Pygmy Rabbit (*Brachylagus idahoensis*) Habitat Use, Activity Patterns and Conservation in Relationship to Habitat Treatments

By

Janet E. Lee

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Plant and Wildlife Sciences

Brigham Young University

August 2008

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Janet E. Lee

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Jerran T. Flinders, Chair
Date	Clayton White
Date	Dennis Eggett

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Janet E. Lee in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

____________________________	____________________________________
Date	Jerran T. Flinders Chair, Graduate Committee

Accepted for the Department

____________________________	____________________________________
Date	Val J. Anderson

Accepted for the College

____________________________	____________________________________
Date	Rodney Brown

ABSTRACT

Pygmy Rabbit (*Brachylagus idahoensis)* Habitat Use, Activity Patterns and Conservation in Relationship to Habitat Treatments

Janet E. Lee
Department of Plant and Wildlife Sciences
Master of Science

This study examined activity patterns and habitat use of pygmy rabbits (*Brachylagus idahoensis*) in mechanically treated and untreated areas in south-central Utah 2005-2008. We monitored fecal pellet plots in continuous sagebrush habitat as well as along treatment edges to record deposition and leporid presence over timed periods. Pygmy rabbit use of big sagebrush was higher than black-tailed jackrabbits (*Lepus californicus*) and mountain cottontail rabbits (*Sylvilagus nuttallii*) ($P < 0.01$) relative to treated areas ($P < 0.01$). We also compared pygmy rabbit use of areas with continuous sagebrush to residual sagebrush in a sample of mechanically treated areas. Our results suggest a treatment effect with higher ($P < 0.01$) average counts of pygmy rabbit pellets in areas with continuous sagebrush compared to sagebrush strips and islands within treated areas.

Before the big sagebrush biotype inhabited by pygmy rabbits is treated to reduce the occurrence and dominance of big sagebrush, we recommend managers consider two options. The first is no treatment, thus preserving, as is, the critical habitat of the pygmy rabbit and other sympatric big sagebrush obligate species of wildlife. The second option cautiously introduces the first prescription of habitat treatment ever recommended in relationship to the pygmy rabbit. This prescription includes recommended widths of the treated areas, seed mixes, widths of the preserved intact big sagebrush habitat for pygmy rabbits as well as suggested grazing systems for domestic livestock.

Activity patterns of pygmy rabbits at their burrow were documented through the use of remote cameras. Photographs were analyzed for temporal and seasonal patterns of activity. Our results suggested that time of day was important in the activity level of pygmy rabbits while season was not. Pygmy rabbits were active during all time periods of the day but the greatest levels of activity occurred at night. Numerous other wildlife species were recorded by our remote cameras including other species of leporids, birds, rodents, reptiles and terrestrial predators.

ACKNOWLEDEMENTS

I would like to thank my advisor Dr. Jerran Flinders for this help on this project. He has provided numerous editorial comments for this document. He has always supported me and answered all of my questions and concerns. I have spent countless hours talking with him about pygmy rabbits as well as other interesting species. He has motivated me to be a great researcher and to always do my best. He has made working towards my M.S. educational and fun.

Thank you also to my other graduate committee members, Dennis Eggett and Clayton White who have provided help and support with preparation of this document. I would also like to thank Randy Larsen for all of his help out in the field as well as with all of the work that goes on behind the scenes of a great research project. He has provided editorial comments for this document as well as numerous government reports and grant proposals.

I would also like to thank all of those who have helped me out in the field as well as with data entry: Jackee Alston, Leslie Hartman, Samantha Hammond & Stacey Strode. My family and friends have also provided faith, love, and support for my work with pygmy rabbits. Finally I would like to thank all others who I have collaborated and discussed pygmy rabbits with: Janet Rachlow, Eveline Larrucea, Christopher Keleher and Brant Hallows.

Funding for this project was obtained from the Endangered Species Mitigation Fund, Natural Resource Conservation Service, Bureau of Land Management and Brigham Young University.

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CHAPTER 1

INFLUENCES OF MECHANICAL BIG SAGEBRUSH TREATMENTS ON PYGMY RABBIT HABITAT USE

ABSTRACT The pygmy rabbit is the smallest leporid in North America and is considered a sagebrush obligate for which there is growing concern. Across Utah, sagebrush ecotypes are being treated to enhance and restore production of under story grasses and forbs. This practice improves habitat for mule deer and elk, increases livestock forage production, and is thought to reduce fire fuels. Because pygmy rabbits live in mature stands of big sagebrush that have or will be treated, we attempted to determine how such activities impact pygmy rabbits and to increase our understanding of their habitat use in treated and untreated areas. In south-central Utah, we monitored fecal pellet plots to record deposition and leporid presence over timed periods. These plots were located in continuous sagebrush habitat as well as along treatment edges. Pygmy rabbit pellet counts were higher in sagebrush areas ($P < 0.01$) compared to treated areas where sagebrush cover was mechanically reduced. Pygmy rabbit use of big sagebrush was higher than black-tailed jackrabbits and mountain cottontail rabbits ($P < 0.01$) relative to treated areas ($P < 0.01$). We also compared pygmy rabbit use of areas of continuous sagebrush to residual sagebrush in a sample of treated areas. Our results suggested a treatment effect with higher ($P < 0.01$) average counts of pygmy rabbit pellets in areas with continuous sagebrush compared to sagebrush islands within treated areas. If treatment of pygmy rabbit occupied stands of mature big sagebrush cannot be avoided, we suggest that future mosaic treatments (that can represent 95% or more replacement of

the big sagebrush habitat type) within pygmy rabbit habitat include preservation of long and wide swaths of undisturbed mature big sagebrush.

INTRODUCTION

Across the western United States, mature stands of big sagebrush (*Artemisia tridentata*) as well as those impaired by drought or other limiting factors have been the concern of many land managers (Holechek, 1981) because of their use by domestic livestock and wildlife species. In Utah, widespread and ambitious managerial treatments of sagebrush range from partial opening of the sagebrush canopy to complete ecotype replacement with native and non-native grasses, forbs and shrubs. Little data are available in regards to the impact of past, present, and future treatments of the big sagebrush ecotype on big sagebrush obligate species of wildlife. The pygmy rabbit (*Brachylagus idahoensis*) is one of these obligate species and is associated with taller and denser stands of big sagebrush (Green & Flinders, 1980a). As the smallest leporid in North America, pygmy rabbits have a home range of approximately 2.8 ha (females, breeding season) to 12.0 ha (males, breeding season) (Sanchez & Rachlow, in press) in relatively high sagebrush cover (21 - 36%) on loose, alluvial soils (Green & Flinders 1980a; Green & Flinders 1980b; Weiss & Verts 1984; Katzner & Parker 1997; Flinders 1999). Pygmy rabbits consume up to 99% big sagebrush during winter months and 51% during summer months (Gahr 1993; Green & Flinders 1980a; Green & Flinders 1980b). Grasses (39%) and forbs (10%) also compose this rabbit's summer diet (Green & Flinders 1980a).

Given the lack of information on the effect of big sagebrush treatments on pygmy rabbits, we compared habitat use in relation to habitat treatments. Between 1997 and 2004, large swaths of mature big sagebrush were removed in our study areas by mechanical treatments with a Dixie Harrow (Vallentine, 1980) under multiple use management to increase grass, forb, and other shrub production. A 435 horsepower tractor was used to pull a 13.1 m (16,000 lb/7272.7 kg) or 8.2 m (8,000 lb/3636.4 kg) wide Dixie Harrow once or twice over areas in a mosaic pattern to remove big sagebrush. In most cases, 15 lbs seed per acre (15 kg/ 1 ha) of mixed native and introduced grasses, forbs, and shrubs were broadcast in front of the harrow and consequently plowed under by the Dixie Harrow (Greenwood, 2004). These included native species such as Indian ricegrass (*Achnatherum hymenoides*), sandberg bluegrass (*Poa secunda*), basin wildrye (*Leymus cinereus*), pubescent wheatgrass (*Thinopyrum intermedium*), sheep fescue (*Festuca ovina*), fourwing saltbush (*Atriplex canescens*), Lewis flax (*Linum lewisii*), and introduced species such as crested wheatgrass (*Agropyron cristatum*), Russian wildrye (*Psathyrostachys juncea*), yellow sweetclover (*Melilotus officinalis*), forage kochia (*Bassia prostrata*), Ladak alfalfa (*Medicago sativa X M. falcata*), sainfoin (*Onobrychis viciifolia*), blue flax (*Linum perenne*), and small burnet (*Sanguisorba minor*). Seeds of big sagebrush were not typically included in the broadcast seed, but treatment occured in the fall when big sagebrush is in seed.

