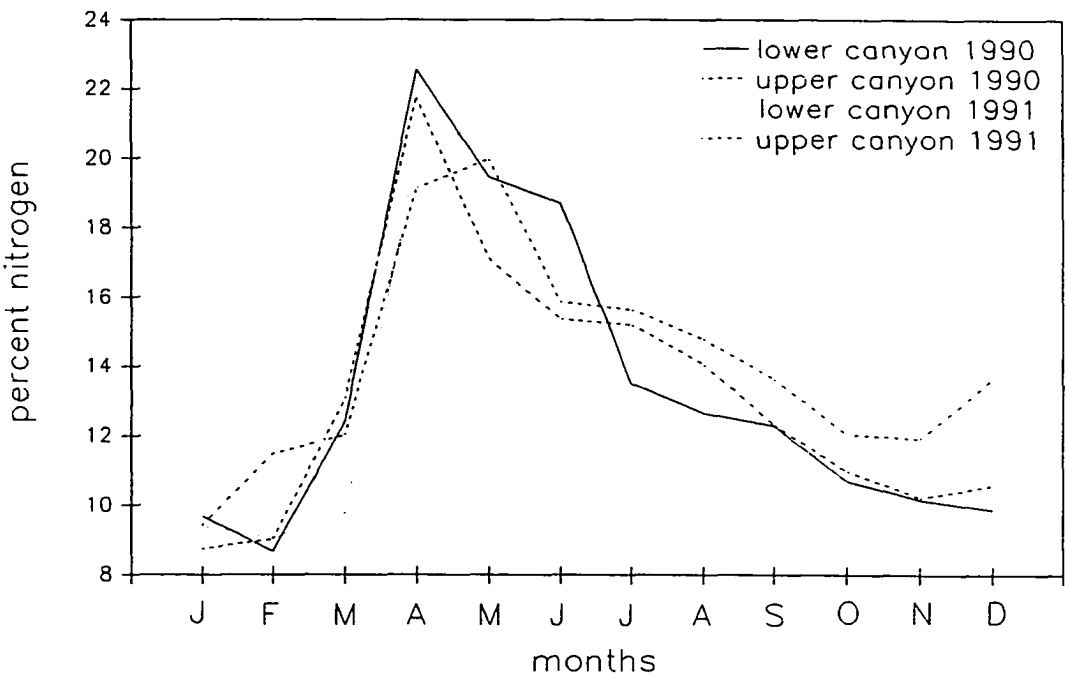

Figure 10. Zion Canyon mule deer fecal nitrogen, monthly means from two sites.

Diet composition

Several plants which deer were observed eating were not observed in fecal material. Such discrepancies are noted in Table 4.

Table 4. Plant species in Zion Canyon mule deer diet by month, as identified by fecal analysis and observation (●) or observations only (O). Unmarked boxes indicate the species was not used that month.

Species	J	F	M	A	M	J	J	A	S	O	N	D
Acer spp.	●	●	●	●	●	●	●	●	●	●	●	●
Amelanchier utahensis				●	●	●	●	●	●	●	●	
Artemisia ludoviciana				O								
Artemisia tridentata	●	●	●	●	●	●	●	●	●	●	●	●
Atriplex canescens	●	●	●	●	●			●	●	●	●	●
Bromus diandrus	●	●	●	●	●	●	●		●	●	●	●
Bromus tectorum				●	●							
Celtis reticulata		●	●	●	●	●	●	●	●	●	●	●
Chorispora tenella				●								
Chrysothamnus nauseosus	●	●	●	●		●	●	●	●	●	●	●
Coleogyne ramosissima	●	●	●	●	●							●
Cucurbita foetidissima						●	●	O				
Elymus canadensis	●	O	●		●							
Elymus glaucus	●	●	●	●	●				●			
Erodium cicutarium			O	O	●							
Festuca ovina		O				●	●	●	●	●	●	●
Festuca pratensis						●	●	●	●			
Fraxinus spp.	●	●	●	●	●	●	●	●	●	●	●	●
Gutierrezia spp.				●	●							
Helianthus petiolaris		O										
Heterotheca villosa		●	●	●	●	●	●	●	●			
Juniperus osteosperma	●	●	●	●	●	●	●	●	●	●	●	●
Mahonia repens	O		●									
Malus pumila									●	●		
Melilotus officinalis					●	●	●	●	●		●	
Panicum oligosanthes	O											
Poa fendleriana	●	●	●	●								

Table 4 (cont.)

Species	J	F	M	A	M	J	J	A	S	O	N	D
Poa pratensis						●	●	●	●	●	●	●
Populus fremontii	●	●	●	●	●	●	●	●	●	●	●	●
Quercus gambelii		●	●	●	●	●	●	●	●	●	●	●
Quercus turbinella	●	●	●	●	●	●	●	●	●	●	●	●
Rhus aromatica						●	●	●	●	●	●	●
Rubia tinctoria				●	●	●	●	●	●			●
Rumex crispus					●	●	●	●				
Rumex hymenosepalus					○							
Salsola iberica	●	○				●	●	●				
Sisymbrium altissimum					●							
Sphaeralcea spp.	●	●	●	●	●	●	○	●	●	●		
Sporobolus cryptandrus	○			●		●		●	●			
Stipa hymenoides				●								
Symphoricarpos longiflorus					●							
Vitis arizonica						●	●	●	●			

Results of microhistological analysis of fecal material for 1990 and 1991 are presented in Tables 5 and 6. Samples from upper and lower Zion Canyon were analyzed separately. Unidentified browse and grass components and particles that lacked distinguishing characteristics were observed each month. Percentages of unidentified material varied between months, making monthly comparisons of actual values invalid. Spearman rank correlations were used to compare relative importance of known forage species between sites. Sixteen out of 24 within month comparisons were positively correlated using an adjusted α level of $.05/1+k-i$ as suggested by Rice (1989). The two sites are not isolated, as extensive trailing can be found on benches between, and there is a remote possibility that some deer move daily between sites. For these reasons, averages of diet composition data from both upper and lower canyon sites are reported here. As will be discussed, diet composition data were maintained separately for comparisons with fecal nitrogen and nutritional data.

Diet composition, by forage class, is presented in Figures 11 through 15. For the purposes of comparing use of forage classes between upper and lower canyon sites, between years and with other populations, values for unidentified particles were added to respective forage classes. Values for unidentified grasses were added to the grass forage class. Unidentified browse, which consisted mainly of woody tissue, was added proportionally to tree, shrub and perennial herb classes. In general, the diet in both years was dominated by tree species, although shrub species were also very important. Forbs were consumed seasonally and at a higher proportion in 1990 than 1991, probably due to higher summer precipitation in 1990 than 1991. Grasses were consumed in every month of the year, however species composition changed.

The coefficient of community was used to measure dietary similarity between sites. Figure 16 illustrates the percentage dietary overlap by forage class between upper and lower Zion Canyon mule deer. Dietary overlap ranged between 57.5% and 96.3%, indicating a high degree of similarity. Monthly dietary overlap by forage class between years ranged from 66.8% to 94.9%, also indicating a high degree of similarity.

Table 5. Monthly percent composition of Zion Canyon mule deer diets, 1990.

Forage species	J	F	M	A	M	J	J	A	S	O	N	D
Acer spp.	11.6	1.7	0.6	1.2	7.8	19.6	19.2	13.4	14.7	8.7	16.9	9.3
Amelanchier utahensis					3.2	3.3	3.6	3.1	2.2	1.6	0.4	
Artemisia tridentata	12.8	1.2	3.8	7.9	2.4	2.0	3.2	2.3	1.4	4.3	0.4	2.8
Atriplex canescens	12.1	4.7	1.0	7.3	8.7			2.8	4.3	7.6	2.3	9.9
Bromus diandrus	5.5	0.7	2.4	5.6	1.1	0.9			2.0	6.0	2.0	13.1
Bromus tectorum				1.1	0.9							
Celtis reticulata				4.6	7.5	2.0	3.0	1.0	11.0	8.8	10.7	2.2
Chorispora tenella												
Chrysothamnus nauseosus	4.4	1.2	0.4	4.4		5.46	2.7	4.9	2.9	6.1	11.2	5.4
Coleogyne ramosissima	4.7	0.6	2.5	0.3	0.3							0.2
Cucurbita foetidissima						0.7	0.8					
Elymus spp.	1.5		2.2	4.6	0.3				0.3			
Erodium cicutarium					0.1							
Festuca ovina						0.6	0.7	2.9	0.6			0.3
Festuca pratensis							0.2	0.5				
Fraxinus spp.	6.0	1.7	0.8	2.5	18.8	4.6	1.9	5.1	3.5	5.4	1.5	3.2
Gutierrezia spp.					0.4							
Heterotheca villosa		0.1	0.5	2.2	5.2	0.6	0.4	0.1	1.1			
Juniperus spp.	11.6	36.5	58.8	6.8	1.1	0.4		0.3	5.2	3.4	2.1	7.2
Mahonia repens			0.1									
Malus pumila									0.4	0.2		
Melilotus officinalis						3.6	1.6	4.3	0.5			
Poa fendleriana	2.4	1.5	1.6	1.6								
Poa pratensis						0.8	0.7	4.0	3.0	2.2	7.9	3.1
Populus fremontii	14.1	29.0	10.1	1.7	8.0	12.2	8.0	6.3	10.1	14.1	9.2	20.5
Populus flower stalks			7.4	1.8	0.2							
Quercus gambelii		4.8	1.9	6.0	10.3	6.2	4.9	9.3	3.5	5.2	17.5	4.1
Quercus turbinella	5.9	10.3	1.3	23.5	3.8	23.5	28.1	15.4	8.0	9.3	4.4	10.6
Rhus aromatica						0.4	0.7	0.3	2.2	1.5	2.4	1.1
Rubia tinctoria				0.2	0.6	1.0	4.9	0.5	0.6			0.2
Rumex spp.						1.4	1.3	3.5				
Salsola iberica	0.5					0.7	2.3	4.4				
Sisymbrium altissimum												
Sphaeralcea spp.	1.1		0.4	0.3	0.3				2.1	0.9		
Sporobolus cryptandrus				0.1				0.7	1.7			
Stipa hymenoides												
Symphoricarpos longiflorus												
Vitis arizonica						0.5	0.5		1.3			
unidentified browse	3.4	4.3	3.1	11.5	16.6	7.7	9.4	11.7	13.4	9.9	9.5	6.0
unidentified grass	2.5	1.7	1.3	5.2	2.5	2.2	2.3	3.1	4.7	4.9	1.7	1.0

Table 6. Monthly percent composition of Zion canyon mule deer diets, 1991

Forage species	J	F	M	A	M	J	J	A	S	O	N	D
Acer spp.	0.9	1.0	0.2	2.7	6.8	9.0	8.4	8.1	9.2	5.0	5.7	5.2
Amelanchier utahensis				3.2	1.2	1.2	1.3	1.9	2.9	2.9	0.5	
Artemisia tridentata	3.7	1.5	0.6	14.8	1.1	2.9	2.0	1.0	3.2	2.5	5.5	4.4
Atriplex canescens	6.5	1.9	3.8	1.2	2.9			1.3	1.7	4.5	3.5	14.3
Bromus diandrus	1.7	1.4	1.8	9.3	11.1	4.4	0.3		10.2	2.6	2.2	5.9
Bromus tectorum				3.2								
Celtis reticulata		0.6	0.1	0.3	7.9	15.1	16.9	24.6	14.1	13.9	10.5	7.7
Chorispora tenella				0.3								
Chrysothamnus nauseosus	1.2	1.0	1.1	1.1		3.3	2.9	4.1	8.1	6.1	16.9	7.5
Coleogyne ramosissima	0.2	2.3	0.2	22.9	0.3							0.5
Cucurbita foetidissima						0.3	0.4					
Elymus spp.	0.5	0.2	0.3	3.2	0.1							
Erodium cicutarium												
Festuca ovina						1.1	0.5	1.3	1.0	1.2	2.5	0.2
Festuca pratensis						0.3	0.1		0.3			
Fraxinus spp.	1.6	0.6	0.2	1.3	6.5	2.9	4.8	3.7	3.6	4.0	9.6	6.7
Gutierrezia spp.				0.3								
Heterotheca villosa			0.1	0.6	1.8	0.1	0.1					
Juniperus spp.	32.6	50.9	34.3	3.2	3.7	5.6	0.1	0.6	1.3	3.7	2.5	3.4
Mahonia repens												
Malus pumila												
Melilotus officinalis					2.0	2.3	1.9	1.3	1.0		0.5	
Poa fendleriana	2.0	3.2	2.2	2.4								
Poa pratensis						1.4	1.7	3.1	4.4	10.4	7.4	3.8
Populus fremontii	38.5	13.3	26.0	0.9	3.3	5.2	6.3	8.6	13.2	13.4	11.6	10.5
Populus flower stalks			15.7	3.0	0.7							
Quercus gambelii		0.5		3.4		10.1	9.3	10.6	4.0	9.1	12.2	6.2
Quercus turbinella	3.3	13.6	8.2	1.0	27.4	11.4	26.5	10.7	10.4	7.4	2.7	13.8
Rhus aromatica						0.8	0.4	0.4	1.1	1.2	0.3	0.3
Rubia tinctoria					0.2	1.1	1.2	0.6				1.0
Rumex spp.					1.0	0.3	0.7	0.4				
Salsola iberica	0.3					0.3	0.4	0.1				
Sisymbrium altissimum					0.7							
Sphaeralcea spp.	0.04	1.2	1.1	2.2	1.6	0.3		0.7	0.4	0.8		
Sporobolus cryptandrus						0.6		0.9				
Stipa hymenoides				1.04								
Symphoricarpos longiflorus					1.8							
Vitis arizonica						1.8	0.8					
unidentified browse	5.6	6.0	2.6	11.2	11.9	11.0	9.0	11.2	7.6	8.1	4.4	6.7
unidentified grass	1.7	1.1	1.6	7.5	6.1	7.3	3.7	5.0	2.4	3.4	1.7	2.1

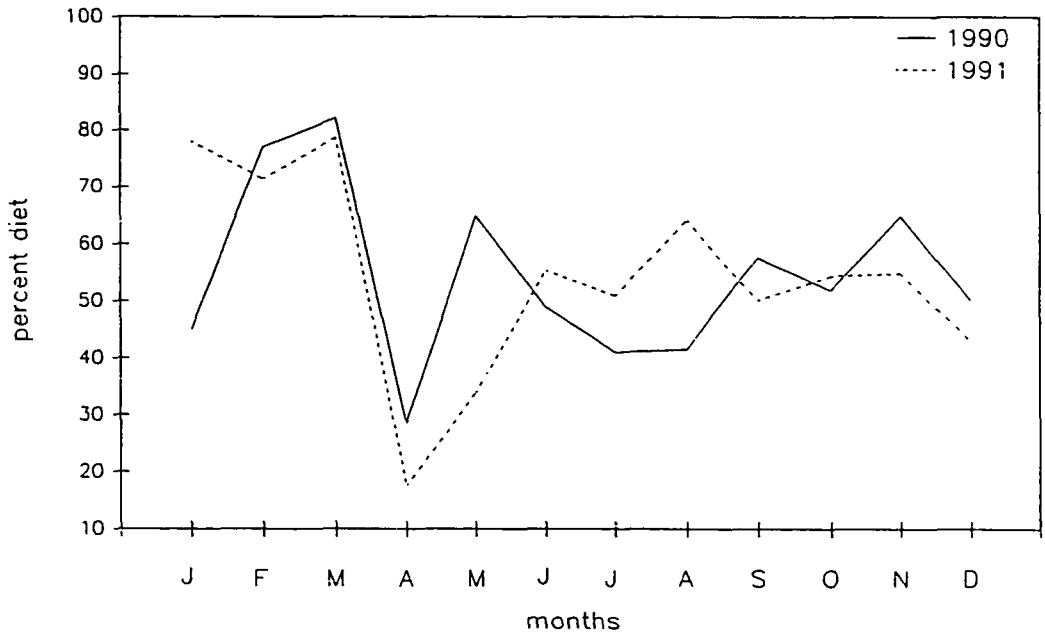

Figure 11. Percentage of Zion Canyon mule deer diet composed of tree species, 1990-1991.

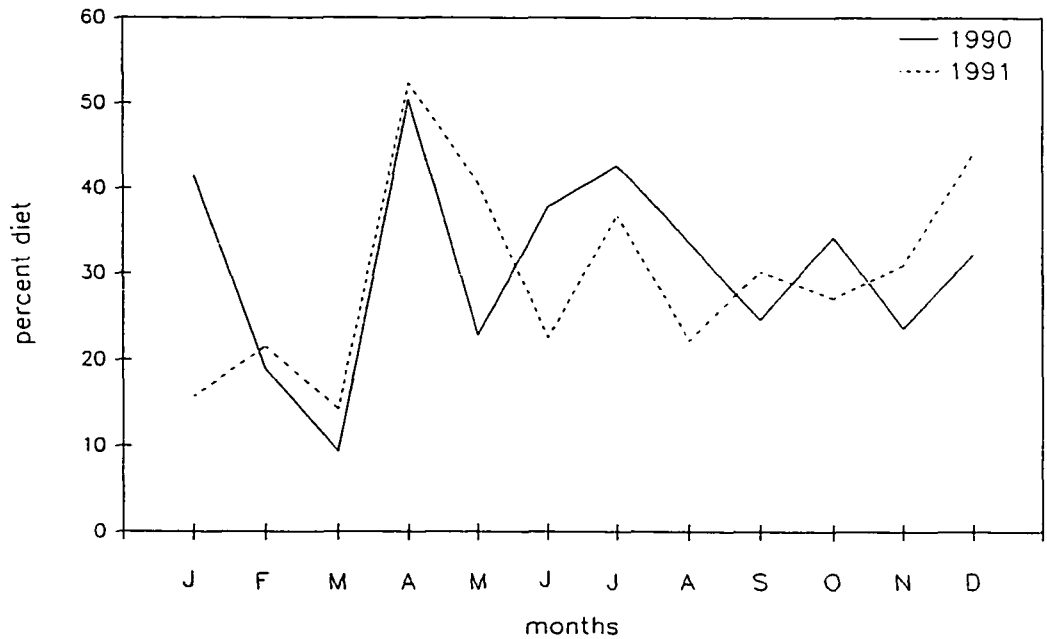

Figure 12. Percentage of Zion Canyon mule deer diet composed of shrub species, 1990-1991.