Sagebrush islands and travel corridors were left untreated in a mosaic pattern to benefit wildlife (Greenwood, 2004). The untreated areas were intended to provide thermal cover, forage, and to meet habitat requirements for a wide number of sagebrush obligate species (Greenwood, 2004). Prior to treatments planners made good faith efforts to avoid evident pygmy rabbit burrow complexes but no research based guidelines were available to serve as a template for these treatments. In this study, we assessed the impact of the mechanical sagebrush removal on pygmy rabbit habitat use by assessing fecal pellet deposition in treated and untreated areas of Grass Valley, Utah.

Fecal pellet counts have been widely used to measure rabbit and hare day-use occurrences, population abundance, and the effects of elements of the vegetative biota on leporid activity world wide (MacLulich, 1937; Arnold & Reynolds, 1943; Taylor & Williams, 1956; Green, 1978; Wood, 1988; Forys & Humphrey, 1997; Sugimura & Yamada, 2004). Fecal pellet counts have also been used to verify pygmy rabbit presence (Rachlow & Whitam, 2004; Ulmschneider, 2004). While other methods are available such as live trapping or direct counts of individuals, pellet counts provide a continuous response that is relatively easy to measure (Palomares, 2001). Such counts have been employed in the study of other wildlife- particularly ungulates (Neff, 1968; White & Eberhardt, 1980). With ungulates however, it is important to recognize pellet groups as one deposition (Batcheler, 1975) whereas with rabbits, pellets can be counted individually which makes data collection more precise (Krebs et al., 1987).

STUDY AREA

We conducted this study in Grass Valley (Piute and Sevier counties) and Parker Mountain (Wayne County) in south-central Utah between April 2005 and October 2007. Grass Valley has an annual precipitation of 24.2 cm per year, snowfall average of 87.4 cm, and a temperature range from -12.2°C to 29.3°C (WRCC, 2007). The elevation of Grass Valley and Parker Mountain ranges from approximately 2,017 m to 2509 m.

Upper hillsides of Grass Valley and Parker Mountain are dominated by juniper (*Juniperus* spp.), pinyon pine (*Pinus edulis*), and aspen (*Populus tremuloides*). Lower elevation areas give way to big sagebrush and other shrub dominated communities as well as wet grassy valley bottoms (mostly agricultural fields). Our focal area for this study was the big sagebrush communities.

METHODS

We established fecal pellet plots to monitor deposition over timed periods. Beginning in 2005, we selected active (Rachlow & Witham, 2004) burrow complexes and depending on their location to mechanical treatments, set up one of two types of fecal pellet plots (0.25 m^2).

Fecal Pellet Plots in Mechanically Treated Big Sagebrush

We randomly selected active burrows in big sagebrush within 15 m of a mechanically treated edge to be the starting point for fecal pellet plots. Once we selected an active burrow, we delineated a 30 m straight line transect originally from a random location around the burrow complex (Fig. 1). Nine 0.25 m^2 square quadrats were established along the transect. We oriented 3 of these plots within the stand of big sagebrush with the remaining 6 quadrats extending into treated areas. The 30 m transect was divided into thirds. Within each 10 m segment we set up plots at 3, 6, and 9 m. We established these plots at 13 different locations in the study area. We counted and cleared all pygmy rabbit, black-tailed jackrabbits (*Lepus californicus*) and mountain cottontail rabbits (*Sylvilagus nuttallii*) fecal pellets once a month from June to October 2005, March to October 2006 and April to October 2007. We identified pellets to species based on size, shape, and color. Plots could not be checked during winter months due to snow cover.

Fecal Pellet Plots in Untreated Big Sagebrush

Active burrows were also located in undisturbed sagebrush stands. Those selected for study were at least 50 m from any type of ecological edge, natural or man made. With the burrow as the center point we set out two, 30 m transects, with 15 m extending each direction from the burrow (Fig. 2). Three, 0.25 m^2 fecal pellet plots were placed in each cardinal direction at 3, 9, and 15 m, giving a total of 12 pellet plots per location. We established 13 sets of these plots. We counted and cleared all pygmy rabbit, black-tailed jackrabbit, and mountain cottontail fecal pellets at each location during the same time period as plots in treated areas and according to the same protocol.

Statistical Methods

Mixed Model Analysis of Variance with Tukey Post Hoc test of Means— To analyze leporid use of sagebrush and non-sagebrush areas using counts of fecal pellets, we used a mixed-model analysis of variance (ANOVA). We discarded any fecal pellet count over 100 as an outlier, which occurred for 3 black-tailed jackrabbit counts at 3 different plots. Also, the plot at 13 m was not included in this analysis since we counted it as a transition area between the sagebrush and non-sagebrush area. We considered year and plot location as random and treated leporid species as fixed. After the test of variance, we used a Tukey Post Hoc means analysis to determine if there were any difference in pellet counts between species and location in relation to treatment. Means of black-tailed jackrabbit and mountain cottontail fecal pellet counts were combined in these analyses and compared to those of pygmy rabbits.

Average of the Fecal Pellet Counts by Distance— All fecal pellet counts were recorded by month and location. We calculated the average for each species at each plot across all locations and year. As with the Mixed Model Analysis of Variance, any pellet count over 100 was discarded as an outlier. Each mean was graphed with a 95% confidence interval. The procedural reference was used for 2006 and 2007 combined. We considered pellet data collected in 2005 as preliminary given the shorter interval (beginning in June compared to March or April) and did not include it in statistical analyses.

Treatment Effect— For 2006 and 2007, each of the types of pellet plots (those in continuous sagebrush and those extending into the treatment) were randomly paired with one of the other type. We randomly selected an arm (N, S, E, W) of the continuous sagebrush plot (3, 0.25 m^2 plots) to compare with the 3 plots in the sagebrush from the treatment transects (Fig. 1). We subtracted mean counts of the 3 plots in the sagebrush treatment transects from the average of the 3 continuous pellet plots. A positive result meant there were more fecal pellets in the continuous sagebrush plots than the plots in residual sagebrush in big sagebrush located adjacent to habitat treatments. We then used a chi-square test on the positive or negative results from these random pairings assuming equal probability of positive and negative differences.

RESULTS

Pygmy rabbit fecal pellet counts were higher ($P<0.01$) in sagebrush areas ($\bar{x}$: 7.2; $P<0.01$) compared to treated areas where sagebrush cover was mechanically reduced ($\bar{x}$ 3.1). Black-tailed jackrabbit fecal pellet counts were higher ($P<0.01$) in mechanically treated areas ($\bar{x}$: 6.2) than areas with continuous sagebrush ($\bar{x}$: 4.1). Mountain cottontail rabbit fecal pellet counts were also higher (P<0.01) in treated areas ($\bar{x}$: 8.1) compared to continuous sagebrush ($\bar{x}$: 3.2).

The mean of leporid fecal counts were compared between pygmy rabbit and a combination of black-tailed jackrabbit and mountain cottontails at these two locations (in sagebrush or out). In the 3 plots within the sagebrush, a mean difference value of 3.6 (t-value: 3.59, df: 52, P< 0.01) was obtained compared to -4.0 (t-value: -4.34, df: 52, P<0.01) in areas devoid of sagebrush. Both black-tailed jackrabbits and mountain cottontails had a higher mean number of pellets in the area devoid of big sagebrush than areas with continuous big sagebrush. Pygmy rabbit mean pellet counts however, were higher in the sagebrush compared to treated areas.