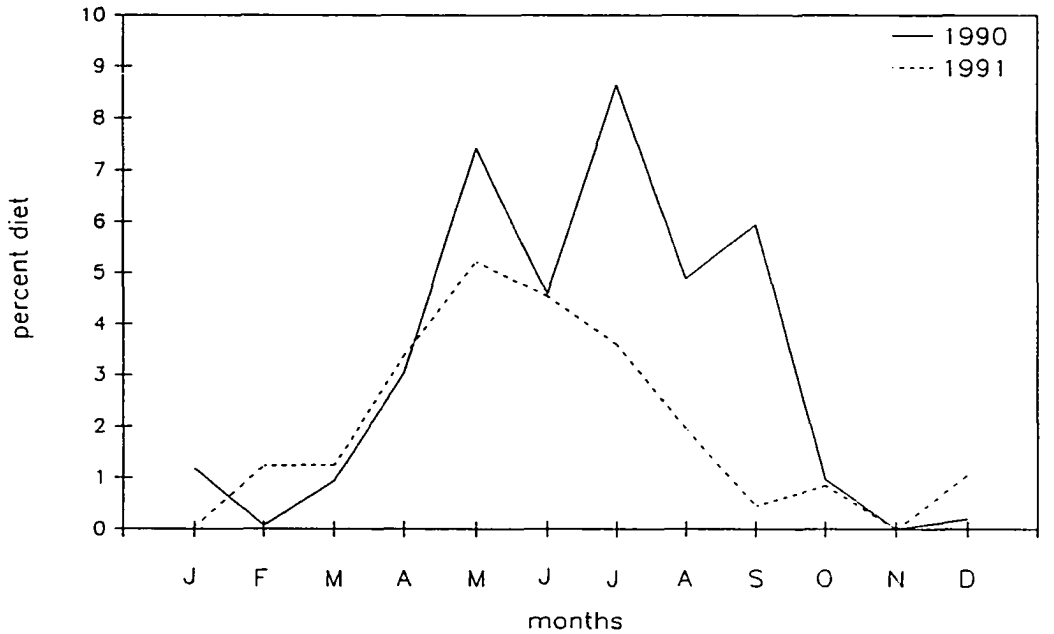

Figure 13. Percentage of Zion Canyon mule deer diet composed of perennial forb species, 1990-1991.

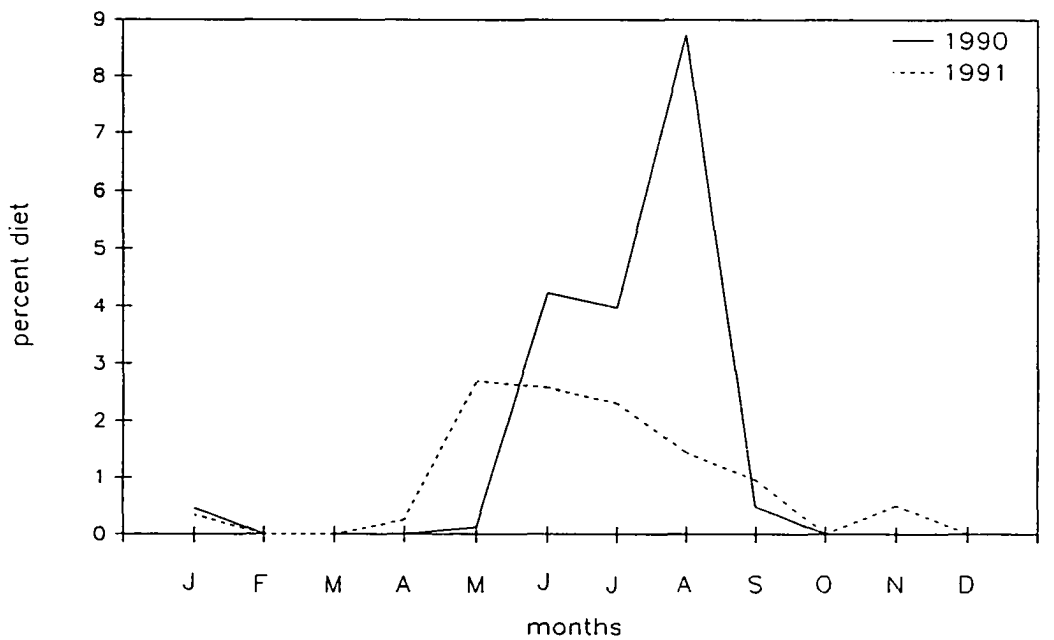

Figure 14. Percentage of Zion Canyon mule deer diet composed of annual forb species, 1990-1991.

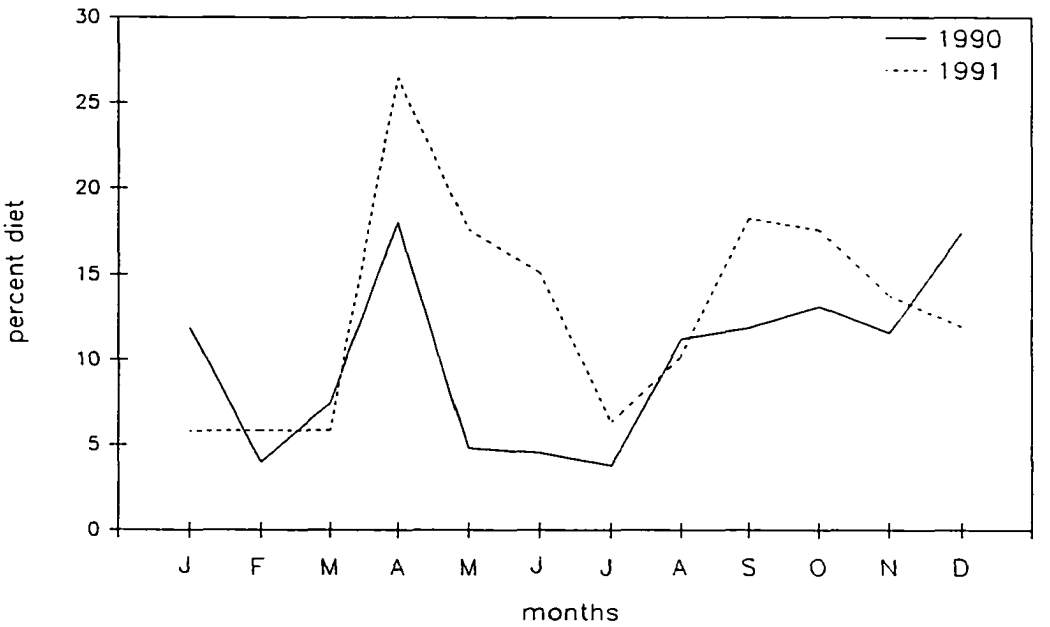

Figure 15. Percentage of Zion Canyon mule deer diet composed of grass species, 1990-1991.

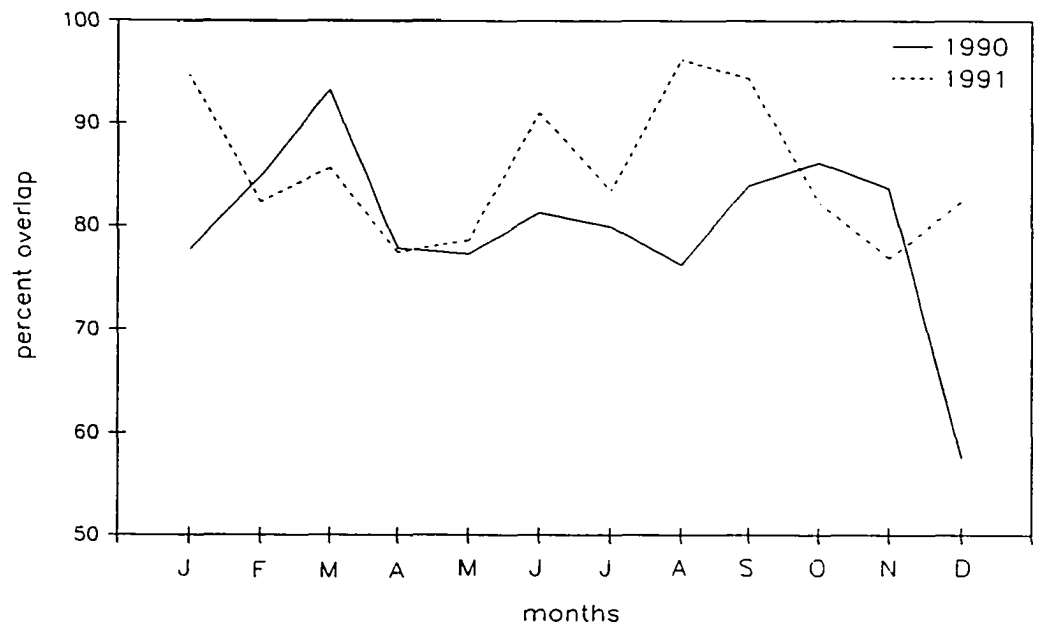

Figure 16. Percentage overlap in mule deer diet composition at two sites in Zion Canyon, 1990-1991.

Forage preference

Results of two-sample binomial comparisons of forage use and availability are presented in Tables 7 and 8. Expected values for plants were derived from plant transects. Only those species found in the diet were used in analysis. Relative use and availability of tree and shrub species are presented in Figures 17 through 20. Relative availability of tree species in Zion Canyon, as measured by diameter at breast height, is as follows: *Quercus gambelii* 31.4 %; *Juniperus* spp. 27.4 %; *Fraxinus* spp. 17.0 %; *Celtis reticulata* 12.5 %; *Populus fremontii* 7.0 %; and *Acer* spp. 4.8 %. Relative cover of shrub species is as follows: *Quercus turbinella* 79.9 %; *Amelanchier utahensis* 4.0 %; *Chrysothamnus nauseosus* 4.0 %; *Coleogyne ramosissima* 2.9 %; *Gutierrezia* spp. 2.7 %; *Atriplex canescens* 2.4 %; *Artemisia tridentata* 2.2 %; *Rhus aromatica* 1.4 % and *Symphoricarpos longiflorus* 0.8 %.

Table 7. Results of preference analysis for trees, tested with 95% confidence intervals around the difference between available and utilized, ● = preferred, O = avoided, unmarked box indicates species was used in proportion to availability.

1990	J	F	M	A	M	J	J	A	S	O	N	D
Acer spp.	●		O		●	●	●	●	●	●	●	●
Celtis reticulata	O	O	O			O		O	●	●		O
Fraxinus spp.		O	O	O	●	O	O		O		O	O
Juniperus spp.		●	●		O	O	O	O	O	O	O	O
Populus fremontii	●	●	●	●	●	●	●	●	●	●	●	●
Quercus gambelii	O	O	O		O	O	O		O	O		O
1991												
Acer spp.	O	O	O	●	●	●	●	●	●	●	●	●
Celtis reticulata	O	O	O	O	●	●	●	●	●	●	●	●
Fraxinus spp.	O	O	O	O		O		O	O	O		
Juniperus spp.	●	●	●		O	O	O	O	O	O	O	O
Populus fremontii	●	●	●	●	●		●	●	●	●	●	●
Quercus gambelii	O	O	O	O	O	O	O	O	O	O	O	O

Table 8. Results of preference analysis for shrubs, tested with 95 % confidence intervals around the difference between available and utilized, ● = preferred, O = avoided, unmarked box indicates species was used in proportion to availability.

1990	J	F	M	A	M	J	J	A	S	O	N	D
Amelanchier utahensis	O	O	O	O	●	●		●	●			O
Artemisia tridentata	●		●	●	●		●	●		●		●
Atriplex canescens	●	●	●	●	●			●	●	●	●	●
Chrysothamnus nauseosus	●			●	O	●		●	●	●	●	●
Coleogyne ramosissima	●		●			O	O	O	O	O	O	
Gutierrezia spp.	O	O	O	O		O	O	O	O	O	O	O
Quercus turbinella	O	O	O	O	O	O		O	O	O	O	O
Rhus aromatica									●		●	
Symphoricarpos longiflorus												
1991												
Amelanchier utahensis	O	O	O					●	●	●		O
Artemisia tridentata	●	●		●		●			●	●	●	●
Atriplex canescens	●	●	●		●					●	●	●
Chrysothamnus nauseosus					O	●		●	●	●	●	●
Coleogyne ramosissima		●		●		O	O	O	O	O	O	
Gutierrezia spp.	O	O	O		O	O	O	O	O	O	O	O
Quercus turbinella	O	O	O	O		O		O	O	O	O	O
Rhus aromatica												
Symphoricarpos longiflorus					●							

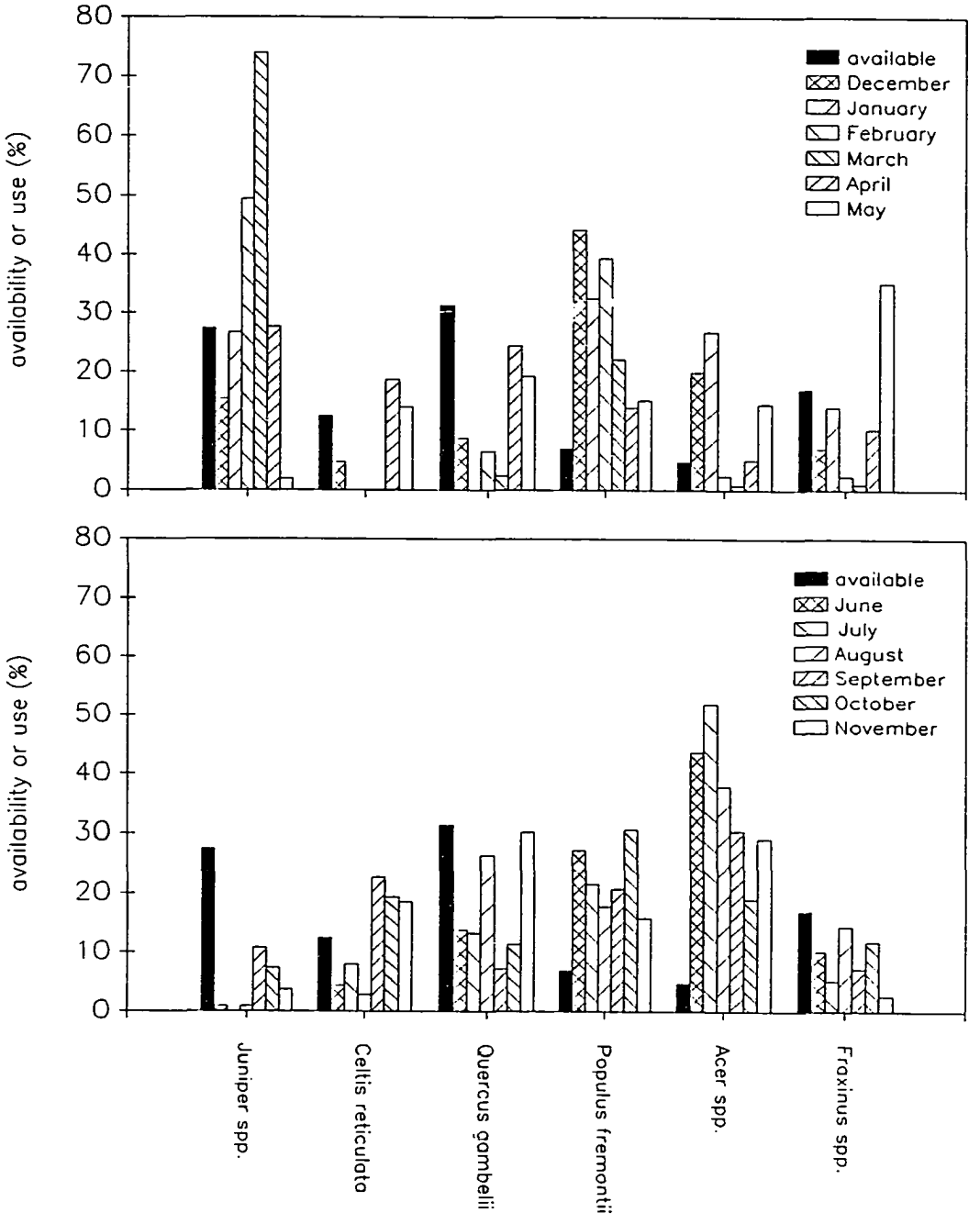

Figure 17. Relative use and availability of tree species for mule deer forage in Zion Canyon, 1990.

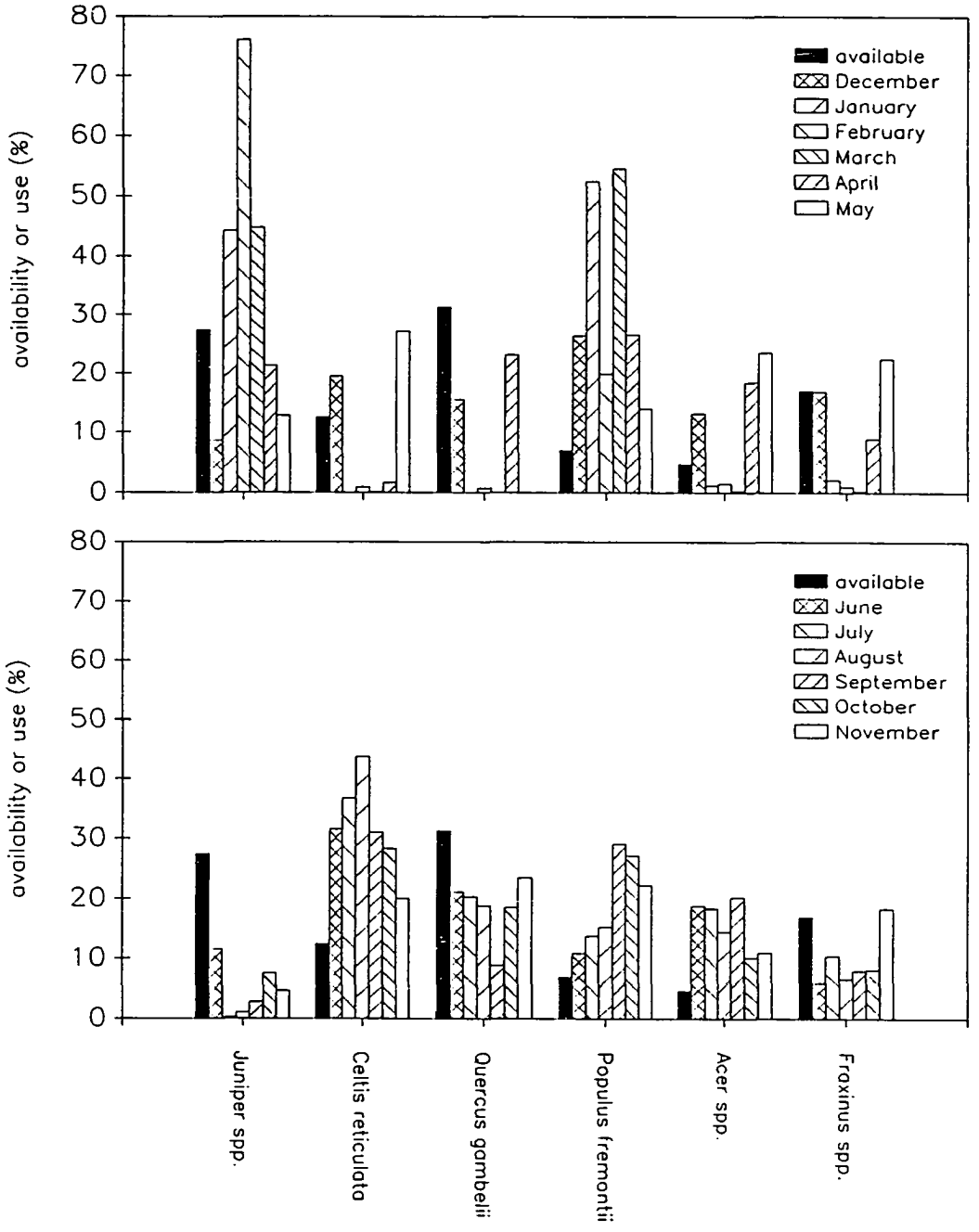

Figure 18. Relative use and availability of tree species for mule deer forage in Zion Canyon, 1991.

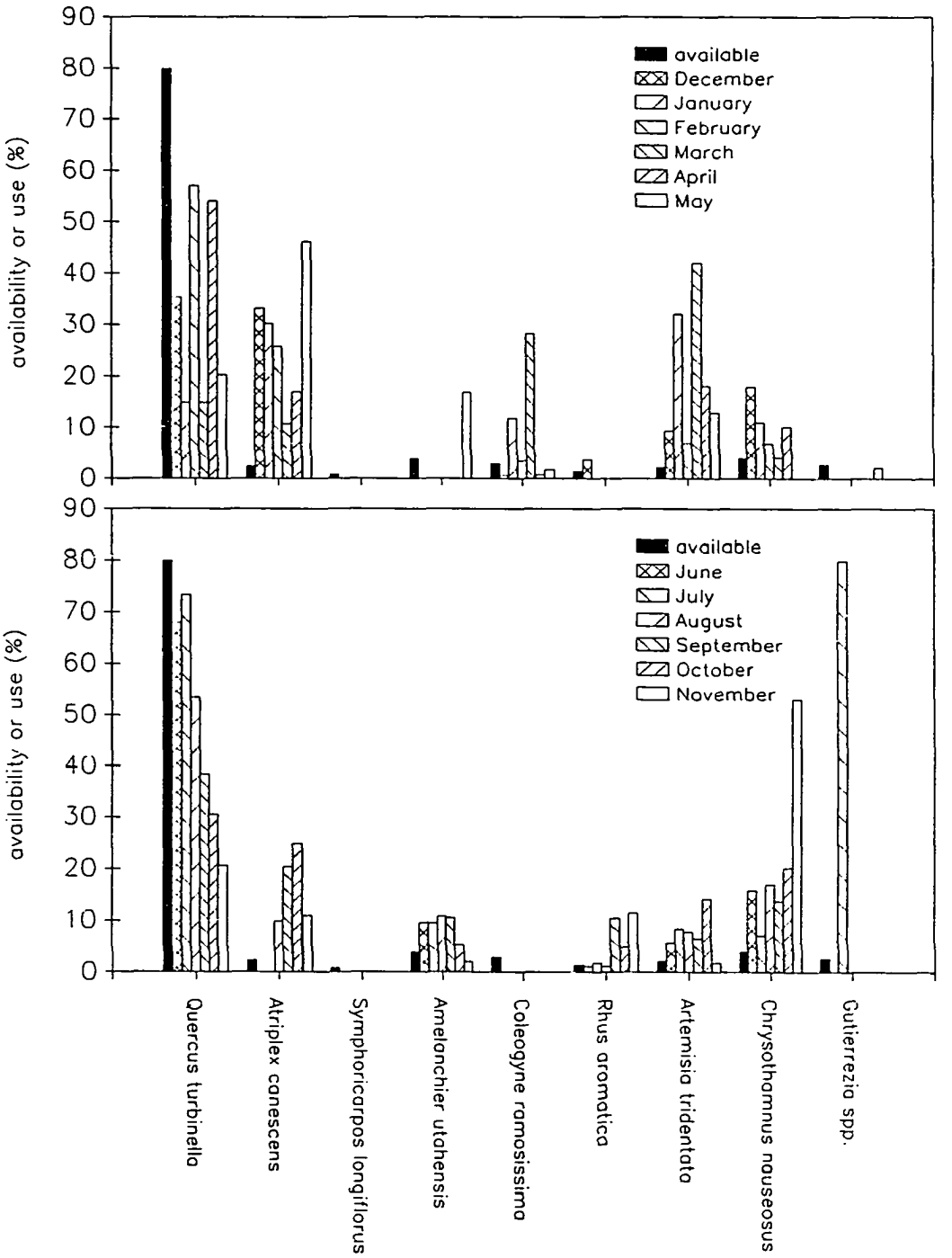

Figure 19. Relative use and availability of shrub species for mule deer forage in Zion Canyon, 1990.

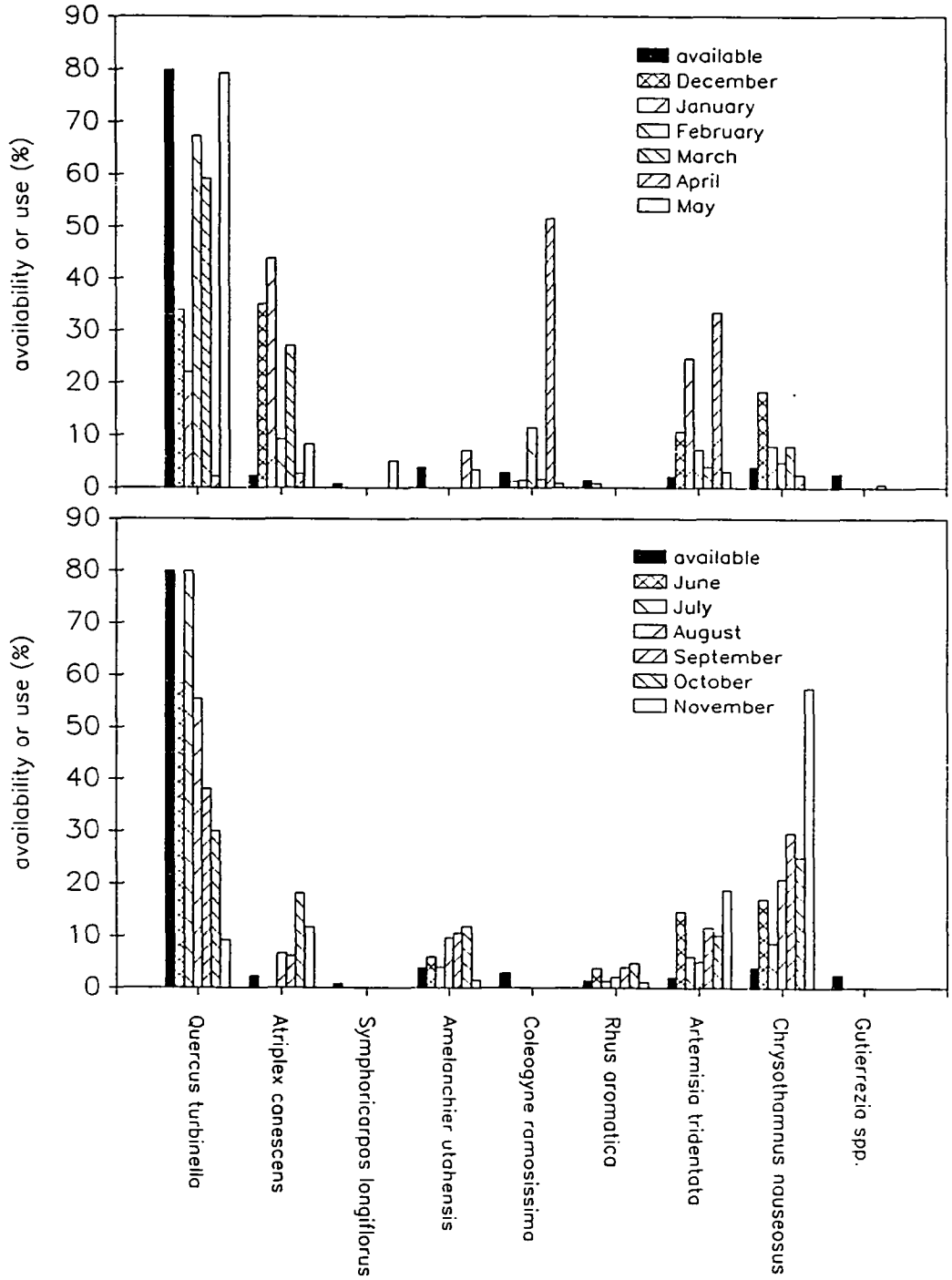

Figure 20. Relative use and availability of shrub species for mule deer forage in Zion Canyon, 1991.

Among tree species, Zion Canyon mule deer preferred *Populus fremontii* nearly every month of the year, preferred *Juniperus* spp. in the winter and avoided them the rest of the year, preferred *Acer* spp. in the summer and fall and avoided or used them in proportion to availability in the winter, avoided *Fraxinus* spp. in most months, and avoided *Quercus gambelii* in most months. A clear trend did not emerge in the use of *Celtis reticulata*. Among shrub species, Zion Canyon mule deer preferred *Artemisia tridentata*, *Atriplex canescens*, and *Chrysothamnus nauseosus* most months and avoided *Quercus turbinella* and *Gutierrezia* spp. nearly every month. *Coleogyne ramosissima* was avoided in all but 4 months in both years and *Symphoricarpos longiflorus* was used in proportion to availability in all but 1 month of one year.

Dramatic changes have taken place over the past 70 years in the vegetation of Zion Canyon. Photographs from the National Park museum collection have been reprinted here, along with photographs of the sites as they appeared in 1991 (Figs. 21 through 23). Increases in shrub cover and trees are the primary differences that have occurred in the vegetation. Grass and forb species are not discernible in the early photographs, but it is very likely that they were more abundant than at present.

Nutrition

Results of nutritional analysis of important forage species are presented in Tables 9 through 12. Ten, 13, 10, and 11 species were analyzed in January, April, July, and October, 1991, respectively. These species comprised 91.6 %, 71.0 %, 80.9 %, and 79.2 % of the 1991 average upper and lower canyon seasonal diets, respectively. Figure 24 illustrates the relative composition of nutritional components as determined by summing the contributions of each species to the total nutrition (Westoby, 1974) and dividing the sums by the percent known of the diet (Leslie and Starkey, 1984). The same process was applied to each site, and no significant differences were found between nutritional values within each season. The relationships between dietary crude protein, fecal nitrogen, and serum urea protein are illustrated in Figure 25.

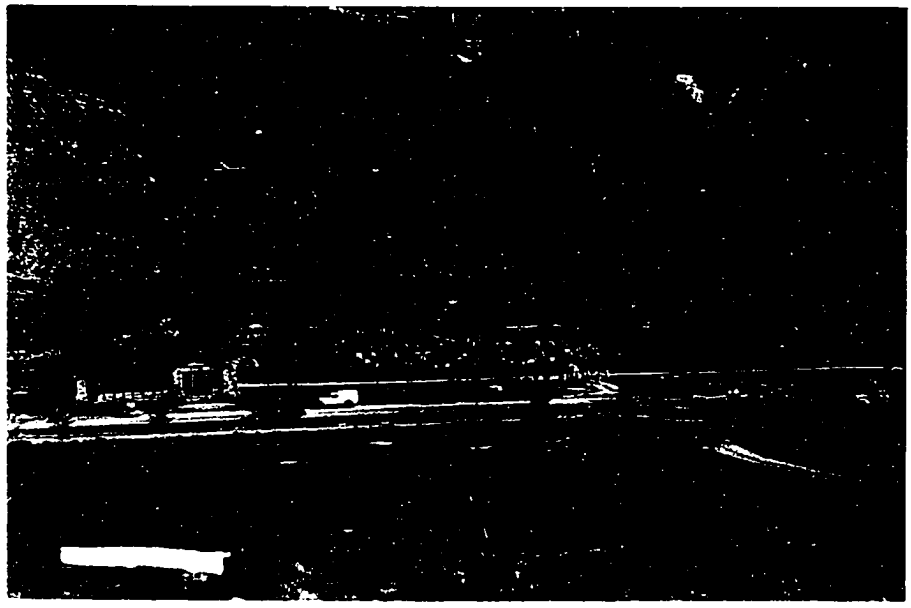

Figure 21a. South campground entrance, Zion National Park, 1935.

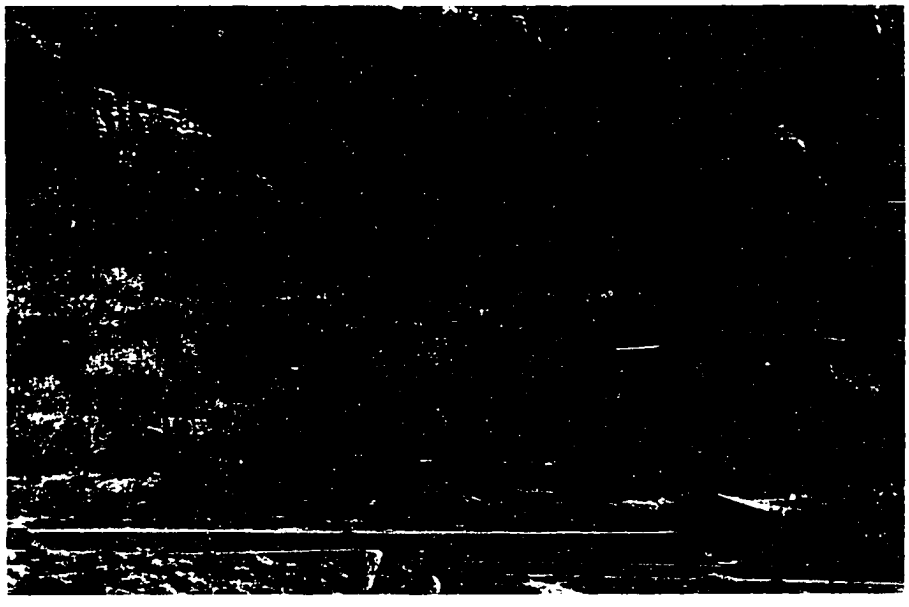

Figure 21b. South campground entrance, Zion National Park, 1991.

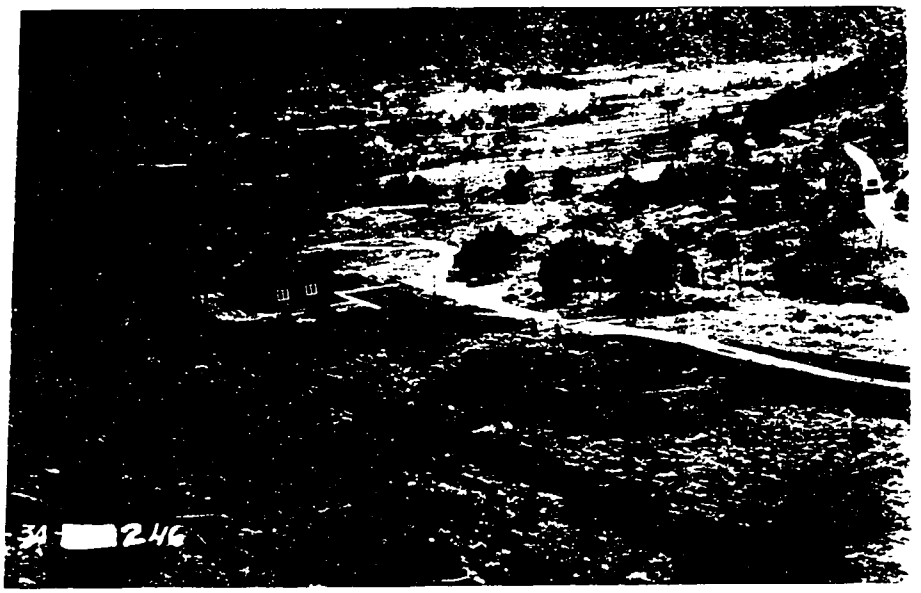

Figure 22a. Oak Creek housing area, Zion National Park, 1934.

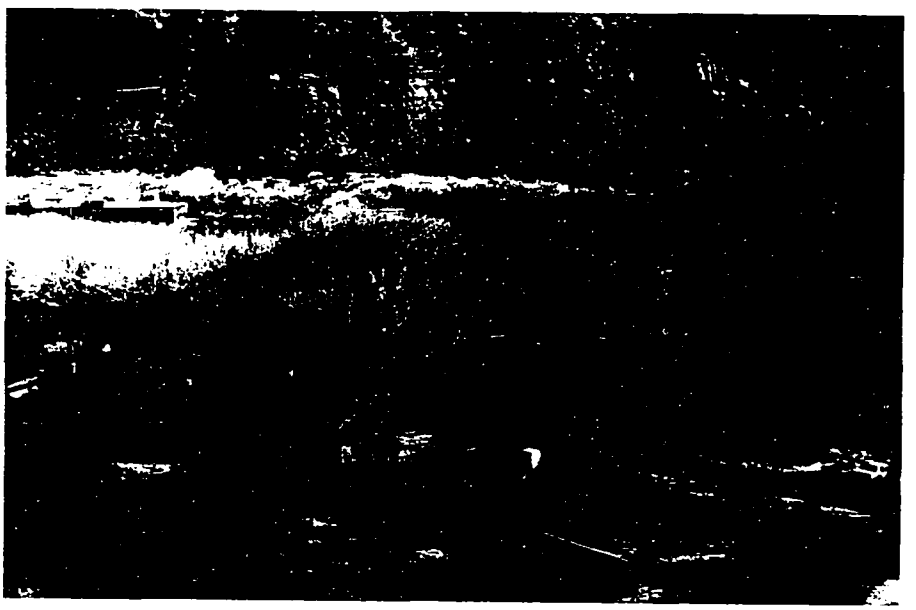

Figure 22b. Oak Creek housing area, Zion National Park, 1991.