To obtain a better idea of leporid use of areas treated by the Dixie Harrow, we calculated the means for each species' fecal pellet count at each 0.25 m^2 plot in relation to distance from treatment edge for all locations and years (Fig. 3). Average pygmy rabbit pellet counts decreased in the average count of pygmy rabbit pellets as the plots extended out into the treated areas. On the other hand, mountain cottontail and black-tailed jackrabbit pellet count averages increased as the plots extended into the treatments.

Of 78 possible positive or negative difference in mean count between treated and untreated habitats, there were 26 positive values compared to 13 negative in 2006 and 36 positive compared to 3 negatives in 2007 indicative of a treatment effect ($\chi^2 = 32.26$; P <0.01).

DISCUSSION

The use of fecal pellet plots is a form of continuous sampling and considered more reliable and relatively easy compared to other methods such as live trapping or direct counts of individuals (Kreb et al., 1987, Palomares, 2001). Data collection is continuous across time periods and includes both day and night assessments. There are however, challenges associated with this method such as observer bias and erosion of pellets by wind or water (Ferguson, 1955; Rogers et al., 1958; Neff, 1968). One of the biggest problems associated with counts of fecal pellet plots is observer bias. Bias can be caused by fatigue, visual acuity, and experience (Neff, 1968). We attempted to limit this bias by having the same individuals count rabbit pellets each month. All researchers were trained in the identification of each species pellet by size, shape, and color, which differ by species, according to identification keys established by Webb (1940), Rachlow & Witham (2004) and Ulmschneider et al. (2004).

Problems may arise however, because young black-tailed jackrabbits or mountain cottontails deposit smaller fecal pellets than adults. We attempted to minimize misidentification by looking at color and shape of the pellets and counting over many months. To mitigate the effects of erosion, we checked and cleared each plot on a monthly basis. Most plots were protected by overhead vegetation, which limited the amount of weathering and erosion. Robinette et al. (1958) indicated that areas with high insect densities may pose a problem with beetles eating or carrying away mule deer pellets. While we did not frequently observe beetles in our study area, we did notice that ants, particularly harvester ants (*Pogonomyrmex barbatus*), carried pellets to their hills. Fecal pellet foraging by ants may be something to evaluate in future studies to.

While grass and forbs are part of the pygmy rabbit's spring and summer diet, sagebrush remains important and is always found in fecal pellets with a frequency of at least 36 to 51% (Grinnell et al.1930; Orr, 1940; Wilde, 1978; Green & Flinders 1980a). During the winter months, a pygmy rabbit's diet is composed of up to 99% big sagebrush (Green & Flinders, 1980a). Green & Flinders (1980a) reported that pygmy rabbit habitat had significantly greater cover and corresponding biomass of woody vegetation than any other sites examined. Big sagebrush provides both critical thermal cover (Katzner et al., 1997) and protection from predators (Davis, 1939; Severaid, 1950; Gahr, 1993; Longland & Bateman, 2002). Not only does the removal of this shrub eliminate pygmy rabbit habitat and cover but it also reduces or removes their main source of food.

Average pygmy rabbit fecal pellet counts decreased with distance from sagebrush edge compared to increased counts for black-tailed jackrabbits and mountain cottontails (Fig. 3). This finding indicated that while pygmy rabbits use the mechanically treated areas, they used them to a much lesser extent than other leporids. In a Least Squares Means of the Mixed Model Analysis of Variance the pygmy rabbit had a higher fecal pellet average in the plots in mature big sagebrush ($P < 0.01$) than areas devoid of big sagebrush ($P < 0.01$). While some of the confidence intervals overlap, the general trends are presented and it is important to note that the average count of pygmy rabbit pellets in plots decreases as these extend into the treated areas (Fig. 3) suggesting a preference of big sagebrush. Black-tailed jackrabbits and mountain cottontails seem to prefer the treated areas.

Although pygmy rabbits used mechanically treated areas, our data showed that wide strips of mechanically treated big sagebrush could negatively impact pygmy rabbits.

When planned and carried out in relationship to our results, such projects may benefit a wide diversity of species (Holechek, 1981) and help meet multiple management use goals. Therefore we suggest two options to land and wildlife managers.

Option One- No Treatment

We recommend avoiding treatment of big sagebrush in areas with pygmy rabbit presence and in areas with all essential habitat conditions. The presence of pygmy rabbits and their burrows identifies the suitable soils, vegetation and slopes that best satisfy some of the critical habitat requirements of this leporid. Evaluations prior to treatment should be conducted to identify these areas. Fragmentation of big sagebrush habitat will limit size and stability of pygmy rabbit populations due to low "capabilities" for dispersal (Katzner & Parker, 1997). Dobler and Dixon (1990) state the primary threat to the pygmy rabbit results from habitat fragmentation by sagebrush removal. Removal isolates populations and may cause local extinctions. Therefore, we recommend the avoidance of treating essential pygmy rabbit habitat whenever possible.

Option Two- Treatment With These Essential Recommendations

Preservation of large swaths of big sagebrush— If the first option (no treatment in essential habitat) is not acceptable, we recommend managers leave large swaths of mature big sagebrush intact to provide both food and cover for pygmy rabbits and other big sagebrush obligates. Moreover, larger untreated areas are more likely to harbor a variety of soil types, topography, and vegetation which would promote wildlife diversity (Longland & Bateman, 2002). The probability of survival of a population of pygmy rabbits is directly related to the amount of contiguous big sagebrush that comprises an island (Dobler & Dixon, 1990). As the size of big sagebrush islands decreases, the likelihood of extinction increases, especially at the edges of pygmy rabbit geographic range (Dobler & Dixon, 1990). There is also evidence that larger undisturbed areas of big sagebrush are needed to provide resources for seasonal, regional, and annual variation in pygmy rabbit populations and habitat (Sanchez & Rachlow, in press).

In an effort to describe treatment widths of big sagebrush, we reviewed 5 studies which describe pygmy rabbit home range and use 5 different estimators. All report different home ranges. Heady & Laundré (2005) report an average summer male home range of 67.9 ha and female range of 37.2 ha on the Idaho National Engineering and Environmental Laboratory (INEEL) in Idaho using a grid method. Katzner & Parker (1997) report an average winter home range of 1.8 ha of the pygmy rabbit using a 95% adaptive-kernal isopleth at Fossil Butte in Idaho. Gahr (1993) reports a summer/breeding season home range of 20.2 ha for males and 2.7 ha for females using a 50% harmonic mean to identify core areas and a 95% harmonic mean to identify areas used in normal movements. Burak (2006) reports a breeding season home range of 4.5 ± 1.3 ha for males and 1.6 ± 0.3 ha for females using the least squares cross-validation (LSCV*h*) method with a smoothed 95% fixed kernel. Sanchez & Rachlow (in press) report an annual home range of 12.6 ± 2.4 ha for males and 4.3 ± 1.4 ha for females across three sites in Lemhi, Idaho; those values included a non-breeding season home range of 3.7 ± 0.9 h for males and 2.6 ± 0.5 ha for females with a breeding season home range of 12.0 ± 1.6 ha for males and 2.8 ± 0.6 ha for females using the LSCV*h* smoothing parameter.

In our description of mechanical treatment widths, we will use Sanchez & Rachlow's (in press) estimation of home range because it uses one of the most reliable home range analysis methods as well as covers pygmy rabbit home range year round, not during one season of the year as the other studies. Furthermore, their analysis includes more individuals and more sites than the other works. Despite these home range studies, it is important to note that very little is known concerning pygmy rabbit use of multiple burrow systems, dispersal, and shifts in pygmy rabbit locations over time (J. Rachlow, personal communication). Pygmy rabbits are known to use more than one core area within their home range (Kaztner & Parker, 1997; Sanchez & Rachlow, in press). Based on this knowledge, as well as other factors influencing pygmy rabbits, we recommend that residual stands of mature big sagebrush be no smaller than the width equal to two breeding male home ranges (24 ha/0.09 mi^2 or approximately 490 m across in any direction). It is important to include both male and female breeding range in big sagebrush habitat calculations because so little is known about pygmy rabbit behavior and habitat requirements, particularly during the breeding season. Treatments should leave ample big sagebrush so that pygmy rabbits will be able to feed, reproduce, avoid predators and disperse.

Our fecal pellet data suggests removed areas of big sagebrush should be narrow (40 m in width) as habitat use decreased with increasing distance from the edge. We show that pygmy rabbits will travel 20 m into the treated areas largely devoid of big sagebrush and it is as likely that they would travel another 20 m to get to another stand of big sagebrush. Large treatment areas may inhibit pygmy rabbit movements since our observations, as well as those of others, indicate these leporids do not often travel over large open areas (Weiss & Verts, 1984; Dobler & Dixon, 1990).

Depending on management objectives, it may also be valid to treat smaller portions of big sagebrush on a scheduled basis. For instance, several smaller strips of big sagebrush perhaps 40 m in width could be removed and planted with grass, forbs, and big sagebrush. Once the big sagebrush in these areas grows back and become occupied by pygmy rabbits, other 40 m strips could be treated in the same manner. Such a practice may help limit the negative impact of big sagebrush removal on pygmy rabbits while establishing more grass and forb diversity in the recovered strips of treated big sagebrush.

Big Sagebrush Mosaic Connectivity Corridors— Insure that mosaics of residual big sagebrush connect to each other to provide corridors of connectivity and thus acceptable pathways for dispersal between remaining stands of big sagebrush. Pygmy rabbits are not known to travel across large open areas (Weiss& Verts, 1984; Dobler & Dixon, 1990) and decreases in big sagebrush cover are likely to decrease pygmy rabbit movement across less vegetated areas (Katzner & Parker, 1997). It is important encourage the genetic mixing of pygmy rabbits by maintaining acceptable corridors for dispersal to other meta-populations. Moreover, male pygmy rabbit home range increases during the breeding season and they travel over larger distances (Gahr, 1993; Heady & Laundré, 2005; Burak, 2006; Sanchez & Rachlow, in press), which increases the need for proper habitat corridors between the big sagebrush mosaics. Habitat corridors should be at least as wide as the width of a female pygmy rabbit annual home range (5.7 ha or approximately 239 m in width) (Sanchez & Rachlow, in press). Isolated populations of pygmy rabbits may also be reconnected to other meta-populations by the reestablishment of corridors of big sagebrush habitat. This may include planting and restoring big sagebrush along fences and streams (Dobler & Dixon, 1990), as well as along the vegetational corridors within the fence boundaries for roads and highways.

Seeding of treated area— If the intent of the mechanical treatments of mature big sagebrush is to add more diversity and biomass of grasses and forbs in treated strips, seed of appropriate and desired accessions of big sagebrush should also be planted. The maturing treated areas would thus exhibit various ages, height, and cover classes of big sagebrush. We suggest the exotic shrub forage kochia (*Kochia prostrata*) not be seeded in pygmy rabbit habitat within the big sagebrush biotype. Forage kochia is native to Eurasia and has no ecologically functional relationship to big sagebrush obligate wildlife. Furthermore, as an aggressive shrub, forage kochia could compete heavily with big sagebrush—the keystone species for this biotype and critical to all associated obligate wildlife. Well established research (Ward, 1971; Green & Flinders, 1980a; Green & Flinder, 1980b; Austin & Urness, 1983; Owens & Norton, 1990; Ngugi et al., 1992; Vincent, 1992; Wood et al., 1995; Burkhardt, 1996; Katzner & Parker, 1997; Crawford et al., 2004; Seefeldt, 2005) identifies some accessions of big sagebrush that are favored as winter forage for some domestic livestock, wild ungulates, and other year-round or seasonal big sagebrush obligate wildlife. Provenza et al.'s work (Provenza & Balph, 1987; Provenza & Balph, 1988; Provenza et al., 1988) shows that domestic sheep and cattle can effectively be behaviorally and nutritionally conditioned to forage on big sagebrush thus removing the argument to seed an exotic shrub for domestic livestock. We recommend adding seed from various accessions of big sagebrush to the mix planted on the treated areas within habitats occupied by pygmy rabbits. By so doing, managers will reestablish genetic, forage, and other forms of ecological diversity to the big sagebrush seral complex that succeeds on the mechanically treated strips. This unrealized goal could be one of the major objectives guiding treatments and subsequent seedings.

We recommend a reduction in the number of exotic grasses and forbs seeded in treated areas within big sagebrush. While these exotics can provide forage for some wildlife species as well as domestic livestock, it is important to insure that plants native to the big sagebrush biotype be featured. There may be special native, even state sensitive, grasses or forbs that naturally occur in an area that need to receive special emphasis in initial or subsequent seedings. Since greater sage grouse (*Centrocercus urophasianus*), as well as other big sagebrush obligate birds, benefit from plantings of particular species of grasses and forbs, we recommend including known beneficial plants in the seeding mixes. Mechanical treatments within mature stands of big sagebrush should not be prescribed unless those areas can be seeded with the recommended mix of seeds using the best and most efficient methods and at the appropriate time of year to foster germination. Seedings completed in drought years may need to be repeated, perhaps more than once, to insure adequate germination of seed and thus establishment of the desired mix of plants.

Grass and forb production varies naturally by year due to precipitation and other factors. However during some years in our study areas, very little new growth of grasses and forbs occurred and thus there was little forage for livestock and wildlife. In some treated areas, seed mixes did not seem to grow and invasive species such as Russian thistle (*Salsola tragus*), bur buttercup (*Ranunculus testiculatus*), and rattlesnake stickweed (*Hackelia ophiobia*) took over much of these areas. It is important to insure that the suite of plants seeded in the treatment actually becomes established.

Domestic Livestock Grazing— We also recommend limiting and closely regulating livestock grazing in areas with pygmy rabbits, particularly areas grazed by cattle. We recognize that in some instances grazing may be beneficial to pygmy rabbits and sagebrush habitats. For instance, seasonal grazing of the mature big sagebrush biotype by domestic sheep on the U.S. Sheep Experiment Station in southern Idaho seemed to benefit the rather robust populations of pygmy rabbits and greater sage grouse (Green & Flinders, 1980a; Green & Flinders, 1980b; Hulet, 1988) found there. Although Siegel Thines et al. (2004) have stated that grazing "may not be compatible with conservation efforts," we recognize that the pygmy rabbit evolved with both the Pleistocene and Holocene complex of grazing and/or browsing wild ungulates including those with body size larger than domestic cattle (Crawford et al, 2004). The multiple entrances of a pygmy rabbit burrow complexes may be an adaptation to cave-ins caused by large ungulates but this issue deserves further study.

We recognize the ecological service pygmy rabbits render by constructing underground tunnels and chambers accessed by multiple burrows. Our and other's (Larrucea, 2007) studies with remote cameras set at burrow entrances show a number of reptiles, mammals, insects and birds that frequent these entrances. However grazing livestock that collapse burrow entrances perhaps trap non-burrowing visitors below ground and thus turn a positive survival strategy into a mortality factor.

Despite prehistoric grazing in areas with pygmy rabbits, the dramatic increase of domestic livestock in the late 1800s not only decreased the diversity of "dominant grazers" but also changed the "timing" and "selective pressures associated with herbivory" (Burkhardt, 1996; Miller et al., 1994, Crawford, 2004). While light to moderate cattle grazing may increase vegetation quality and sustain plant regrowth in late spring, grazing during other seasons of the year can reduce the amount grass and forbs available for the rest of the year (Laycock, 1991; Crawford et al., 2004). Siegel Thines et al. (2004) found that cattle grazing in late summer through winter reduced available grass by 50% and also reduced the nutritive qualities of remaining grass. Moreover, heavy grazing may increase invasion and distribution of undesirable plants (Crawford et al., 2004). Cattle have also been known to collapse pygmy rabbit burrows (Rauscher, 1997; Siegel Thines, 2004). Indeed, pygmy rabbit habitat in Washington ungrazed by cattle contained substantially more pygmy rabbit burrows than areas that were grazed (Gahr, 1993; Siegel Thines et al., 2004). As pygmy rabbits appear to dig separate single entry natal burrows (Rachlow et al., 2005), it is important to limit cattle grazing in pygmy habitat during the breeding season so as not to collapse these important burrows. The collapsing of single entry natal burrows during heavy spring and summer grazing could prove detrimental to pygmy rabbit populations.