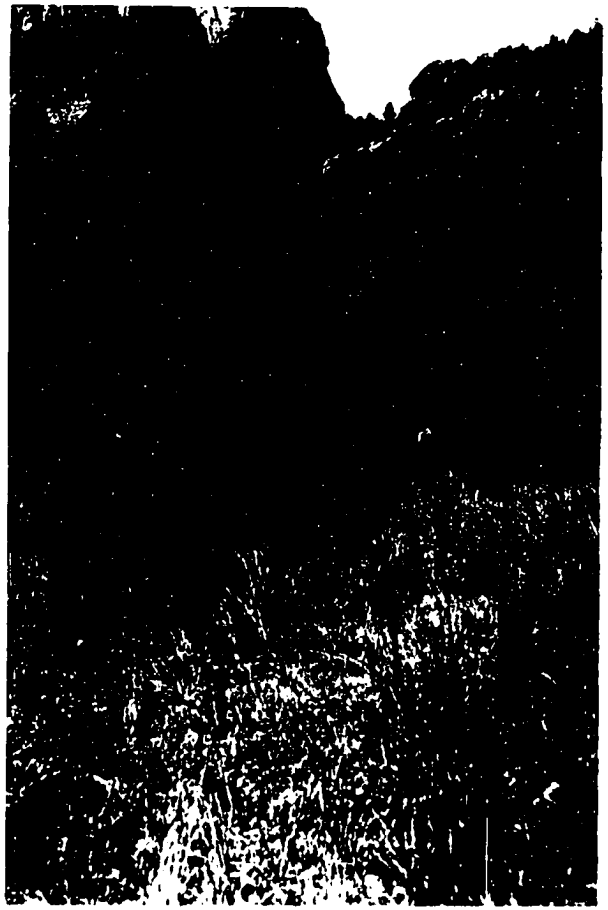

Figure 23a. One quarter mile south of Zion Lodge, Zion National Park, 1953.

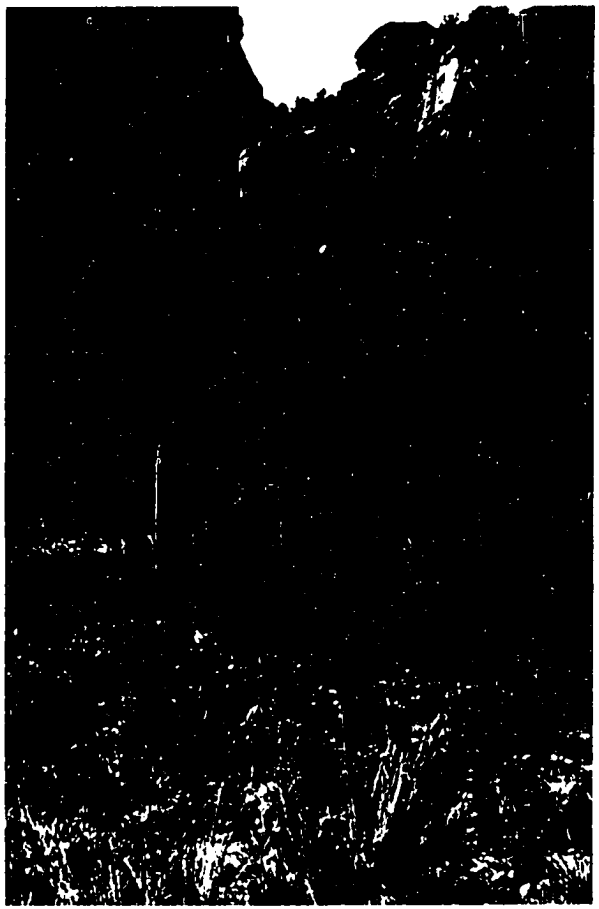

Figure 23b. One quarter mile south of Zion Lodge, Zion National Park, 1991.

Table 9. Nutritional composition (%) of major forage species in Zion Canyon mule deer diets, January, 1991: NDF= % neutral detergent fiber, ADF= % acid detergent fiber, ADL= % acid detergent lignin, AIA= % acid insoluble ash.

Species	% in diet	protein	fat	ash	NDF	ADF	ADL	AIA
Acer negundo	0.9	9.0	4.7	15.5	42.3	28.5	9.0	1.0
Artemisia tridentata	3.7	14.4	18.0	4.1	32.2	22.9	10.4	0.1
Atriplex canescens	6.5	12.5	1.4	10.4	53.0	27.4	14.8	0.3
Bromus diandrus	1.7	24.2	4.6	11.8	38.9	17.8	3.2	0.3
Chrysothamnus nauseosus	1.2	5.7	12.5	3.4	52.6	36.9	11.4	0.1
Fraxinus velutina	1.6	6.3	4.3	7.0	55.5	39.5	10.8	0.5
Juniperus osteosperma	32.6	5.6	15.1	3.7	32.4	23.5	12.4	0.9
Poa fendleriana	2.0	13.1	5.6	4.4	47.6	24.9	3.7	0.1
Populus fremontii	38.5	4.2	3.3	9.3	49.5	35.3	16.5	0.6
Quercus gambelii	3.3	6.4	4.6	5.0	52.1	37.2	18.0	0.4
Nutritional value of analyzed diet		5.9	7.5	6.3	39.4	27.1	12.8	0.6

Table 10. Nutritional composition (%) of major forage species in Zion Canyon mule deer diets, April, 1991: NDF= % neutral detergent fiber, ADF= % acid detergent fiber, ADL= % acid detergent lignin, AIA= % acid insoluble ash.

Species	% in diet	protein	fat	ash	NDF	ADF	ADL	AIA
Acer negundo	2.7	10.1	4.1	10.8	49.7	33.8	11.2	0.1
Artemisia tridentata	14.8	22.9	7.6	11.2	24.9	17.9	3.8	0.2
Bromus diandrus	9.3	26.6	4.2	10.5	51.1	22.4	1.8	2.6
Bromus tectorum	3.2	14.5		9.8				
Chrysothamnus nauseosus	1.1	19.0	7.8	10.4	27.8	17.6	6.2	0.5
Coleogyne ramosissima	22.9	7.5	4.8	5.7	57.4	41.6	15.4	0.6
Elymus glaucus	3.2	30.0	3.2	10.6	55.9	25.0	3.3	0.3
Juniperus osteosperma	3.2	6.3	12.1	5.9	34.7	20.1	10.2	0.8
Poa fendleriana	2.4	14.1	3.5	7.5	61.9	32.4	4.6	0.4
Populus fremontii	0.9	5.8	3.0	10.6	56.4	41.5	12.7	0.3
Populus fremontii fl. stlks.	3.0	11.8	6.9	9.9	43.9	31.7	13.1	0.1
Quercus gambelii	3.4	6.5	3.4	6.5	54.1	38.9	18.1	0.5
Quercus turbinella	1.0	13.4	2.5	4.4	41.5	24.0	7.9	0.5
Nutritional value of analyzed diet		10.8	3.7*	6.0	31.7*	20.5*	6.4*	0.5*

*calculated for 67.88% of diet, values unavailable for *B. diandrus*.

Table 11. Nutritional composition (%) of major forage species in Zion Canyon mule deer diets, July, 1991: NDF= % neutral detergent fiber, ADF= % acid detergent fiber, ADL= % acid detergent lignin, AIA= % acid insoluble ash.

Species	% in diet	protein	fat	ash	NDF	ADF	ADL	AIA
Acer negundo	8.4	15.6	7.2	7.4	32.0	21.6	8.9	0.1
Artemisia tridentata	2.0	15.7	5.0	12.3	45.3	34.3	18.0	2.1
Celtis reticulata	16.9	13.8	2.7	13.3	36.9	22.2	6.5	0.7
Chrysothamnus nauseosus	2.9	11.0	12.7	6.9	32.1	24.0	11.2	0.6
Fraxinus anomala	4.8	8.5	4.3	12.1	21.5	16.2	6.1	0.1
Melilotus officinalis	1.9	15.8	2.0	9.7	42.0	32.0	13.5	0.9
Poa pratensis	1.7	15.8	8.7	8.0	64.4	31.5	10.3	1.8
Populus fremontii	6.3	9.8	5.3	10.3	31.5	22.5	8.2	0.9
Quercus gambelii	9.3	13.4	3.1	4.2	42.5	23.8	8.6	0.5
Quercus turbinella	26.5	8.9	2.2	4.2	57.1	38.8	17.1	0.6
Nutritional value of analyzed diet		9.5	3.1	6.4	34.8	22.8	9.1	0.5

Table 12. Nutritional composition (%) of major forage species in Zion Canyon mule deer diets, October, 1991: NDF= % neutral detergent fiber, ADF= % acid detergent fiber, ADL= % acid detergent lignin, AIA= % acid insoluble ash.

Species	% in diet	protein	fat	ash	NDF	ADF	ADL	AIA
Acer negundo	5.0	10.6	13.2	12.6	29.3	17.5	6.0	0.1
Amelanchier utahensis	2.9	7.2	8.2	7.9	29.4	16.7	6.5	0
Atriplex canescens	4.5	14.6	2.2	17.9	41.9	21.3	7.4	0.3
Bromus diandrus	2.6	30.3		18.2				
Celtis reticulata	13.9	11.7	7.4	22.5	31.1	20.1	9.9	4.5
Chrysothamnus nauseosus	6.1	12.7	12.1	8.5	40.0	27.1	9.5	0
Fraxinus anomala	4.0	7.3	6.3	12.4	17.8	13.1	5.2	0
Poa pratensis	10.4	19.3	5.4	9.2	46.8	23.1	3.9	0.7
Populus fremontii	13.4	4.1	3.6	15.1	35.4	24.0	7.2	0.1
Quercus gambelii	9.1	10.6	3.5	5.2	41.4	25.7	10.2	0.2
Quercus turbinella	7.4	9.5	3.1	5.6	54.2	36.3	14.1	0.2
Nutritional value of analyzed diet		11.5	6.0*	12.8	37.9*	23.4*	8.3*	1.0*

*calculated for 76.59% of diet, values unavailable for *B. diandrus*.

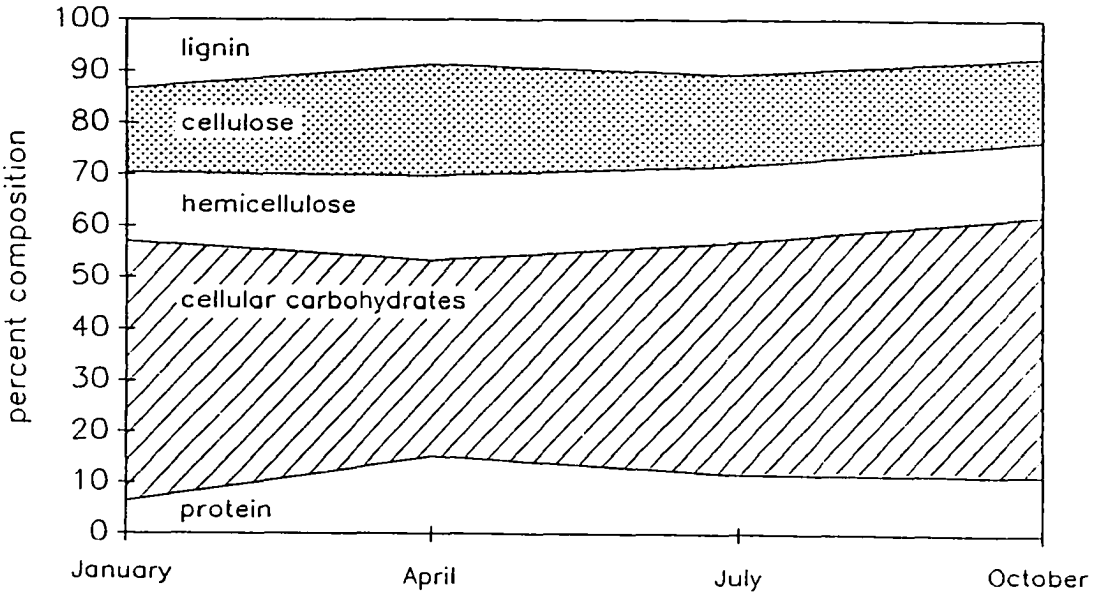

Figure 24. Nutritional composition as accumulated percent of diet for Zion Canyon mule deer diets, 1991.

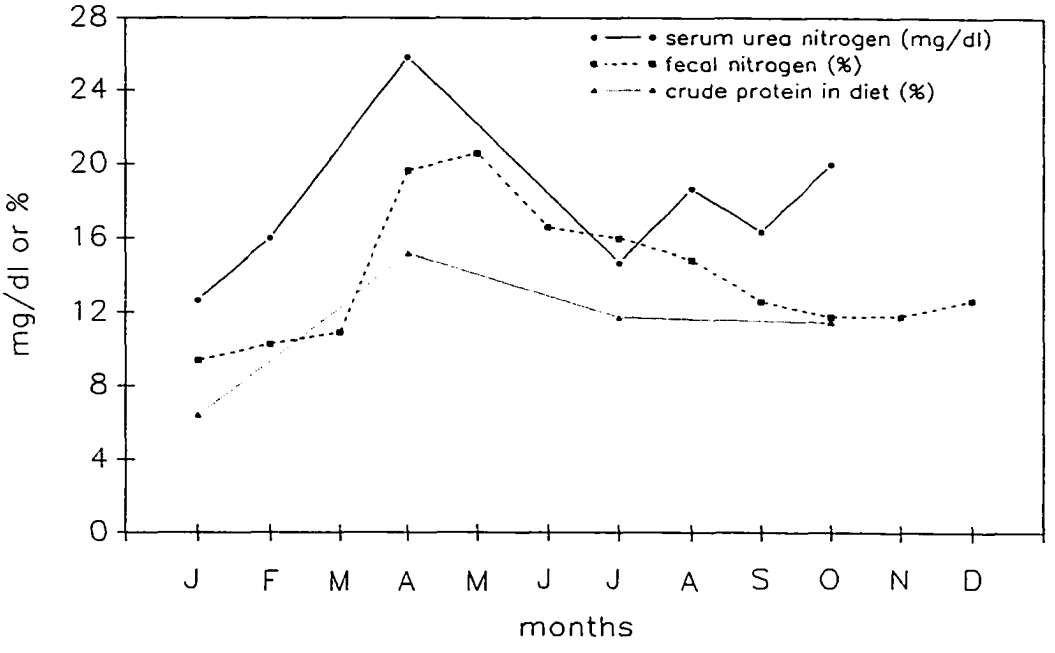

Figure 25. Serum urea nitrogen, dietary protein, and fecal nitrogen of Zion Canyon mule deer, 1990-1991.

Herd composition and reproduction

From late spring through early fall deer were observed feeding in small (<10 animals) groups. Group size increased in fall as wintering deer entered the canyon and females were herded by males in rut. Adult males (>2 yrs.) were rarely seen in the canyon outside the breeding season, which took place between mid-November and late December. June 14 was the earliest date of fawning observed in this study.

Results of three roadside surveys in 1991 for the upper and lower canyon sites are presented in Table 13. The maximum number of deer counted in three surveys in 1991 was 105, with a doe to fawn ratio of 1:0.60. A summary of all counts conducted in Zion Canyon from 1965 through 1991 is presented in Table 14. Yearling animals of both sexes were placed in adult categories. Several of the earlier observers recorded male and female yearling numbers separately from adult figures. For several reasons, yearling and adult numbers are combined in Table 14; in winter it can be difficult to distinguish yearling from adult females, separate yearling and adult numbers are not available for all censuses, and yearlings are capable of having fawns and therefore are included in doe to fawn ratios (recruitment rates) reported elsewhere.

Table 13. Roadside Deer Census Summary, Zion Canyon, 1991.

Location	Date	Total	Adult males	Adult females	Fawns	Unknown	Doe:Fawn ratio
Upper canyon	Dec. 23	39	7	20	12		1:0.600
	Dec. 26	40	8	27	5		1:0.185
	Dec. 29	30	11	12	6	1	1:0.500
Lower canyon	Dec. 23	59	7	27	25		1:0.926
	Dec. 26	65	8	29	28		1:0.966
	Dec. 29	54	4	22	24	4	1:1.090

Table 14: Roadside Deer Census Summary, Zion Canyon, 1965-1991.

Date	Total	Adult Males	Adult Females	Fawns	Unknown	Doe:Fawn ratio	Authors*
Nov. 23, 1965	55	16	28	11		1:.393	1
Dec. 17, 1965	85	20	50	15		1:.300	1
Jan. 13, 1966	120	28	64	24	4	1:.375	1
Nov. 14, 1966	134	19	54	18	43	1:.333	1
Jan. 10, 1967	119	7	16	6	90	1:.375	1
Feb. 15, 1967	140				140		1
Mar. 23, 1967	90				90		1
Nov. 30, 1967	115	25	58	32		1:.552	1
Dec. 1, 1967	39	7	22	10		1:.455	1
Dec. 9, 1967	112	26	47	39		1:.830	1
Dec. 11, 1979	40	8	17	15		1:.882	2
Dec. 26, 1982	54	6	27	21		1:.777	3
Dec. 10, 1986	101	14	47	15	27	1:.319	2
Jan. 21, 1988	56	5	39	12		1:.308	3
Feb. 8, 1988	86	4	54	24	4	1:.444	4
Dec. 23, 1991	98	14	47	37		1:.787	5
Dec. 26, 1991	105	16	56	33		1:.589	5
Dec. 29, 1991	84	15	34	30	5	1:.882	5

*1 Moorhead, 1976; 2 unknown, Park files; 3 Mitchell and Anglin, Park files; 4 Mitchell and Given, Park files; 5 Cunningham and Manns, Park files.

Climate

Weather records for Zion Canyon were examined for trends that may be affecting the condition of canyon deer. A nearly complete data set of temperature and precipitation since 1904 is available. From 1904 to 1911 the weather station was located in Springdale. From 1911 to 1933 it was at park headquarters, then located at the junction of Pine Creek and the Virgin River (Fig. 1). From 1933 to present, the weather station has been located behind park headquarters, along Oak Creek (Fig. 1).

Zion Canyon has received an average of 365 mm of yearly precipitation from 1904 through 1991. Yearly total precipitation has oscillated widely around the mean (Fig. 26). Figure 27 shows the distribution of precipitation throughout the year, determined by monthly averages from 1904 through 1991. Summer and winter precipitation and temperature histories may be found in the Appendix.

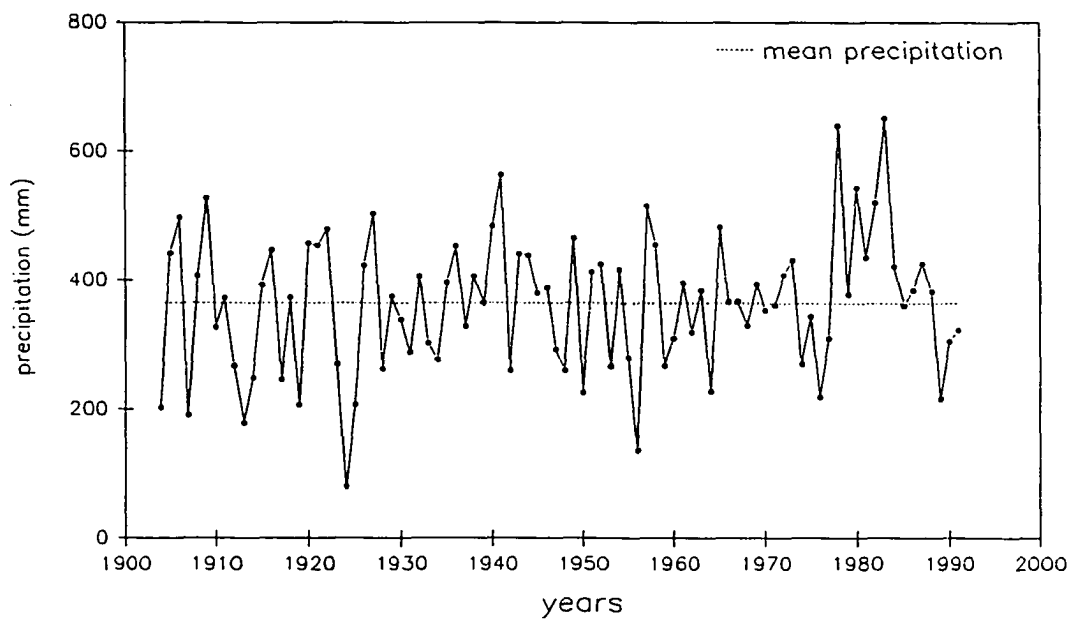

Figure 26. Annual precipitation, Zion Canyon, UT, 1904-1991.

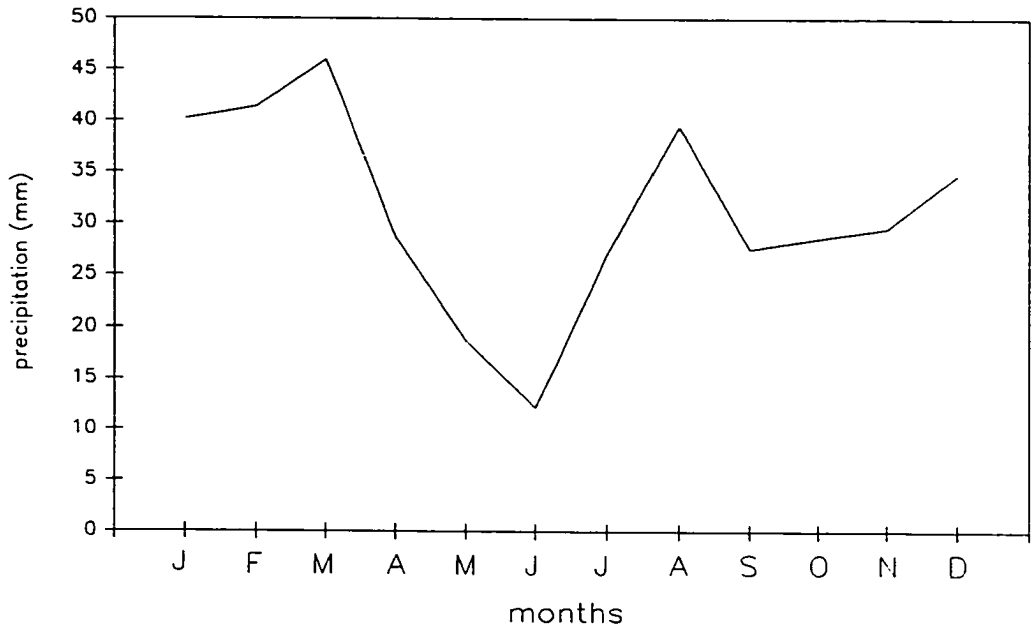

Figure 27. Mean monthly precipitation, Zion Canyon, UT, 1904-1991.

DISCUSSION

Nutritional value of the Zion Canyon mule deer diet, as evaluated by chemical analysis of major forage species and comparison of blood values with those of other mule deer populations, is adequate. Zion Canyon deer are exposed to at least 4 common livestock diseases, however, serum titer levels do not indicate a current infection. Prevalence of parasites, as determined by necropsies of 2 deer and eosinophil levels in 26 immobilized deer, is higher than reports in the literatu e for other mule deer populations. The recruitment rate for the herd is comparable to that of other healthy populations, indicating that parasitism is not significantly reducing reproductive ability. Mild weather conditions in the past decade may be affecting the age distribution of Zion Canyon deer by increasing the survivorship of older animals. In addition, older migratory animals may be remaining in the canyon all year in response to the mild weather conditions in the canyon, increasing the proportion of older animals in the canyon population.

Blood values obtained in this study are very similar to those of other studies of mule deer and white-tailed deer (*Odocoileus virginianus*). Although they are distinct species, blood values of mule deer and white-tailed deer are very similar. Since most controlled experiments to determine cause and effect relationships between blood values, nutrition, and diseases have been performed on captive white-tailed deer (Bahnak et al., 1979; Bubenik and Brownlee, 1987; Card et al., 1985; DelGuidice et al., 1987, 1990a; DeLiberto et al., 1989; Seal et al., 1972, 1978; Warren et al., 1981), these data are used in the interpretation of results from this study.

Serum chemistry

Serum chemistry can be a useful indicator of an animal's condition (Brown, 1984). However, several of the values have been shown to be affected by handling stress and immobilization drugs (Seal et al., 1972). As a result of these effects some values, such as glucose and creatine phosphokinase (CPK), have a wide range of "normal" values. The best a researcher

can hope to do is minimize stress to study animals and be consistent in collection procedures.

Glucose- Serum glucose levels are affected by the release of epinephrine when an animal is stressed by capture (Benjamin, 1978; Seal et al., 1972) and by the prandial state of the animal. Seal et al. (1972) found no correlation between diet quality and serum glucose levels. Mean glucose levels for deer maintained on different diets ranged from 132 to 164 mg/dl (Seal et al., 1972). In a study of white-tailed deer, Seal et al. (1978) found no difference between glucose levels of animals in four different habitats, but found that serum glucose decreased from November to April. This may be a reflection of a decline in diet quality or of habituation to handling, as the animals were captured 4 times each (Seal et al., 1978). The overall average glucose level of 23 deer sampled was 165 mg/dl, the same mean as obtained from the Zion Canyon deer.

Kie et al. (1983) measured glucose levels of deer maintained at two different population densities. Although the mean values were quite different, 145 mg/dl from the low density herd and 127 mg/dl from the high density herd, the variation within each herd was so great that the differences were not significant. Smith (1976) measured serum glucose levels in mule deer from three sites in Arizona and reported a range of means from 105.7 to 161.1 mg/dl. In winter and early spring, deCalesta et al. (1977) found a mean serum glucose concentration of 106.8 in 12 wild mule deer and of 126.5 and 125.8 mg/dl for 1972 and 1973, respectively, in captive mule deer.

Cautious interpretation of the serum glucose levels of wild animals is necessary. Although there were no significant differences between the effects (season, gender, and lapse of time from collection to laboratory) in Zion Canyon mule deer, there was a wide range of values (78 to 272 mg/dl). The overall average of serum glucose levels of Zion Canyon deer is within the range found in other studies, but conclusions about health of the animals cannot be made with this parameter.

Serum urea nitrogen- Serum urea nitrogen (SUN) has been shown to change seasonally with changes in dietary protein levels (Bahnak et al., 1979; Seal et al., 1978). Seal et al. (1978) reported a mean SUN of 14.0 mg/dl for adult white-tailed deer in the winter, similar to the winter value (14.3 mg/dl) found in Zion Canyon. Blood samples collected in the spring and fall in central Utah in 1968 and 1969 had ranges of mean SUN values from 10.2 to 17.3 mg/dl (Pederson, 1970). In northern Arizona, deer from three sites had mean SUN values between 14.4 and 29.8 mg/dl (Smith, 1976) and DeCalesta et al. (1977) found a mean SUN of 8.2 mg/dl in 12 wild mule deer and a range of means for two years from 17.7 to 23.9 mg/dl in captive mule deer. Wesson et al. (1979) investigated the effects of time of blood sampling after death and did not find a significant difference between SUN levels of blood collected at the time of collapse and 30 minutes after death. SUN levels of Zion canyon mule deer differed seasonally (Fig. 3) with the lowest level in the winter and the highest level in the spring, however all means were within the normal range for deer. The spring SUN concentration for Zion Canyon deer (25.0 mg/dl) is a reflection of the high protein content of their diet in that season.

Creatinine- Serum creatinine levels are used to estimate glomerulus filtration rate and to evaluate kidney function and are proportional to muscle mass. Kie et al. (1983) found a significant difference between serum creatinine levels of deer maintained at low densities (1.44 mg/dl) and of those at high densities (1.27 mg/dl). Waid and Warren (1984) collected blood from white-tailed deer bimonthly for one year and reported a range of creatinine concentrations from 1.44 to 2.12 mg/dl. Seal and Erickson (1969) reported serum creatinine levels for adult male and female white-tailed deer of 2.6 and 2.1 mg/dl, respectively. Although serum creatinine concentrations in Zion Canyon deer are lower than those found in other deer, the mean (1.2 mg/dl) is within the range expected for large mammals (Kaplan and Pesce, 1984). The low level in Zion Canyon deer may be a reflection of the high proportion of females in this sample in comparison to other studies with more equal proportions of the dimorphic sexes.

Sodium- Sodium (Na) reabsorption by the tubules of the kidneys is essential for the regulation of electrolytes in the blood (Kaplan and Pesce, 1984). Anderson et al. (1972a) reported no significant difference between male and female serum Na levels of 148.5 and 148.8 mEq/l, respectively. DelGuidice et al. (1990b) reported an average serum Na level of 149 mEq/l for 10 adult desert mule deer. Very similar values have been determined in studies of white-tailed deer (DeLiberto et al., 1989; Kie et al., 1983; Seal et al., 1978; Wilber and Robinson, 1958). The mean serum Na level in Zion Canyon deer was within the normal range for large mammals (Kaplan and Pesce, 1984; Kaneko and Cornelius, 1970).

Potassium- Serum potassium (K) concentrations have been shown to decrease in animals deprived of proper nutrition (Anderson et al., 1972a; DelGuidice et al., 1987). Mean serum K levels between 5.7 and 8.88 mEq/l have been reported for mule deer (Anderson et al., 1972a; DelGuidice et al., 1990b) and between 4.4 and 11.2 mEq/l for white-tailed deer (DeLiberto et al., 1989; Seal et al., 1978; Wilber and Robinson, 1958). The serum K average of Zion Canyon deer (4.95 meq/dl) indicates a diet sufficient in potassium.

Chloride- Factors that affect serum chloride (Cl) in mammals are the same as for sodium. Rohwer (1970) examined the blood of 370 mule deer from three sites in Nevada in winter and reported a range of means from 103.2 to 110.1 meq/l and Wilber and Robinson (1958) reported a Cl mean of 101 mEq/l in white-tailed deer. Seal et al. (1978) reported an average serum Cl level of 102.4 meq/l for 23 white-tailed deer examined over a 6 month period. The average serum Cl level of Zion Canyon deer (103.6 meq/l) falls within the range of values found in other studies.

Carbon dioxide- Serum levels of carbon dioxide are measured to evaluate the acid-base balance of the blood (Kaplan and Pesce, 1984). Few studies of deer serum chemistry report CO_2 levels,

perhaps because they are affected by handling stress and improper collection and storage of samples. Seal et al. (1978) reported a mean serum CO_2 value of 21.2 meq/l in adult white-tailed deer in the winter, lower than found in Zion Canyon deer (31.2 mEq/l). The paucity of studies presenting "normal" CO_2 levels in mule deer blood precludes any judgement of the levels found in Zion Canyon deer. The values are reported here for future comparisons.

Anion gap- Additional anions that are not directly measured in the blood can be estimated by the anion gap, a calculation of the measured cations minus the measured anions. This measurement is used to track the acid-base status of the blood (Kaplan and Pesce, 1984). The overall mean anion gap in Zion Canyon deer (12.3 mEq/l) falls within the normal range for mammals as reported by Kaplan and Pesce (1984).

Osmolality- Osmolality is a colligative property, affected by the seasonal differences in all the ions of the blood and the overall mean value for osmolality (289.4 mos/kg) falls within the range of normal values for mammals as reported by Kaplan and Pesce (1984).

Phosphorus- Serum phosphorus (P) concentrations are frequently measured for indications of mineral deficiencies (Benjamin, 1978). Pederson (1970) studied serum chemistry of mule deer in the La Sal and Henry Mountains of central Utah and reported mean values for 1968 and 1969 from the La Sal Mountains of 11.11 and 9.81 mg/dl, respectively and 12.54 and 9.45 mg/dl for the Henry Mountains in 1968 and 1969, respectively. Rohwer (1970) found a serum P level of 6.4 mg/dl in wintering Nevada mule deer and Hunter (1973) reported an overall value of 5.25 mg/dl from Nevada mule deer collected in the winter, with a decrease in P in older animals. Mean serum P values from 7.2 to 10.4 mg/dl have been reported in mule deer in Colorado and Arizona (Anderson et al., 1972a; DelGuidice et al., 1990a; Smith, 1976).

Mean serum P values between 4.96 and 9.8 mg/dl have been reported for white-tailed

deer (DeLiberto et al., 1989; Kie et al., 1983; O'Brien et al., 1974; Seal et al., 1978; Waid and Warren, 1984). This range of values may reflect the tendency for phosphorus levels to elevate with stress and excitation (DelGuidice et al., 1990a).

Serum P levels in Zion Canyon mule deer (5.4 mg/dl) may indicate a minor deficiency. However, other factors, such as ability to repair fractured bones and high reproductive rates (discussed in another section), indicate that this deficiency is probably not significant.

Calcium- Serum calcium levels are used to indicate insufficient calcium in the diet or disorders involving absorption of the mineral (Kaplan and Pesce, 1984). Rohwer (1970) and Hunter (1973) found that Ca levels differ between the sexes. The mean serum Ca level in 217 female mule deer in Nevada in the winter of 1969 was 10.4 mg/dl and the mean in 130 males was 10.1 mg/dl (Rohwer, 1970). Hunter (1973) also found female Nevada mule deer to have higher Ca levels than males with 12.5 mg/dl in 261 females and 12.1 mg/dl in 211 males. Hunter (1973) also found a slightly higher value for serum Ca in deer over 9 yrs. old, however, Rohwer (1970) and Anderson et al. (1972a) have reported decreases in Ca levels with older animals. Smith (1976) examined mule deer from three sites in Arizona and found a range of Ca means from 9.37 to 10.45 mg/dl and DelGuidice et al. (1990b) reported a serum Ca mean of 10.1 mg/dl in Arizona mule deer. Serum calcium values found in Zion Canyon mule deer fall within the expected range for large mammals (Kaplan and Pesce, 1984) and are only slightly lower than those found in other mule deer studies. Calcium, like potassium, can be elevated in the blood by excitation, and the differences found in these studies may be attributable to differences in capture techniques.

Protein- Serum protein concentration is not considered a good measure of nutritional status (Brown, 1984), however, it can be an indicator of numerous diseases and disorders (Benjamin, 1978). Pederson (1970) found mean serum protein values of 6.87 and 5.18 g/dl from mule deer of the La Sal Mountains and 6.65 and 6.85 g/dl from the Henry Mountains of central Utah in

1968 and 1969, respectively. Anderson et al. (1972b) reported a mean of 6.02 g/dl in 70 mule deer in Colorado and Smith (1976) reported a range of serum protein means from 6.64 to 7.59 g/dl from three sites in Arizona.

Reported serum protein values in white-tailed deer range from 5.9 to 7.2 g/dl (Seal et al., 1978; Waid and Warren, 1984). A wide range of serum protein concentrations is possible in healthy deer populations, and the concentration found in blood from Zion Canyon deer (6.2 g/dl) is not unusual.

Albumin- Albumin concentrations in the blood reflect liver functions, low levels indicating liver disease or malnutrition (Benjamin, 1978). Rohwer (1970), studying mule deer in three areas of Nevada, found a range of albumin levels from 3.87 to 4.42 g/dl, however Hunter (1973), studying deer in the same area, found an overall average of 2.34 g/dl. Mule deer from the La Sal and Henry Mountains in central Utah had a range of serum albumin levels over a two year period from 1.28 to 1.82 g/dl (Pederson, 1970). Smith (1976), studying mule deer on three sites in Arizona, found a range of serum albumin means from 2.56 to 2.98 g/dl. Mean serum albumin in Zion Canyon mule deer (3.0 g/dl) falls within the range of values found by other researchers.

Globulin- Abnormal serum globulin concentrations can indicate liver disease, liver damage, or an infectious disease (Benjamin, 1978). In wintering Nevada mule deer Rohwer (1970) found globulin levels differed by age of the animals, from 2.13 to 2.46 g/dl, with the lowest value found in the youngest age class. Hunter (1973) studied deer in the same area and found an overall value of 3.45 g/dl, with an age dependent trend similar to that found by Rohwer (1970). Smith (1976) found a range of serum globulin means from 3.36 to 5.13 g/dl from three sites in Arizona. In white-tailed deer, values between 1.2 and 4.2 have been reported (Seal et al., 1978,; Waid and Warren, 1984). The overall mean globulin concentration found in blood sampled from Zion Canyon deer (3.3 g/dl) falls within the range of values found by other researchers.