Therefore we suggest that grazing be limited in areas with pygmy rabbits. In cases where grazing occurs in pygmy rabbit habitat, we suggest rest-rotational grazing by livestock thus allowing some domestic grazing while also providing time for regeneration. Not only has rotational/deferred grazing become more common, it has also contributed to improvement of range conditions over the past few decades (Burkhardt, 1996). We cannot recommend the systems known as high intensity and low duration grazing (Herbel & Pieper, 1991), especially by cattle, since this purposely increases the trampling effects by livestock, which would logically collapse more burrows of pygmy rabbits.

Management Implications

While our data shows that mechanical treatments of big sagebrush have the potential to negatively impact pygmy rabbits, further research is needed. Little is known about pygmy rabbit dispersal, home range, breeding and general biology of the pygmy rabbit; larger intact stands of big sagebrush may be needed to support viable populations of this leporid. Based on current, but limited information regarding pygmy rabbits, we have described two different options regarding the big sagebrush biotype. By following our suggestions, we believe that managers will be better able to conserve and manage pygmy rabbits in impaired sagebrush habitats.

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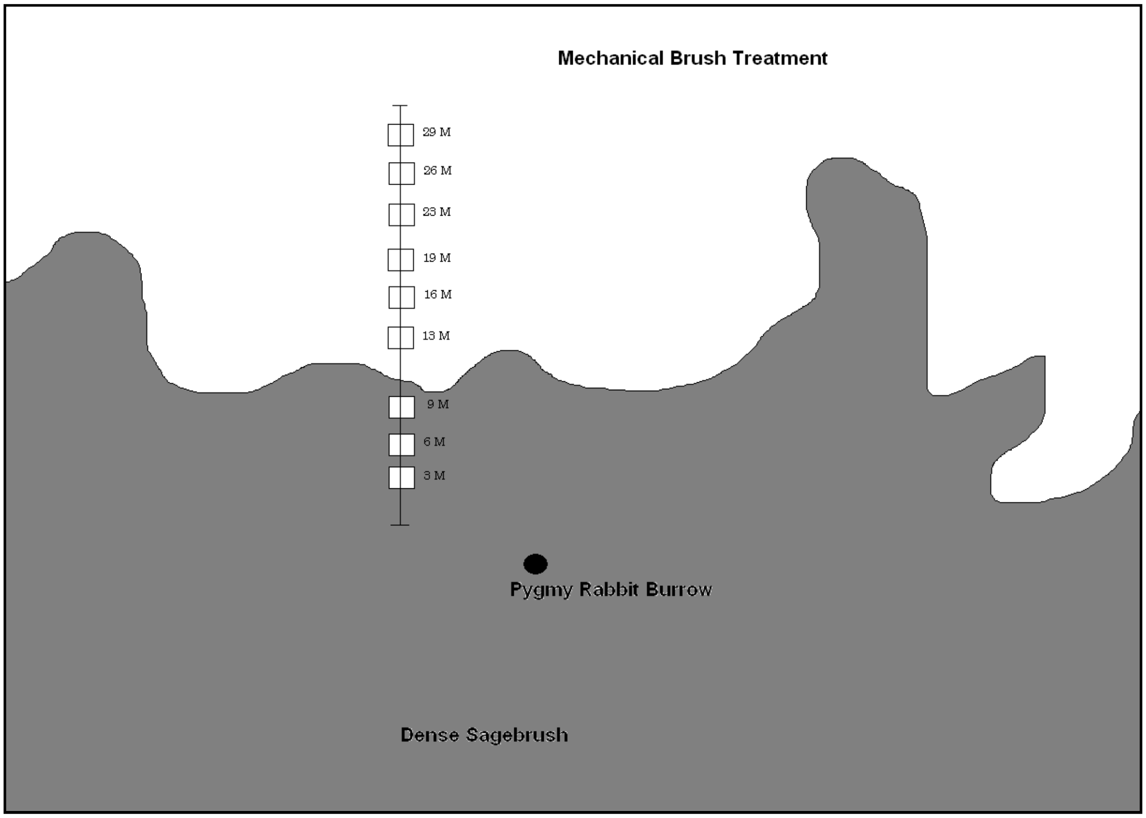

Figure 1. An illustration of a typical fecal pellet transect established to determine leporid abundance and use in relation to mechanically treated sagebrush.

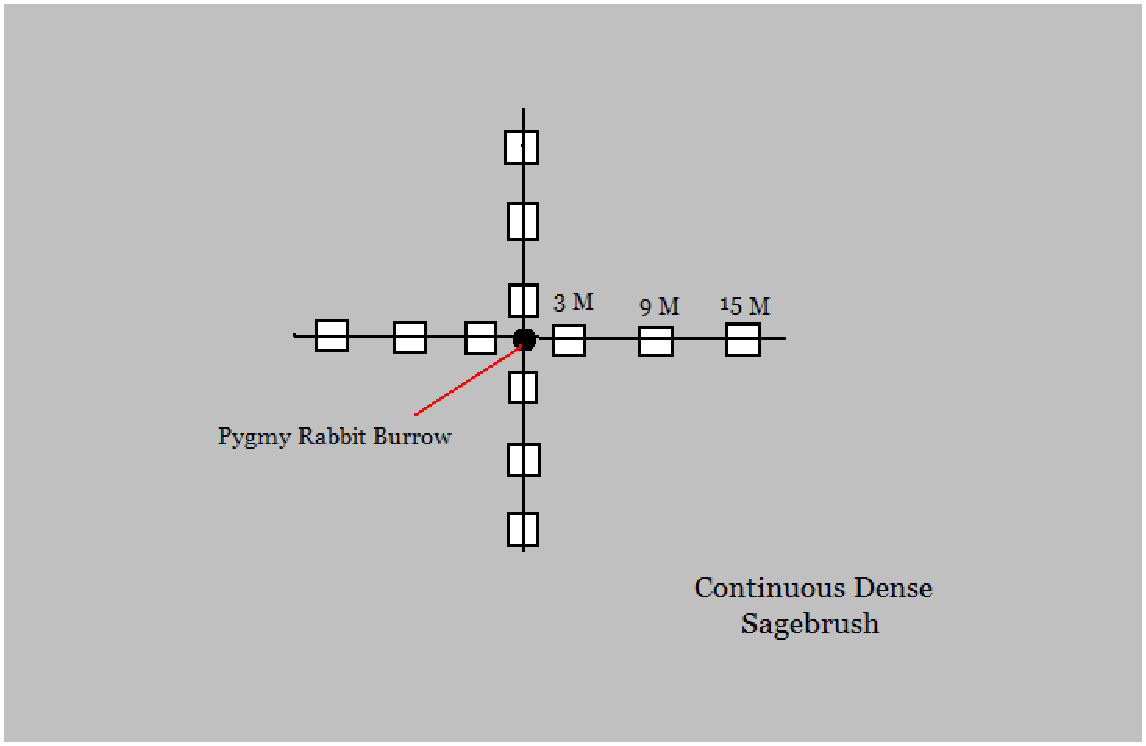

Figure 2. Illustrated here is a typical fecal pellet count transect established to determine leporid abundance and use in continuous big sagebrush habitats.