Bilirubin- Serum bilirubin concentration is the result of the destruction of senescent red blood cells (Benjamin, 1978) and a low bilirubin level, such as found in the Zion Canyon deer (0.2 mg/dl) is an indicator of healthy liver function. Smith (1976) reported a range of mean total bilirubin values from 0.47 to 0.72 mg/dl from Arizona mule deer. Kie et al. (1983) reported a range of means from 0.21 to 0.24 mg/dl from white-tailed deer kept at two population densities. They found no significant difference in bilirubin levels of those maintained at a high density and those at a low density of individuals.

Alkaline phosphatase- Alkaline phosphatases are enzymes that play an important role in the transportation of sugars and phosphates and abnormal levels can indicate functional impairment of the liver (Benjamin, 1978). Simeson (1970) reviews the literature on alkaline phosphatase activity in domestic animals and reports a great deal of variation within a species, but not in individuals. Pederson (1970) reported alkaline phosphatase levels ranging from 93.7 to 246.9 IU/l. The wide range of values found by Pederson illustrates how diverse the results can be.

Smith (1976) reported a range of alkaline phosphatase means from 53.5 to 133.2 in mule deer from three sites in Arizona. Kie et al. (1983) studied adult white-tailed deer kept at two population densities, high and low and found alkaline phosphatase levels of 67 and 107 IU/l respectively. The bimonthly average for each group ranged from low in the 30's in the winter to well above 100 in the summer. Seal et al. (1978) reported a mean value of 37 IU/l alkaline phosphatase for adult white-tailed deer in the winter and 142 units/l for white-tailed fawns. These ranges of values demonstrate the difficulty in interpreting the alkaline phosphatase values. Although the levels in Zion Canyon deer differ by gender (Fig. 4), the values for males range widely, and the results are inconclusive.

Aspartate aminotransferase- Aspartate aminotransferase (AST), also known as serum glutamic oxalacetic transaminase (SGOT), is an essential enzyme in the formation of oxalacetic and

glutamic acids from aspartic and alpha-ketoglutaric acids. Serum AST level may be increased by muscle damage, liver damage, or physical stress (Benjamin, 1978; Seal et al., 1972). Seal et al. (1972) examined blood collected from white-tailed deer maintained on different quality diets and found a range of AST values from 58 to 79.7 IU/l in captive deer and a range from 84 to 581 IU/l in wild deer. The extremely high values in the wild deer were attributed to handling stress. Seal et al. (1978) examined 23 adult white-tailed deer and found a mean of 97 IU/l and Kie et al. (1983) found no difference between deer maintained at two population densities, high and low, and found no significant difference between the AST values (168 and 132 IU/l respectively).

In the La Sal Mountains of central Utah, Pederson (1970) found mule deer AST concentrations of 183 and 113 IU/l for 1968 and 1969, respectively and 149 and 138 IU/l in mule deer from the Henry Mountains in 1968 and 1969, respectively. In Zion Canyon, the serum AST concentrations in individual deer varied considerably, from to , however the mean (59.3 IU/l) is within the range of values found by other researchers.

Creatine phosphokinase- Creatine phosphokinase (CPK) is essential in the process of regenerating ATP molecules from ADP and it is elevated in cases of tissue destruction caused by physical and emotional stress (LeResche et al., 1974). CPK is also affected by storage procedures, decreasing until samples are frozen. Seal et al. (1972) reported a range of mean CPK values from 38 to 223 IU/l in white-tailed deer. Seal et al. (1978) collected serial blood samples from 23 white-tailed deer and reported highly variable means. DelGuidice et al. (1990b) reported a mean CPK of 258 IU/l in desert mule deer in winter, with individual values ranging from 117 to 414 IU/l.

CPK values in this study ranged from 21 to 811 IU/l. Because the serum was not always frozen within 24 hours after collection the CPK mean presented here should be used with caution.

Gamma-glutamyl transferase- Serum gamma-glutamyl transferase (GGT) is essential to the

resorption of amino acids in the kidneys. High serum GGT concentrations are usually caused by liver disease (Kaplan and Pesce, 1984). Means reported by Kie et al. (1983) from adult white-tailed deer maintained at two population densities varied from 62.8 IU/l (low density) to 67.2 IU/l (high density), but the difference was not significant. The GGT mean of 57.7 IU/l in Zion Canyon deer is quite similar to that found by Kie et al. (1983).

Amylase- Amylase is produced in the pancreas, liver, intestinal mucosa, and salivary glands. An increased serum amylase level may indicate a pancreatic or liver disease (Benjamin, 1978). Serum amylase values are not commonly reported for wildlife (Brobst, 1970) and the values for Zion Canyon mule deer are reported here for future comparisons.

Lipase- Most serum lipase is produced in the pancreas, elevated levels indicating pancreatic disease (Benjamin, 1978; Brobst, 1970). Like serum amylase, serum lipase values are not commonly reported in studies of wildlife, and values for Zion Canyon deer are reported here for future comparisons (Fig. 5).

Cholesterol- As previously discussed, serum cholesterol has been examined as a potential indicator of nutritional condition (Card et al., 1985; Coblentz, 1975; DelGuidice et al., 1987; Seal et al., 1972; Waid and Warren, 1984; Warren et al., 1981). It has not been found to reflect diet quality, except in extreme cases of starvation (DelGuidice et al., 1987 and 1990a), however it may reflect seasonal changes in thyroid hormone production (Card et al., 1985). Most of the serum cholesterol is produced by the liver; therefore it also may be used as an indicator of proper liver function.

Serum cholesterol level has been reported in a number of studies of white-tailed and mule deer. DelGuidice et al. (1990a) studies the effects of undernourishment on the serum cholesterol levels of captive white-tailed deer. They found an increase in cholesterol levels after

several weeks of severe undernourishment. Serum cholesterol levels increased from 40.5 to 59.8 mg/dl after 16 weeks on a low energy-low protein diet (DelGuidice et al., 1990a). DelGuidice et al. (1987) found an increase in cholesterol levels in deer that were fasted with an increase in mean cholesterol concentration from 37.8 to 63 mg/dl in 4 weeks of fasting. The cholesterol level returned to normal after feeding resumed. This response has been attributed to hypothyroidism affecting lipid metabolism (DelGuidice et al., 1987, 1990a). In wintering Nevada mule deer from three sites, Rohwer (1970) found a range of serum cholesterol values from 85.1 to 96.9 mg/dl in 1969 and Hunter (1973) found an overall mean of 101.8 mg/dl in 1970.

Serum cholesterol levels may be artificially elevated by collection and storage procedures. Collecting blood from immobilized animals, as opposed to hunter kills, and transporting or freezing the serum within 24 hours produces a more stable set of values for cholesterol. It is more likely that the lower values, from 40 to 70 mg/dl are the correct "normal" values for mule deer serum cholesterol (G. DelGuidice, personal communication). More work has been done on white-tailed deer serum chemistry, and cholesterol levels for white-tailed deer tend to be in this low range (DeLiberto, 1989; DelGuidice et al., 1990b; Seal and Erickson, 1969; Seal et al., 1978; Waid and Warren, 1984). The overall mean cholesterol level in blood from Zion Canyon deer (43.5 mg/dl) falls within the range predicted for healthy ungulates as found by other researchers.

Triglycerides- As for cholesterol, serum triglyceride concentration has been found to be affected by hypothyroidism caused by starvation. DelGuidice et al. (1987) reported an increase in triglyceride levels from 29.8 to 56.5 mg/dl in 4 weeks of fasting. DelGuidice et al. (1990a) reported an increase in triglycerides, from 18.2 to 54.7 mg/dl, when deer were kept on a low-energy low-protein diet for 16 weeks. The overall serum triglyceride mean for Zion Canyon mule deer (9.9 mg/dl) is lower than that found in other studies, most likely for the same reasons given for cholesterol: collection and storage differences.

Magnesium- Serum magnesium deficiencies are usually associated with calcium deficiencies and like calcium, a magnesium deficiency is usually caused by poor diet (Kaplan and Pesce, 1984). Rohwer (1970) found a range of serum magnesium levels in wintering Nevada mule deer that differed by age from 1.9 to 2.5 meq/l, the lowest values found in the oldest animals. Anderson et al. (1972a) reported no significant difference between serum Mg levels of 3.11 and 3.34 mEq/l in male and female mule deer, respectively and Seal et al. (1972) found no significant difference in the serum magnesium levels (2.23 to 2.74 meq/l) of deer on different diets. The seasonal means for Zion Canyon deer (Fig. 6) fall within the range found by other researchers. A Bonferroni range test revealed that winter and fall means differ from spring and summer means. These differences may be due to dietary changes or to the small sample size.

Iron- Serum iron is important for the transport of oxygen and electrons and deficiencies are usually accompanied by decreases in hemoglobin and hematocrit values (Fowler, 1986). Perhaps because iron deficiencies can be detected through hemoglobin and hematocrit values serum iron values are not often reported in studies of deer. Seal and Erickson (1969) reported serum iron values for male and female adult white-tailed deer as 234 and 228 μg/dl, respectively. The low serum iron concentration of Zion Canyon mule deer (150.5 IU/l), along with low hemoglobin concentration and hematocrit (as discussed in the next section) indicate a mild anemia (Benjamin, 1978; Kaplan and Pesce, 1984).

The mild anemia is most likely caused by parasitism. As discussed in the following section, eosinophil levels in 21 out of 25 blood samples were higher than normal. Necropsies of two animals revealed low levels of parasitism. Other serum chemistry values are indicative of healthy deer.

Hematology

Leukocytes (White blood cells)- The total white blood cell (WBC) count can be elevated by

handling stress, increased blood flow causing a decrease in WBC margination. It also can be an indicator of infection: viral, bacterial, rickettsial, or protozoan. Mean WBC counts from 3.0 to 3.9 $10^3/\mu l$ have been reported for mule deer (Anderson et al., 1970; Browman and Sears, 1955; DelGuidice et al., 1990b). Although seasonal mean WBC counts in this study ranged from 2.4 $10^3/\mu l$ in the winter to 4.6 $10^3/\mu l$ in the summer, the means did not differ significantly. The overall mean value (3.5 $10^3/\mu l$) is quite similar to that found in other studies.

Neutrophils- Neutrophils, one type of white blood cell, are associated with inflammations due to injury or infections. They act to engulf and phagocytize bacteria and other foreign particles (Benjamin, 1978). Neutrophil levels of Zion Canyon mule deer varied seasonally (Fig. 7), with the spring mean value lower than those of other seasons. Anderson et al. (1970) reported a mean neutrophil concentration of 40.6% in 176 mule deer in Colorado. In a study of captive white-tailed deer, those with no known infections had a mean neutrophil level of 65.3%, and a group with chronic infections had a mean neutrophil level of 38.5% (Bubenik and Brownlee, 1987). Neutrophil levels in Zion Canyon deer (Table 2) are comparable to those found in other free-ranging populations (Anderson et al., 1970) and are inconclusive for a diagnosis.

Lymphocytes- There are two major types of lymphocytes: T and B lymphocytes. T lymphocytes initiate cell-mediated immune responses, and B lymphocytes are the precursors to plasma cells that produce immunoglobulins (Benjamin, 1978). Lymphocyte concentration in the blood of Zion Canyon mule deer varied seasonally (Fig. 8), with the spring mean value being higher than those of the other seasons. Anderson et al. (1970) reported a mean lymphocyte concentration of 43.4% for 176 Colorado mule deer. In a study of captive deer, healthy white-tailed deer had a mean lymphocyte concentration of 29.2%, and those with chronic infections had an elevated mean of 56.1% (Bubenik and Brownlee, 1987). The spring lymphocyte mean of 56% for Zion Canyon deer appears to be pathologically high. Lymphocytes interact with eosinophils in combating

parasitic infestations (Schalm, 1986). The winter and spring samples may be elevated by animals succumbing to infestations during the winter months.

Eosinophils- Eosinophils have a phagocytic ability, more limited than that of neutrophils. A more unique function of eosinophils is their interaction with lymphocytes to kill parasites. Healthy, adult animals are expected to have an eosinophil level below 10 % (Fowler, 1986) and a higher level is associated with parasitic infections and allergic reactions to proteins produced by parasites (Schalm, 1986). Anderson et al. (1970) examined the blood of 176 mule deer and reported an eosinophil range from 0 to 41.0 % with a mean of 8.3 %. The age of the deer sampled ranged from 1 month to 13.5 years, with an average of 3.7 years. Bubenik and Brownlee (1987) reported a range of eosinophil values for healthy white-tailed deer adults from 2.6 to 6.4 %. The high eosinophil level found in the Zion Canyon mule deer (mean=21.0 %, with only four animals below 10 %) indicated parasitic infections in most of the animals (Benjamin, 1978; Schalm, 1986).

Erythrocytes (Red blood cells)- Red blood cells (RBC) are the vehicles by which respiratory gases are transported to and from the cells. RBC counts from 8.7 to 13 $10^6/\mu l$ have been reported for mule deer (Anderson et al., 1970; Browman and Sears, 1955; DelGuidice et al., 1990b; Rosen and Bischoff, 1952). The overall mean in this study (7.00 $10^6/\mu l$) is low, but the RBC indices, MCV and MCH, are in the normal range (Kaplan and Pesce, 1984).

Hemoglobin- Hemoglobin is the oxygen carrier of the red blood cell, and a measure of its weight in the plasma indicates the health of the animal and its access to iron. Hemoglobin values from 12.8 to 21.1 g/dl have been reported for mule deer (Browman and Sears, 1955; DelGuidice et al., 1990b; Rohwer, 1970). Mean hemoglobin in Zion Canyon deer (Table 2) is lower than means from other studies and, together with low serum iron values (Table 1), indicates an iron deficiency.

Hematocrit- The percentage of the blood volume that is red blood cells is the hematocrit value, also reported as the packed cell volume (PCV). Reported hematocrit values range from 24.0 to 52.7 % in mule deer (Anderson et al., 1970; Browman and Sears, 1955; Kie et al., 1983; Rohwer, 1970; Rosen and Bischoff, 1952). Rohwer (1970) reported a range of means from 48.2 to 52.7 % for mule deer in Nevada. The lowest mean was obtained from animals over 9 years of age. Kie et al. (1983) also found a lower mean hematocrit value in adults than in fawns. Hematocrit mean value of Zion Canyon deer (30.6 %) is lower than the means of most other mule deer studies, supporting the low hemoglobin and low serum iron indications of an iron deficiency (Benjamin, 1978; Kaplan and Pesce, 1984).

Mean corpuscular volume- There are several indices by which hemoglobin content is measured in relation to red blood cell volume and number. The mean corpuscular volume (MCV) measures the average volume of the red blood cells (Benjamin, 1978). Reported MCV values in mule deer range from 37.0 to 52.8 femtoliters (fl) (Anderson et al., 1970; DelGuidice et al., 1990b). DelGuidice et al. (1990a) reported a range of means in captive white-tailed deer from 30.5 to 34.2 fl and Seal et al. (1978) found an average MCV of 41.7 fl in 23 white-tailed deer. The MCV mean for this study (43.1 fl) falls within the range reported by other researchers.

Mean corpuscular hemoglobin- Mean corpuscular hemoglobin (MCH) is the average amount of hemoglobin, by weight, in a red blood cell (Benjamin, 1978). DelGuidice et al. (1990b) reported a mean MCH of 14 picograms (pg) in desert mule deer. DelGuidice et al. (1990a) examined white-tailed deer blood and reported MCH mean values from 11.5 to 13.7 pg. The overall mean value in this study (16.2 pg) is higher than that found in other studies of deer, however not enough data on deer have been reported on which to base conclusions. The values may have been elevated by handling procedures in the field.

Mean corpuscular hemoglobin concentration- As a measure of the concentration of hemoglobin in the red blood cell, mean corpuscular hemoglobin concentration (MCHC) is more commonly reported in the literature than is MCH. Average MCHC values reported for mule deer range from 35.1 to 37.7 g/dl (Anderson et al., 1970; DelGuidice et al., 1990b) and from 33.6 to 38.0 g/dl for white-tailed deer (Seal et al., 1972, 1978; Seal and Erickson, 1969). As illustrated in Figure 9, the MCHC values in this study varied by season, however all the seasonal means fall within the range of values reported by other researchers.

Fibrinogen- Fibrinogen is a plasma protein, important in the coagulation process and in the isolation of diseased tissues. An increase in the plasma fibrinogen level can be the result of tissue injury or inflammation, whereas a decrease may indicate liver disease or a clotted sample (Benjamin, 1978). Seal et al. (1972) reported plasma fibrinogen values in white-tailed deer from 166 to 325 mg/dl. Seal et al. (1978) found fibrinogen levels in deer of different habitats did not differ significantly. Mean fibrinogen in Zion Canyon deer (256.0 mg/dl) is within the expected range as reported by other researchers.

Hematocrit, hemoglobin, and serum iron values of Zion Canyon mule deer indicate a mild anemia. Other hematological values are indicative of healthy deer.

Diseases

Domestic sheep, cattle, and horses are pastured on the southern boundaries of Zion Canyon. Deer have access to these pastures and are exposed to vectors of disease, such as ticks and lice. Coyotes, foxes, mountain lions, and domestic cats and dogs are found within the range of Zion Canyon deer. These carnivores are essential to the transmission of many parasites between livestock and deer.

Antibody titer levels change over time and differ among individuals of a population and conclusions cannot be drawn about the status of diseases in populations of wild animals from

single blood tests. Repeated sampling of individuals is the only conclusive, non-destructive method for confirming an infection, however the location of the Zion Canyon herd within a National Park and the difficulties involved in immobilization made serial sample collection unfeasible.

Titer levels to infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD), and respiratory syncytial virus (RSV) (Table 3) indicate Zion Canyon deer may have been exposed to these viruses sometime in their lives, but not recently. The high titer levels to PI-3, 62% of samples tested were between 1:10 and 1:160, which can indicate an infection, but without serial tests of these individual deer we can only conclude exposure. PI-3 is common in domestic sheep and may be transmitted to wild ruminants. The effects of PI-3 on deer are unknown, but the disease can be very detrimental to bighorn sheep populations. Lung and liver samples taken from two Zion Canyon deer in October, 1991, were negative for antibodies to all four viruses (Table 3), but the sample size is far too small to conclude the population is not affected by exposure to PI-3.

Many studies have focused on these four viruses because deer readily adapt to use of ranges with cattle and sheep. How much deer are affected by livestock diseases and if they can act as reservoirs for reinfection of livestock is of interest to range and livestock managers. Stauber et al. (1977) found 95% of mule deer examined in south central Idaho tested positive for antibodies to PI-3. In the same study, 29% and 91% tested positive for antibodies to BVD and IBR, respectively. Couvillion et al. (1980) found 34% of mule deer tested in New Mexico had antibodies to BVD (titers $\geq$ 1:16), whereas 29% of mule deer tested in Nebraska had antibodies to RSV (Johnson et al., 1986).

Although the card test has produced false positive results for anaplasmosis in mule deer (Peterson et al., 1973), none of the 16 deer tested in this study reacted to the serological test. Merrell and Wright (1978) tested 111 mule deer in Utah and reported no positive results. Thirty four percent of the mule deer sampled by Behymer et al. (1989) tested positive for antibodies to

anaplasmosis, using the ELISA procedure. Waldrup et al. (1989) examined 20 mule deer and found 6 tested positively for antibodies to anaplasmosis. Serum from Zion Canyon deer did not test positively for toxoplasmosis, compared to 20 % prevalence in one California mule deer population (Franti et al., 1975) and 12 % in another California population (Behymer et al., 1989).

Although only 16 serum samples were tested for antibodies to diseases in this study, the nearly complete absence of reactions to the tests (Table 3) is surprising. Zion Canyon deer are not isolated from other deer populations or livestock. Seasonal migrations of deer from the surrounding plateaus, where cattle and domestic sheep are grazed, are expected to expose canyon deer to pathogens carried by migrating deer. Deer are frequently seen in the town of Springdale, where cattle, horses, sheep, and domestic cats and dogs are numerous. Despite this exposure, it appears disease is not playing a major role in the health and population dynamics of Zion Canyon deer. The titer levels found in Zion Canyon mule deer are unusually low for animals sympatric with livestock.

Parasites

The removal of animals from the population for internal parasite studies was limited by park policy and population size. At the time of collection, October, 1991, migratory deer had not yet entered the canyon and fewer than 75 animals were in the study site and all adults were female. It was decided that collection of a significant sample size could be detrimental to the breeding population. The hematology of the population sample is very indicative of parasitic infections, and it was hypothesized that animals with high eosinophil levels (>10.0 %) were reacting to a parasitic infection.

Four species of internal parasites were found in two necropsied deer. Cysticeri of *Taenia* spp. are common in mule deer (Kie et al., 1984; Olsen and Williams, 1959; Pybus, 1990; Stubblefield et al., 1987; Worley and Eustace, 1972). The *Taenia* spp. found in Zion Canyon mule deer are dependent upon carnivore hosts for the sexual phase of their life cycles (Davies,

1981; Klein, 1965; Marchiondo et al., 1986; Olsen and Williams, 1959).

Olsen and Williams (1959) shot five deer randomly on a range in Colorado and found tapeworm cysticeri (*T. krabbei*) in all of them, whereas Kie et al. (1984) found 68 and 81% of black-tailed deer in two herds in California were infected with tapeworms cysts. Prevalences as low as 13 and 14% also have been reported in mule deer populations (Boddicker and Hugghins, 1969; Pybus, 1990; Worley and Eustace, 1972). Intensities of *T. krabbei* and *T. hydatigena* cysticeri infections in mule deer tend to be low, between 1 and 15 cysts per individual (Kie et al., 1984; Klein, 1965) and the level of infection found in Zion Canyon mule deer was thus not unusual.

Mule deer are natural hosts to many species of nematodes (Eve and Kellogg, 1977; Klein, 1965; Worley and Eustace, 1972). Intestinal nematodes occur with high prevalence in deer, however none were found in two deer necropsied in this study. Fecal samples of 25 deer, collected during immobilization for blood collection, also were negative for intestinal parasites.

Elaeophora schneideri, an arterial nematode, was recovered from one of the two deer examined. Mule deer are the natural definitive hosts to *E. schneideri*, but the parasite is also found in elk, white-tailed deer, moose, and domestic sheep (Georgi, 1969; Hibler and Adcock, 1968). This parasite has been recovered from other mule deer populations in Utah, though at very low prevalences (Jensen et al., 1982; Pederson et al., 1985).

Sarcocystis hemionilatrantis is a parasitic protozoan common in the muscles of herbivores and transmitted via canids (Dubey et al., 1983; Dubey and Kistner, 1985; Speer et al., 1980). Sarcocystis has been found in many sppecies of ungulates. Although sympatric populations of deer, sheep, and cattle may be infected by sarcocystis, the degree of transmission between domestic and wild herbivores is not well understood (Hudkins-Vivion et al., 1976; Prestwood et al., 1976). The occurrence of sarcocystis in mule deer in Zion Canyon was expected, as prevalence of sarcocystis infection has been reported from 68 to 100% in mule deer populations throughout the western U.S. and Canada (Dubey and Kistner, 1985; Dubey and Speer, 1985;

Emnett and Hugghins, 1982; Mahrt and Colwell, 1980; Pond and Speer, 1979; Sayama, 1952).

In one Utah mule deer population 100% of deer examined were infected with bot fly larvae (McMahon and Bunch, 1989) and infestations have been reported in other areas (Cogley, 1987). Infestation of bot fly larvae in Zion Canyon mule deer was anticipated, but was not observed in either animal necropsied.

Hematological results indicate a parasitic infestation in Zion Canyon mule deer. Necropsies of two adult deer recovered 6 species of parasites, all of which are naturally occurring in mule deer, however intensities of individual species of parasites were not severe. The level of parasitism observed in this population is probably the cause of high eosinophil and low iron levels in the blood.

Ectoparasites, such as ticks and lice, are common on mule deer and heavy infestations can cause anemia (Jellison and Kohls, 1938). The tick species found on Zion Canyon mule deer also has been found on mule deer in north and central Utah (Coffey, 1954) and in most other western states (Walker and Becklund, 1970). The prevalence of ticks on Zion Canyon mule deer (62%) is likely contributing to the mild anemia observed in the blood analysis.

Fecal nitrogen

Fecal nitrogen in Zion Canyon mule deer was highest in April, corresponding to spring growth of major forage species. Although no significant difference was found fecal nitrogen levels between sites or years, more similar trends were seen between sites within years than between years within sites (Fig. 10). Although monthly data are not available for serum urea nitrogen and dietary crude protein, Figure 25 illustrates the correspondence between these parameters. Diet composition in upper and lower canyon sites does not overlap 100%, but fecal nitrogen data support the conclusion that they are not significantly different.

Diet composition

O.C. Wallmo, U.S. Forest Service wildlife biologist and authority on black-tailed and mule deer, summarized the difficulties of determining diet composition of such adaptable herbivores with the statement, "The list of foods that they can eat seems to be limited only by the persistence of the investigators" (Wallmo, 1978). Mule deer diets vary considerably between habitat types. The variety of habitats to which mule deer can adapt is apparent in the summary of ungulate diets by Van Dyne et al. (1980). Although a great deal of variation in use of forage classes exists, there are general seasonal trends to mule deer diet composition. In pinyon pine - juniper habitat, mule deer diet composition is dominated by browse species in all seasons (Anderson, 1965; Boeker et al., 1972; Hansen and Dearden, 1975). Winter diets are composed more of shrubs and grasses than forbs. Spring diet composition is more evenly distributed between the three forage classes, with shrubs still the most important. Summer and fall diets are dominated by shrubs and forbs (Van Dyne et al., 1980). Dietary trends reflect both phenology and changes in nutritional value of forage plants.

In this study, diet composition was determined by observation of feeding behavior and fecal analysis. Deer consumed several plants species during observations which were not observed in fecal material. These discrepancies are noted in Table 4.

Tree leaves composed the highest percentage, by forage class, of mule deer diets in every season in two years and 19 out of 24 months. Deer were observed eating fallen leaves in every month. Box Elder (*Acer negundo*) and Fremont Cottonwood (*Populus fremontii*) branches, broken during storms, were quickly denuded of leaves and a distinct browse line exists on hackberry (*Celtis reticulata*) and junipers (*Juniperus osteosperma* and *J. scopulorum*) in the canyon. Geist (1990) is one of few authors who have noted heavy use of dried *Populus* spp. leaves by mule deer. Dried Balsam Poplar (*Populus balsamifera*), a major winter food source for Canadian mule deer studied by Geist, were nosily consumed, much as *P. fremontii* leaves are by Zion Canyon mule deer.

Shrubs were second in importance among forage classes for Zion Canyon mule deer. Dominant shrubs in the diet were Rabbitbrush (*Chrysothamnus nauseosus*), Big Sagebrush (*Artemisia tridentata*), Shrub Oak (*Quercus turbinella*), and Four-winged Saltbush (*Atriplex canescens*). Serviceberry (*Amelanchier utahensis*), Blackbrush (*Coleogyne ramosissima*), and Three-leaved Sumac (*Rhus aromatica*) were consumed seasonally (Tables 5 and 6).

Shrub use was highest in summer and lowest in fall in 1990 and highest in spring and lowest in winter in 1991. However, in both years, monthly use was highest in April and lowest in March (Fig. 12). The nearly 5 fold increase in use from March to April coincides with spring growth of shoots. New growth of shrubs is most palatable in early spring, before becoming lignified (Deitz, 1972).

Perennial herbs never composed more than 9% of mule deer diets, as determined by fecal analysis (Fig. 13). Use was highest from May through September in 1990 and from May through July in 1991. Below average precipitation from June through September, 1991 was probably limiting the availability of forbs, whereas 1990 had above normal precipitation in June and July. A similar trend is seen in deer use of annual forbs, a higher use from June through August in 1990 than 1991. As previously described Zion Canyon has been disturbed by farming and grazing. The slopes are now dominated by shrubs and the floodplains by trees and grasses. Even during the summer peak in plant growth, annual forbs do not comprise a high percentage of the vegetation of Zion Canyon, so it is not surprising that mule deer diet composition is not high in annual forbs.

Highest use of grasses occurred in April in both years, when deer consumed early growth of Ripgut grass (*Bromus diandrus*), Blue Wildrye (*Elymus glaucus*), and Muttongrass (*Poa fendleriana*). Because of mild temperatures and moist conditions in winter, *Bromus* sprouts and dominates the Virgin River floodplain. Deer were observed eating *Bromus* in every month except August. Even after awns had developed on the seeds, deer ate the green blades. Several deer were observed with abscesses on their cheeks and throats, possibly caused by *Bromus* seeds

or those of other awned grasses, such as foxtail (*Hilaria jubatum*). In January and February deer consumed *Poa fendleriana*, a very palatable bunchgrass and few plants of this species could be found that were not clipped to within 2 cm. of the ground.

Forage preference

Unfortunately, forage preference analysis was possible only for shrub and tree species. Zion Canyon mule deer distinctly preferred or avoided most species (Table 7 and 8). This finding supports the classification of deer as selective browsers.

Zion Canyon mule deer may be unusual in their preference for dry cottonwood leaves. Although preference analysis has shown avoidance for some species, such as shrub live oak, it should be noted that these species can make up a large portion of the diet, but are so abundant in the canyon that preference analysis concludes that deer avoid them.

Nutrition

Nutritional value of an herbivore diet is difficult to evaluate because minimum levels of many nutritional components essential to their diet have not been established. Although 7% crude protein is accepted as the minimum requirement for ungulates, many wild populations drop below that in dietary intake seasonally, resulting in catabolism of stored energy. Other complicating factors include the presence of secondary compounds in plants, which may bind with protein, rendering it unavailable to herbivores. How much dietary protein is affected by this is very difficult to ascertain as some herbivores, including mule deer, have the ability to minimize the loss of protein with digestive chemicals that bind with and inactivate the secondary compounds (Robbins et al., 1987b).

Although the detergent fiber method for measuring nutritional value of forage has been criticized (Gauthier et al., 1991; McArthur, 1988), it has become a standardized technique to compare populations and available alternative methods are also subject to error and are costly

(Hobbs et al., 1983; Spalinger et al., 1986). No matter what method of analyzing plant samples is used, resulting nutritional values must be interpreted cautiously. It is difficult to mimic browsing accurately when collecting plant samples. It is very likely deer are able to minimize consumption of less nutritious plant parts, so lignin and fiber values may be higher in tissue samples collected by researchers than the tissues actually consumed by deer.

The Zion Canyon mule deer diet is nutritionally adequate according to our current understanding of ungulate nutrition. High percentages of cellular carbohydrates and proteins indicate a high quality diet. In comparison to nutritional values for mule deer in central Colorado, Zion Canyon mule deer have a more stable diet (Wallmo et al., 1977). This may be the result of milder seasonal differences in Zion Canyon or of the deer's ability to change diet selection to compensate for seasonal changes in quality of forage species. The Zion Canyon mule deer diet is nutritionally comparable to that found for mule deer in other areas of the west (Bartmann, 1983; Leslie and Starkey, 1984; Sowell et al., 1985; Urness et al., 1971).

Herd composition and reproduction

Although parturition is expected to be synchronized with the increasing temperatures and vegetation growth of spring (Bischoff, 1957), recent research has revealed that proper nutrition in the last few months of gestation may delay parturition (Bowyer, 1991; Leopold and Krausman, 1991). Earlier mild temperatures in southern Utah are expected to lead to earlier fawning dates than found in northern Utah, however the breeding phenologies of the two areas are the same (Robinette and Gashwiler, 1950). Although Zion Canyon is low in elevation, the canyon acts as a sink for cold night air from the surrounding plateaus and may not be warmer than the higher elevations. The deer population characterized in this study is a mixture of resident and migratory animals, and no attempt was made here to distinguish between them. Breeding occurs in the period of time when migratory deer from northern ranges are entering Zion Canyon.

Roadside surveys have been used to obtain estimates of deer herd composition.

Although the accuracy is questionable for areas with poor visibility and scattered deer (Robinette et al., 1977), the topography and winter vegetation of Zion Canyon and habituation of the deer lend themselves to making roadside surveys successful.

Because fawn mortality is greatest in the first few months of life (Robinette et al., 1977), the number of fawns in a wintering population has been used as a measure of fawn survival and yearly herd production. Robinette et al. (1977) reported an average pre-hunt doe to fawn ratio of 1:0.68 from 1946 to 1957 in mule deer of northern Utah. Pederson (1970) reported pre-hunt mule deer herd compositions on two mountain ranges in central Utah. From 1967 through 1969 fawn numbers in the LaSal Mountains ranged from 89 to 94 per 100 does and from 48 to 67 fawns per 100 does between 1967 and 1969 in the Henry Mountains. The difference in fawn production between the two central Utah ranges was attributed to differences in range quality as determined by vegetation analysis (Pederson, 1970). Julander et al. (1961) reported on deer herds in south-central Utah, and found a pre-hunt doe to fawn ratio of 1:0.50 in 1954 and 1:0.51 in 1956. The range used by these animals was considered overgrazed and of poor quality. Julander et al. (1961) attributed the low fawn production to the poor range and compared it to high production on a high quality range in southern Idaho.

Doe to fawn ratios obtained in this study (Table 14) are comparable to those obtained in Zion Canyon from the winter of 1966-67 through 1982. Fawn production in Zion Canyon was lower than current levels in 1965, 1966, and in 1988. An examination of weather records revealed nothing unusual about these years that would affect survival of fawns or vegetation quality. Yearly figures in these surveys vary widely, but the overall results indicate fawn production is similar to that of other Utah herds (Julander et al., 1961; Pederson, 1970; Robinette et al., 1977).

Fawn survival is affected by many factors. When a population is at or near carrying capacity, low recruitment is expected. In a simple regression of the number of adults versus number of fawns in the data from roadside surveys, no correlation was found ($r^2 = .006$), indicating that fawn survival was not affected by density of animals during this period. Other

factors that affect fawn survival are predation and automobile accidents. In an examination of 87 deer carcasses killed by predators and automobiles, O'Gara and Harris (1988) found 47% were fawns, 93% of which were killed by vehicles and mountain lions and coyotes killed more deer in the 1 to 6 year age class than any other age class. The total number of deer killed by automobiles in Zion Canyon is unknown due to failure to report incidents, difficulties in finding injured animals, and disturbance of carcasses by scavengers. The restricted topography of the upper part of Zion Canyon increases the percentage of canyon floor that is adjacent to the road, making the upper canyon a more dangerous habitat for deer. The three roadside surveys conducted in 1991 had consistently lower numbers of fawns per doe in the upper part of the canyon (Table 13). This may be due to differences in a single or combination of unmeasured factors affecting the upper and lower canyon sections: mortality due to vehicle traffic, vegetation quality, and predation.

Climate

Lactation is very costly energetically, and does are often in poor condition until fawns are weaned. Drought conditions may decrease the time of availability and production of perennial forbs and annuals, affecting nutrition and does' abilities to nurse fawns. This may lead to increased fawn mortality and poor doe condition. Summer precipitation in Zion Canyon in the past decade has been below normal in June, but above normal for 7 out of 10 years in July and August. Although total precipitation for the year has been below normal for the past three years, precipitation deficits have not occurred in the summer months, so summer drought conditions are not affecting the nutritional value of the Zion Canyon mule deer diet. This conclusion is supported by the chemical analysis of their 1991 diet, showing an adequate nutritional content.

Heavy snowfall can increase winter mortality by increasing energetic costs of foraging (Hanley and Rogers, 1989; Wallmo et al., 1977) and forcing animals onto roadways for daily movements, where they are hit by vehicles (O'Gara and Harris, 1988). Winter precipitation

(December through February) has oscillated within 0.5 standard deviations of the mean since 1981. Previous to 1981, precipitation sporadically peaked several standard deviations above the mean in winter months. Precipitation in January, the coldest month of the year, has been below normal in 6 of the past 11 years, and the highest precipitation in that time period was only standard deviations above the mean.

Winter temperatures in the past decade have been mild. Extremely low average temperatures occurred in three winters; 1913 (4 standard deviations below the mean); 1937 (3.2 s.d.'s below the mean); and 1949 (2.5 s.d's below the mean). Extremely high summer temperatures could limit the time period during which perennial forbs and annuals are available, however average daily temperatures in July deviated little from the mean. Temperature data from Zion Canyon indicates the last decade has been mild, relative to the overall weather history of the area.

CONCLUSIONS

Although many deer in Zion Canyon appear to be in poor condition, this study has demonstrated that their diet is nutritionally adequate and their blood physiology is normal. High eosinophil levels, found in 84 % of the animals sampled, were probably reactions to parasites. However, the number of parasites isolated in this study were not sufficiently great to adversely affect deer health and deer are natural hosts to all species found.