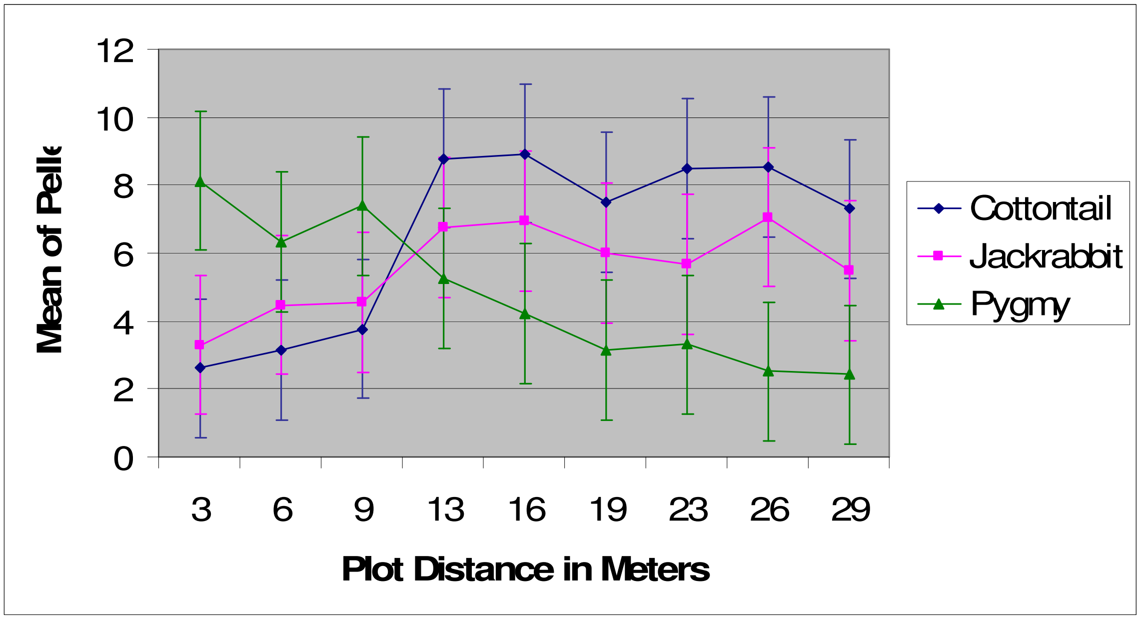

Figure 3. Plotted here are the average number of fecal pellets for each leporid species along transects extending into treatment areas with 95% confidence intervals.

CHAPTER 2

TEMPORAL AND SEASONAL PATTERNS OF PYGMY RABBIT ACTIVITY IN UTAH

ABSTRACT The pygmy rabbit is a secretive obligate sagebrush-steppe resident of the Intermountain West and is one of two rabbits in North America to dig its own burrows. Although the pygmy rabbit has been recorded to have a home range of 0.21 ha to 67.9 ha in relatively high sagebrush cover (21 - 36%), they spend much of their time within 30-100 m of a burrow system. Due to big sagebrush cover in preferred habitat and the secretive behavior of pygmy rabbits, it is often difficult to study this leporid through direct observation. We documented pygmy rabbit activity at burrow systems through the use of remote cameras in south-central Utah from 2005-2008. Photographs obtained from the remote cameras were analyzed for temporal and seasonal patterns of activity. Our results suggested that time of day was important in activity level while season was not. Pygmy rabbits were active during all time periods of the day, but the greatest activity occurred at night. Numerous other species were recorded by remote cameras including other leporids, birds, rodents, reptiles, and terrestrial predators.

INTRODUCTION

A resident of the big sagebrush (*Artemisia tridentata)* biotype, the pygmy rabbit (*Brachylagus idahoensis*) is found in the Intermountain Regions of the United States (Green & Flinders 1980a; Green & Flinders, 1980b). The pygmy rabbit is an obligate big sagebrush-steppe resident and is one of only two rabbits in North America to dig its own burrows (Green & Flinders, 1980a; Green & Flinders, 1980b; Katzner & Parker, 1997). Pygmy rabbits consume a diet of up to 99% big sagebrush during winter months and 51% during summer months (Green & Flinders, 1980a; Green & Flinders, 1980b; Gahr, 1993).

As the smallest leporid in North America, the pygmy rabbit has an estimated home range as small as 0.21 ha in winter in some locations in Idaho (Katzner & Parker, 1997) to 67.9 ha during the breeding season (Heady & Laundré, 2005) in relatively high (21 - 36%) sagebrush cover (Weiss & Verts, 1984; Katzner & Parker, 1997; Flinders 1999). A home range of approximately 2.6 $\pm$ 0.5 ha (non-breeding) to 2.8 $\pm$ 0.6 ha (breeding) for females and 3.7 $\pm$ 0.9 ha (non-breeding) to 12.0 $\pm$ 1.6 ha (breeding) for males appears to be more common (Sanchez & Rachlow, in press). Despite these estimates, this unique leporid spent much of its time within 30-100 m of a burrow system (Katzner & Parker, 1997; Heady & Laundré, 2005; Sanchez & Rachlow, in press). Evidence suggested that the pygmy rabbit is a “central-place forager” (Rosenberg & McKelvey, 1999) which may account for its restricted movement (Heady & Laundré, 2005).

Recent research has emphasized identifying pygmy rabbit geographic distribution, habitat, home range, and diets (Green & Flinders, 1980a; Green & Flinders, 1980b; Katzner et al., 1997; Katzner & Harlow, 1998; Bartels & Hays, 2001; Heady et al., 2001; Siegel, 2002). However, few studies document pygmy rabbit activity and burrow systems (Larrucea, 2007). Because pygmy rabbits use burrows year round (Larrucea, 2007), it is essential to gain a more thorough knowledge of temporal and seasonal use of burrows. Remote photography provides such an opportunity (Kucera & Barrett, 1993; Cutler &

Swann, 1999; Larrucea, 2007) and many researchers prefer remote photography over more traditional methods (Savidge & Seibert, 1988; Kleintjes & Dahlsten, 1992; Major & Gowing, 1994; Larrucea, 2007).

Remote photography may reduce observer bias (Cowardin, 1969) and may be less costly and time consuming compared to long-term observation of wildlife (Cutler & Swann, 1999). These units are also ideal to record data at night and in inclement weather (Enderson et al., 1972; Craig & Craig, 1974; Capen, 1978; Mace et al., 1994). Remote photography can also be effective in the study of secretive wildlife difficult to observe (Mace et al., 1994; Karanth, 1995). Larrucea (2007) has demonstrated the effectiveness of using remote cameras in certain applications to study of pygmy rabbits.

STUDY AREA

We conducted this study in parts of Beaver, Garfield, Iron, Piute, Sevier and Wayne Counties, south-central Utah between April 2005 and April 2008. Precipitation, snowfall, and temperature varied between study sites, but ranged from of 13.5 cm to 39.8 cm per year. Snowfall ranged from 13.2 cm to 114.6 cm and temperature from -13.6°C to 41.0°C (WRCC, 2007). Elevation was variable, but all study sites were between 1589 m and 2581 m. Upper hillsides of our study areas were dominated by juniper (*Juniperus* spp.), pinyon pine (*Pinus edulis*), and aspen (*Populus tremuloides*). Lower elevations gave way to big sagebrush and other shrub-dominated foothills and wet, grassy valley bottoms (mostly agricultural fields). We focused our study in big sagebrush communities.

METHODS

Field Methods

Beginning in May of 2005 until April 2008, we placed Digital Ranger S600 SB CamTrak Cameras (CamTrak South Inc., Georgia) at pygmy rabbit burrows showing varying levels of activity. We set cameras to take photographs continuously day or night (with a 30 s delay between photos) within 3 m of a burrow entrance to minimize differential detection (Culter & Swann, 1999). Cameras were placed at a burrow for 2 to 4 weeks with a few exceptions (i.e. remote location, inclimate weather) before being moved to a new burrow.

We placed cameras at known locations of burrows discovered previously by walk transects and recorded the activity level of burrows using two different activity level ranking systems currently in use (Table 1). The first burrow ranking system developed by Rachlow and Whitam (2004) contained 4 activity categories ranging from “active” to “very old”. The second ranking scheme was created by the cumulative effort of several state and federal agencies and has 8 categories ranging from “active” to “collapsed” as well as rankings for possible burrows and fecal pellets (Ulmschneider et al., 2004). We placed remote camera units at burrows with all levels of activity indiscriminately.

Data Analysis

We pooled all remote camera data into one sample unit. For seasonal analysis, we divided the year into fourths (winter: December-February, spring: March-May, summer: June-August, and fall: September-November). We also grouped photographs of pygmy rabbits into 4 blocks of time (morning, afternoon, evening, and night) using Mountain

Standard Time. We defined morning and evening time blocks as 3 hours before and after sunrise or sunset, respectively. Afternoon and night blocks were determined by the remaining time between morning and evening blocks and varied somewhat throughout the year. Definitions of season and time period blocks follow Larrucea (2007).

We divided the data into two different sets. Dataset 1 contained all photographs taken of pygmy rabbits. For Dataset 2, we excluded duplicate photos from the same rabbit taken within one hour of the original photo. We then divided the number of photographs in each time block by the effort (defined as the number of remote cameras in operation during that month) to obtain the activity level per hour (Larrucea, 2007). We analyzed differences in activity levels of pygmy rabbits for each season and time block using a generalized linear model (GLM). We then used least square means and differences between least squares means to test for variation within model parameters.

RESULTS

Remote cameras took 5,758 photographs of pygmy rabbits (Fig. 1) at 153 different burrow complexes (Fig. 1). Of those photographs, we used all of them in our first analysis of pygmy rabbit activity levels (Dataset 1). In our second analysis, only 2,810 photographs were included because they were the first photograph of each individual within each one hour segment (Dataset 2).

Activity levels were graphed by time, season and year (Fig. 2). A test of fixed effects within the mixed procedure indicated that time of day was important in activity level of pygmy rabbits (Dataset 1: $P<0.01$; Dataset 2: $P=0.01$), while season was not (Dataset 1: $P=0.35$; Dataset 2: $P=0.28$). Pygmy rabbits were active during all time periods of the day, but the greatest activity levels occurred at night for every year in both datasets. Activity levels at night activity were significantly different from the afternoon ($P<0.01$), evening ($P<0.01$), and morning ($P<0.01$) in Dataset 1 and evening ($P=0.01$) and morning ($P=0.04$) in Dataset 2. Pygmy rabbit activity at night was also significantly different than other times of day in 5 of the 8 seasons from both datasets (Dataset 1: Fall: $P<0.01$, Spring: $P<0.01$, Winter: $P<0.01$; Dataset 2: Spring: $P=0.02$, Winter: $P<0.01$). Winter afternoons also had high levels of pygmy rabbit activity (Dataset 1: $P=0.09$; Dataset 2: $P<0.01$). No other time of day with season was significant. As results were quite similar for Dataset 1 and Dataset 2, we addressed them together in the rest of this document.

Other wildlife species were recorded with our remote cameras. While photographs of pygmy rabbits (Fig. 2, Table 2) occurred with the highest frequency of appearance (59.72%), other leporids such as black-tailed jackrabbits (*Lepus californicus*, 5.91%) and cottontails (*Sylvilagus spp.*, 23.30%) also occurred at high frequencies (Table 2). Numerous other wildlife species occurred as well, but generally at lower frequencies (Table 2).

DISCUSSION

Throughout the Intermountain West, pygmy rabbits have experienced severe population declines (Flinders, 1999; Janson, 2002) due to anthropogenic disturbances (e.g. habitat fragmentation, increased fire frequency, and overgrazing) currently impacting the sagebrush-steppe habitat type (Heady & Laundré, 2005). This leporid is listed as a state species of special concern throughout its range in California, Idaho, Montana, Nevada, and Utah. Small remaining populations in Washington are listed as state and federally endangered (Federal Register, 2003). In our study we not only used the remote cameras to catalogue activity, but also confirm the presence of pygmy rabbits in a given area. Through these efforts, we have been able to more extensively catalogue the geographic distribution of the pygmy rabbit in Utah.

Pygmy rabbits inhabit large stands of mature big sagebrush with relatively high cover (21 - 36%) (Weiss & Verts, 1984; Katzner & Parker, 1997; Flinders, 1999). This preference for high cover can make it difficult to detect and observe pygmy rabbits, particularly because pygmy rabbits move by running from shrub to shrub and do not cross large open areas (Weiss& Verts, 1984; Dobler & Dixon, 1990). We found that remote cameras placed at burrow entrances recorded valuable information on behavior, sociality, burrow activity that would otherwise be difficult to obtain. While there is some indication that the presence of remote photography equipment may affect animal behavior (Pearson, 1959; Osterberg, 1962; Knudsen, 1963), many species appear to accept the presence of remote photography equipment (Royama, 1970; Franzreb & Hanula, 1995; Larrueca, 2007). This appears to be the case with the pygmy rabbit. While several individuals noticed the remote camera the first time it took a picture, the same individual soon seemed unaffected by the presence of the camera as numerous pictures were taken of it thereafter.

Temporal Differences

Pygmy rabbits are the smallest North American rabbit and measure approximately 26.1-30.8 cm long and weigh between 370-524 g (Janson, 2002). These dimensions give pygmy rabbits a high volume to surface volume ratio, which may make them more vulnerable to temperature extremes (Larrucea, 2007). Pygmy rabbits in our study areas were active during all times of the day but were most active at night. While Larrucea (2007) has documented high crepuscular burrow activity, we found that crepuscular activity was not significant when compared to night time activity in our study areas. This is particularly interesting as some of our study areas can reach lows of -13.6°C in the winter. However, little is known about density of hair, thickness of winter pelage and metabolic adjustments that may limit the effects of volume to surface volume ratios. A diet of big sagebrush, for instance, could create more metabolic heat than other vegetation through the digestion of secondary compounds in big sagebrush, thus allowing the pygmy rabbit to be active in colder temperatures. Moreover, the creation of subnivean tunnels to access big sagebrush and to provide escape cover may help mitigate the effects of this volume to surface volume ratio. Further research is needed to understand this aspect of pygmy rabbit biology.

Pygmy rabbits have many natural predators including badgers (*Taxidea taxus*), bald eagles (*Haliaeetus leucocephalus*), barn owls (*Tyto alba*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), ferruginous hawks (*Buteo regalis*), golden eagles (*Aquila chrysaetos*), great horned owls (*Bubo virginianus*), long-eared owls (*Asio otus*), long-tailed weasels (*Mustela frenata*), northern harriers (*Circus cyaneus*), prairie falcons (*Falco mexicanus*), ravens (*Corvus corax*), red foxes (*Vulpes vulpes*), red-tailed hawks (*Buteo jamaicensis*), rough-legged hawks (*Buteo lagopus*), short-eared owls (*Asio flammeus*), and Swainson's hawks (*Buteo swainsoni*) (Green & Flinders, 1980b; Gahr, 1993; Janson, 2002). While a few of the species listed above are nocturnal predators, a large majority of them are diurnal.

Larrucea (2007) observed that while weasels and badgers can enter the pygmy rabbit burrows, other terrestrial and avian predators outside of the burrow are also a great risk. Avian predation risk is likely reduced by their nocturnal activity since most avian predators are active diurnally. Many of our study areas had high numbers of diurnal avian predators and they could be seen flying over the big sagebrush biotype throughout the day. This was particularly true during the autumn raptor migration and the study area in Grass Valley has an extraordinarily high number of raptors present during this time. The majority of avian predators mentioned above were present in our study areas in large numbers (particularly golden and bald eagles) and many could be found year round. Most owls however, with the exception of the great horned owl, most likely migrated south out of the area for the winter. While these owls are present during the spring and summer in our study areas, there are only 3 (4 in cases when a barn owl is present) species of owls that prey on pygmy rabbits while there are 9 hawk, eagle, and raven species that feed on this leporid. Weasels, badgers, coyotes, and red foxes are present year round and likely prey on pygmy rabbits consistently. However it appears that diurnal avian predators may be a larger risk to pygmy rabbits than their terrestrial counterparts.