Age and mild weather may be contributing to the apparent condition of the deer. This study suggests the deer population has a greater proportion of older animals than other herds, perhaps due to mild weather conditions and the high nutritional value of Zion Canyon forage. Ages and condition of necropsied deer indicate deer may survive and reproduce longer than deer in other populations. In addition, all internal parasite species isolated in the necropsies accumulate in animal tissues with age and the high prevalence of parasites, as inferred from the eosinophilia in this herd, may be characteristic of a population with many older animals. Additional research focusing on does with small fawns is recommended.

The decrease in numbers of deer in the canyon relative to past surveys may be the result of vegetation changes. When the park was created in 1909 the canyon had been intensively farmed and grazed. Because in some habitats early stages of secondary succession are more favorable for deer populations than climax communities (Wallmo and Schoen, 1981), the high population numbers in the late 1930's and early 1940's may have been the result of early successional stages that occurred in Zion Canyon during that period. Although this study has shown that the forage of Zion Canyon is nutritionally adequate and the habitat is favorable for mule deer, the current vegetation, dominated by trees and shrubs, may no longer be capable of supporting such large herds.

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APPENDIX

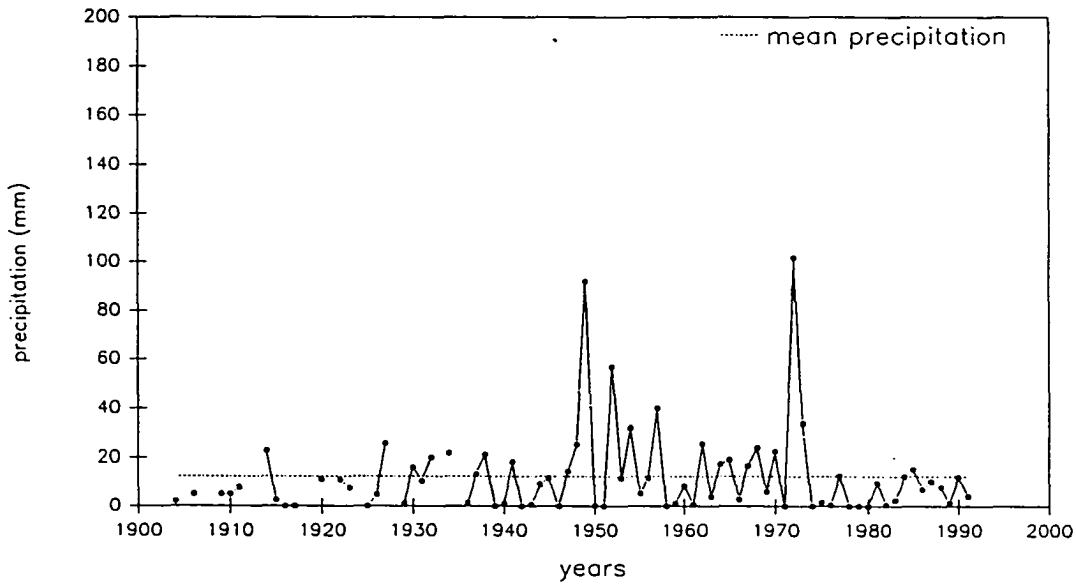

Figure 28. June precipitation, 1904-1991, Zion Canyon, UT.

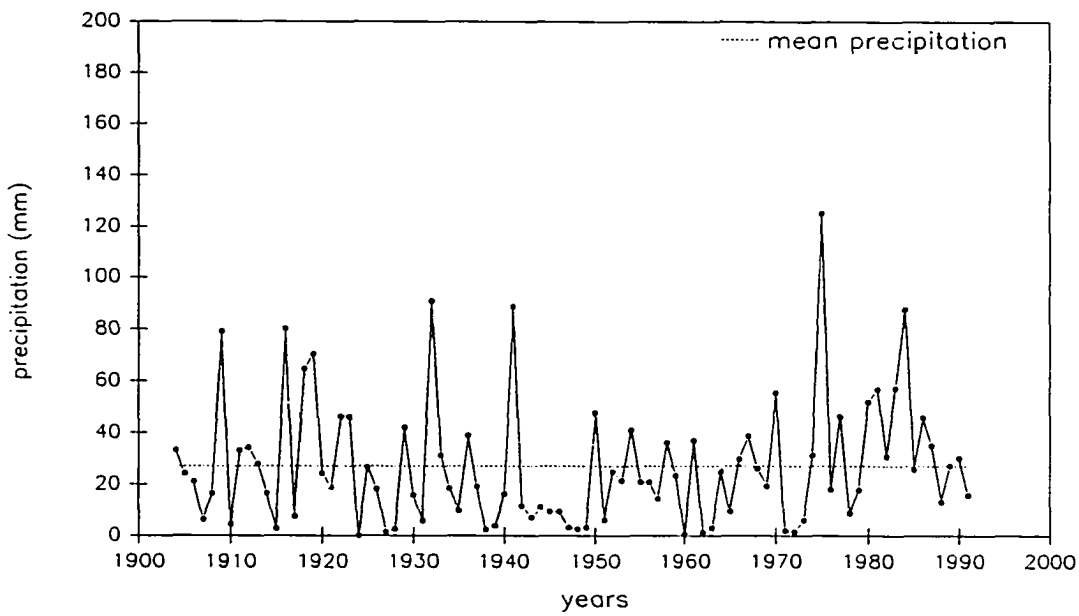

Figure 29. July precipitation, 1904-1991, Zion Canyon, UT.

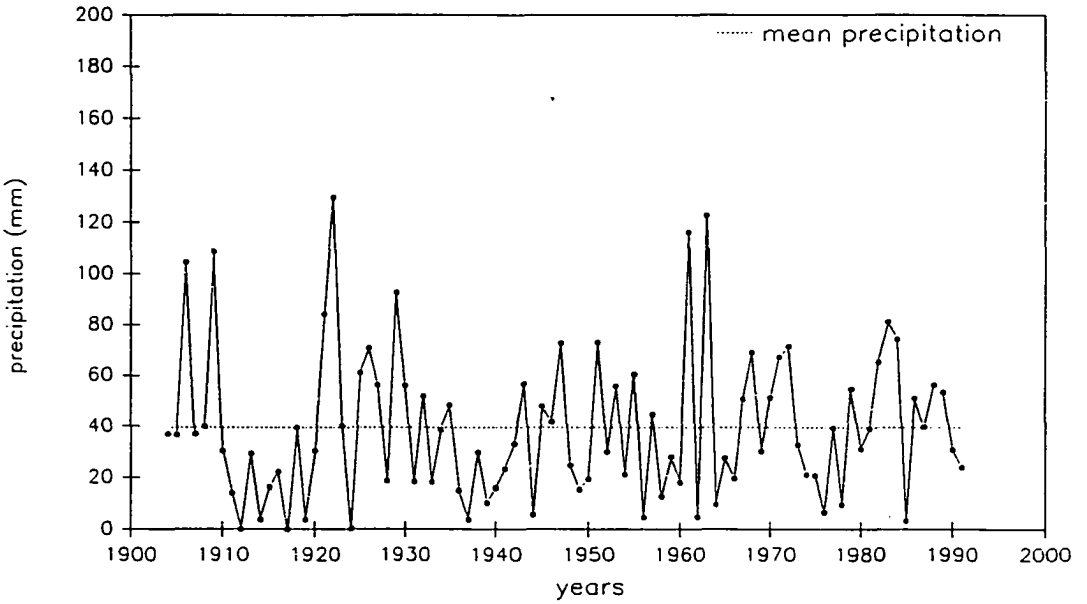

Figure 30. August precipitation, 1904-1991, Zion Canyon, UT.

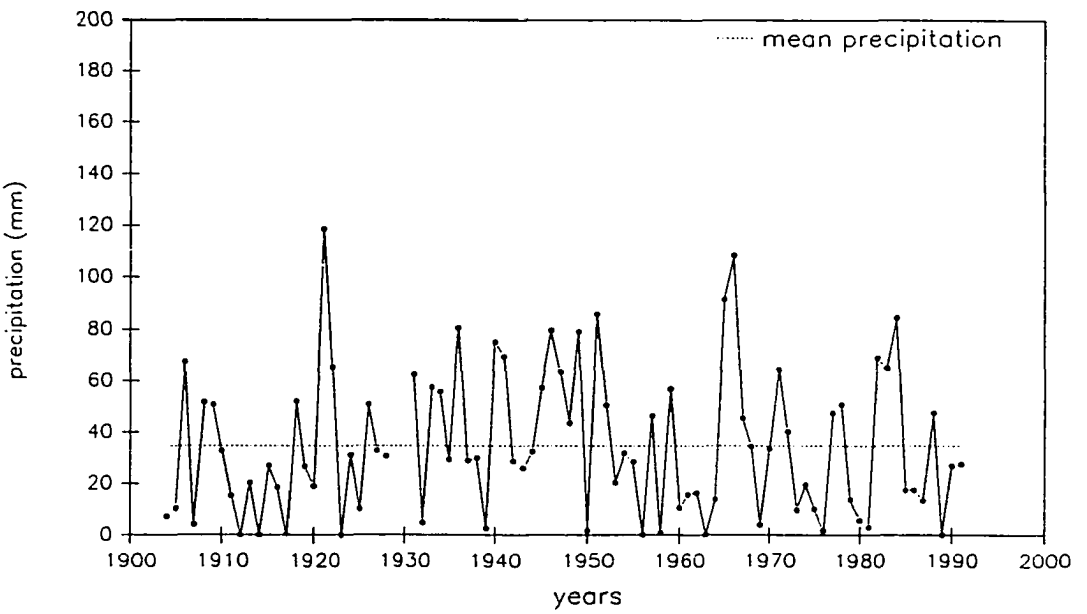

Figure 31. December precipitation, 1904-1991, Zion Canyon, UT.

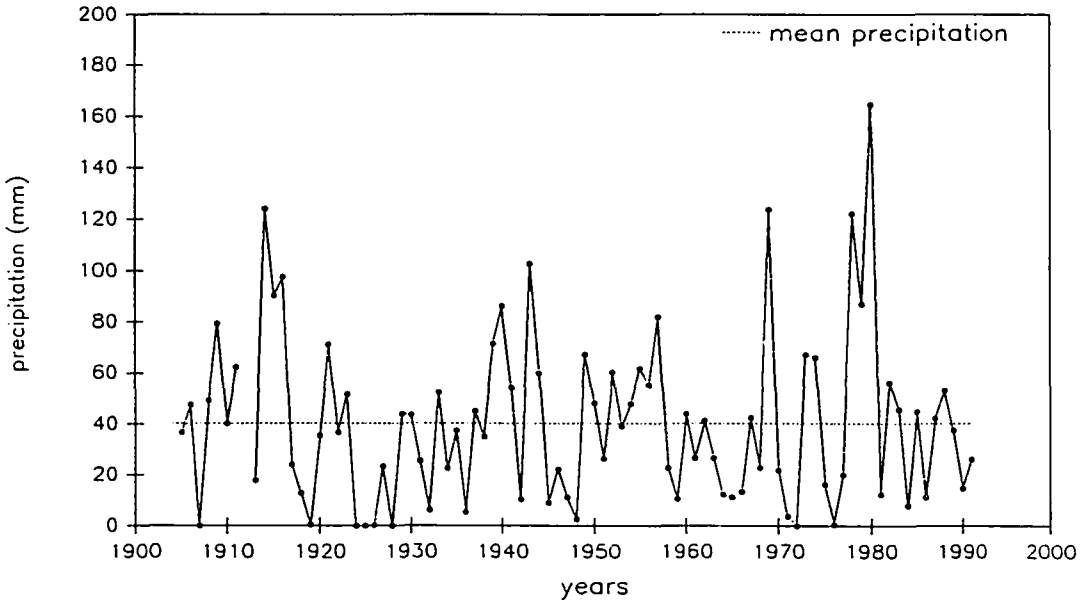

Figure 32. January precipitation, 1904-1991, Zion Canyon, UT.

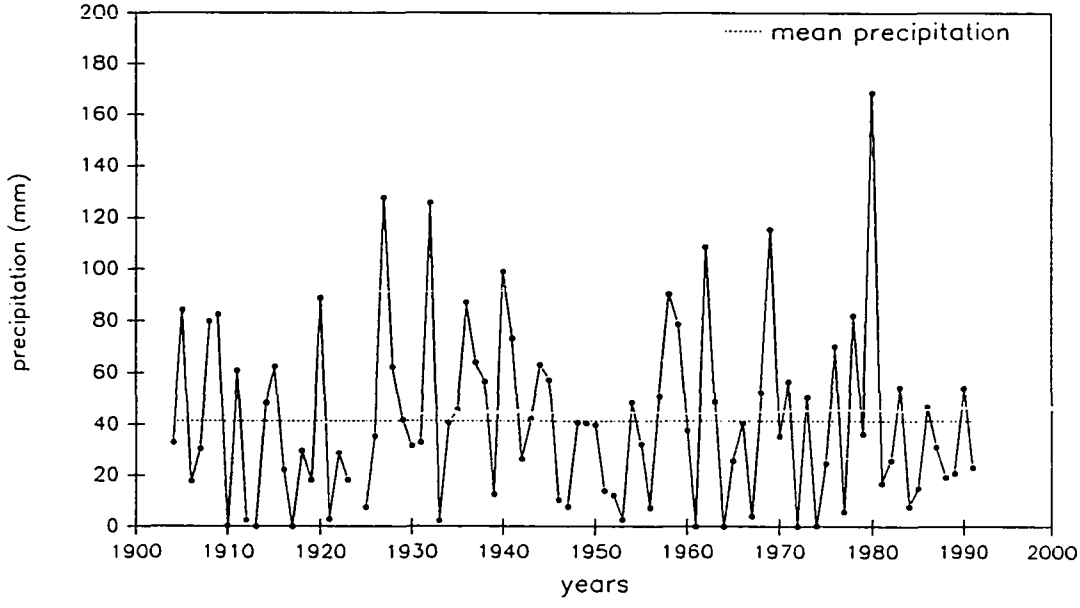

Figure 33. February precipitation, 1904-1991, Zion Canyon, UT.

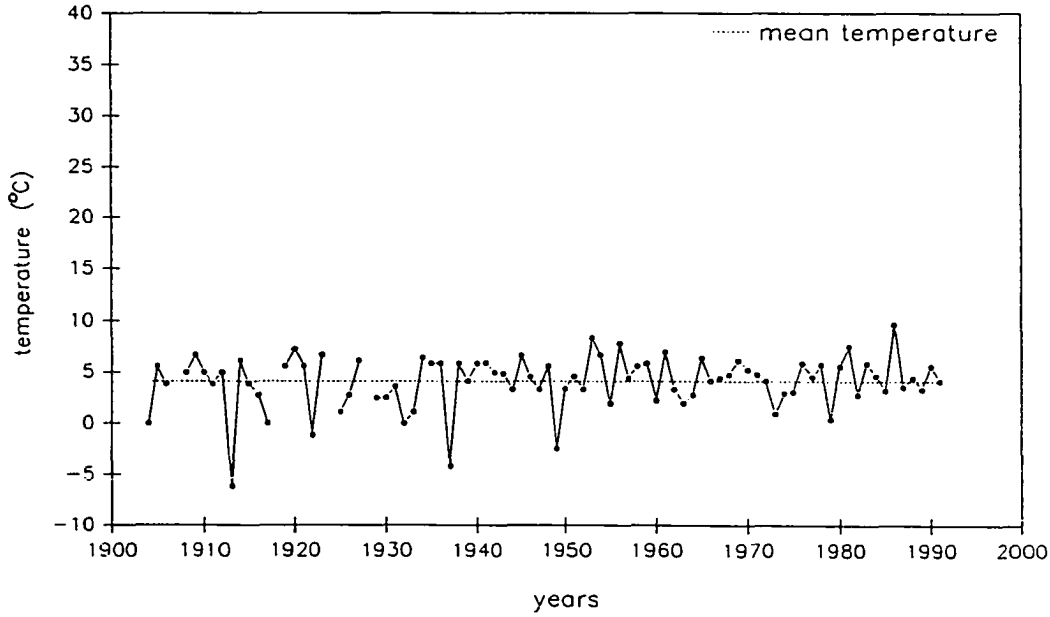

Figure 34. January mean daily temperature, 1904-1991, Zion Canyon, UT.

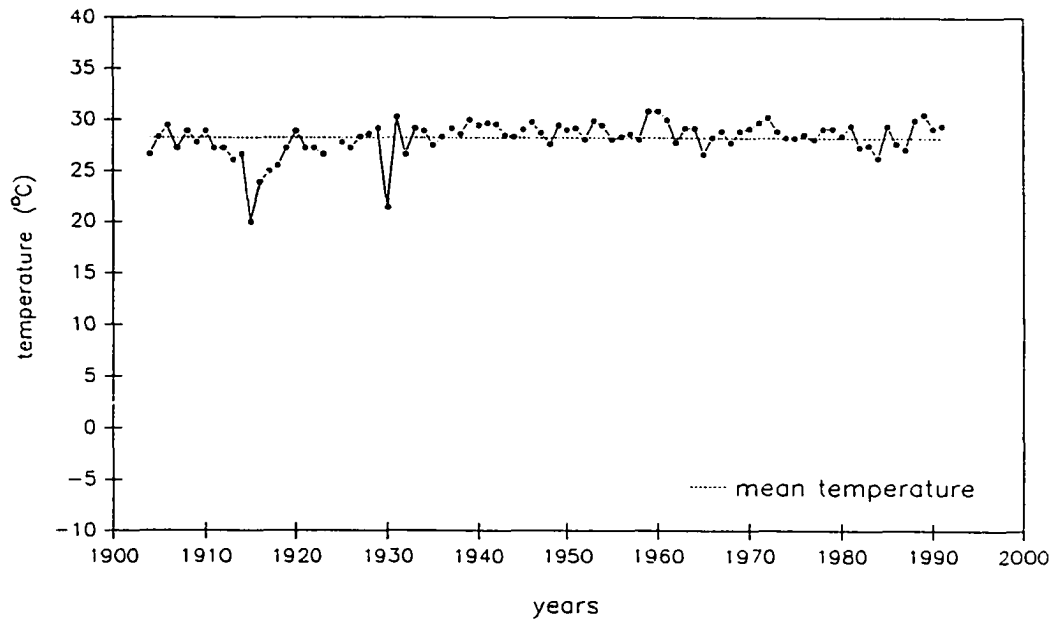

Figure 35. July mean daily temperature, 1904-1991, Zion Canyon, UT.