As stated by Larrucea (2007), big sagebrush, the main food source for pygmy rabbits, is available at all times and would not account for time of activity. However, in our study area, many large mechanical treatments of big sagebrush have replaced this shrub with native and non-native grasses, forbs, and shrubs. As grasses and forbs compose a portion of their diet during the spring and summer (grasses 39% and forbs 10%; Green & Flinders, 1980a; Green & Flinders, 1980b), pygmy rabbits may enter these treated areas to feed on vegetation that is absent from the stands of big sagebrush. Since these treated areas have very little cover, pygmy rabbits may feed at night to avoid the high number of diurnal avian and terrestrial predators that reside in surrounding areas.

In addition to food and predators, pygmy rabbits may have been more active at night because black-tailed jackrabbits and cottontails also displayed some night time activity (Larrucea, 2007). With a higher number of rabbits active at a particular time, regardless of species, the fitness cost of an individual would decrease (Larrucea, 2007). In other words, the more rabbits that are active, the less likely an individual is to be attacked by a predator. Since pygmy rabbits prefer relatively high sagebrush cover (21 - 36%) (Green & Flinders, 1980a; Green & Flinders 1980b; Weiss & Verts, 1984; Katzner & Parker, 1997; Flinders, 1999), black-tailed jackrabbits and cottontail rabbits that enter more open areas may be subject to higher risk of predation.

Seasonal Differences

There was no significant difference in activity between seasons, but we did find that the majority of night time blocks and seasons were significantly different from all other combinations of time of day and season (Fig. 2). This indicated that pygmy rabbits in our study areas were more active at night, regardless of season. Winter afternoons also had high pygmy rabbit activity but not enough to be significant. As mentioned above, pygmy rabbits have a high surface to volume ratio (Larrucea, 2007) and may be more susceptible to cold weather. Winter afternoons are often the warmest part of the day and pygmy rabbits may take advantage of the warmer weather to sun themselves next to burrow entrances.

We found that deep snow and blizzards made it difficult to photograph pygmy rabbits in winter months. In areas with deeper snow, pygmy rabbits created subnivean tunnels. In some instances, pygmy rabbits stayed below the surface in the snow tunnels, thus preventing cameras from taking their picture unless they came out of the snow tunnel onto the surface. Occasionally snow fall was great enough to completely cover cameras.

Other Wildlife Species

The presence of other wildlife species at pygmy rabbit burrows was not surprising because the burrow can provide refuge from predators and weather for other leporids, rodents, birds, lizards, and insects. Each species may not have the same level of detectability by cameras, as larger wildlife may be more easily detected (Hernandez et al., 1997).

Thirteen species of birds were recorded by our remote camera. Little is known about the presence of birds at pygmy rabbit burrows. Whether they used the actual burrows during the heat of the day or simply used the shade provided by sagebrush is unknown. While not photographed, some birds may "dust bathe" in the soil at the burrow entrances. Further research on this topic is needed to understand avian use of the burrow area.

Our study is the first to record the presence of the western spotted skunk (*Spilogale gracilis*) and feral house cat (*Felis catus*) at pygmy rabbit burrows. The spotted skunk is a known predator of rodents, leporids, and larger insects. They most likely hunt in pygmy rabbit burrows and use these burrows for thermal and security cover. Our remote cameras also recorded feral house cats investigating the burrows of pygmy rabbits. As a feline, the presence of this cat introduces a “sit and wait” predator to the pygmy rabbit. While many terrestrial predators would leave the area of the burrow after a certain amount of time, a feral house cat would typically wait until the pygmy rabbit came back out. Feral house cats may be very effective predators on the pygmy rabbit.

Conclusion

Temporal and seasonal activity patterns are essential to understanding the behavioral ecology critical to the conservation of pygmy rabbits. Use of remote cameras provides a way to understand levels of burrow use by pygmy rabbits and can verify their presence in areas of interest. Remote photography also provides a way to learn what other species may depend upon and use pygmy rabbit burrows.

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Table 1. Pygmy rabbit burrow ranking systems as described by Rachlow & Witham (2004) and Ulmschneider et al. (2004) used in our studies in Utah.

Rachlow & Witham (2004) Rating System

Burrow Activity Ranking	Abbreviation	Description
Active	Level 1	Open/intact burrow entrance, fresh pellets and fresh diggings
Recent	Level 2	Open/intact burrow entrance, old/weathered pellets, absent/old/few tracks
Old	Level 3	Intact/open/debris present at burrow entrance, pellets absent/old/few
Very Old	Level 4	Burrow collapsed, pellets absent, digging absent/ old/few

Ulmschneider et al. (2004) Ranking system

Burrow Activity Ranking	Abbreviation	Description
Used burrow plus fresh pellets	B+FP	Brown pellets near a burrow, at least one entrance open, without cobwebs or debris that shows lack of use, usually shows a trail
Unused burrow plus fresh pellet	UB+FP	Burrow entrances have cobwebs, grass seeds, or other debris in entrance, but with brown pellets. May show transitory use.
Burrow plus old pellets	B+OP	Only grey pellets at a burrow, entrances may show signs of non-use
Burrow, no pellets	B	Burrow entrance is not collapsed but no pellets found
Collapsed burrow	COL	No pellets
Pellets only	P	No burrows found, but pellets appear right for pygmy rabbit
Fresh digging at a burrow but no pellets	B+DIG	Digging may have been by a predator such as coyote or badger
Possible PR burrow	POSS	Burrow seems right for pygmy rabbit, but there are confusing pellets or no pellets, or it is not in association with other pygmy rabbit burrows (identified by pellets or sightings)

Table 2. The following wildlife species were photographed by remote cameras focused at pygmy rabbit burrow entrances.

Order/Genus/Species	Common Name	Number Seen	Percent Frequency		Order/Genus/Species	Common Name	Number Seen	Percent Frequency
Brachylagus idahoensis	Pygmy rabbit	4944	59.72%		Orthoptera	Grasshopper spp.	5	0.06%
Sylvilagus spp.	Cottontail	1929	23.30%		Spizella breweri	Brewer's sparrow	4	0.05%
Lepus californicus	Black-tailed jackrabbit	489	5.91%		Coleoptera	Beetle spp.	4	0.05%
Peromyscus maniculatus	Deer mouse	258	3.12%		Zonotrichia leucophrys	White-crowned sparrow	4	0.05%
Unidentifiable lagomorph	Rabbit spp.	175	2.11%		Odocoileus hemionus	Mule deer	3	0.04%
Eutamias minimus	Least chipmunk	96	1.16%		Pipilo chlorurus	Green-tailed towhee	3	0.04%
Sceloporus spp.	Lizard	74	0.89%		Bos taurus	Domestic Cow	3	0.04%
Oreoscoptes montanus	Sage thrasher	61	0.74%		Pooecetes gramineus	Vesper sparrow	2	0.02%
Dipodomys ordi	Ord kangaroo rat	55	0.66%		Sialia currucoides	Mountain bluebird	2	0.02%
Mustela frenata	Long-tailed weasel	50	0.60%		Amphispiza belli	Sage sparrow	2	0.02%
Ammospermophilus leucurus	Whitetail antelope squirrel	28	0.34%		Junco hyemalis	Dark-eyed junco	2	0.02%
Salpinctes obsoletus	Rock wren	25	0.30%		Piplo maculatus	Spotted Towhee	1	0.01%
Taxidea taxus	American badger	20	0.24%		Ovis aries	Domestic Sheep	1	0.01%
Felis domesticus	Feral cat	13	0.16%		Spizella passerina	Chipping sparrow	1	0.01%
Spilogale gracilis	Western Spotted skunk	8	0.10%		Tyrannus verticalis	Western kingbird	1	0.01%
Citellus variegatus	Rock squirrel	8	0.10%		Gryllidae Rhaphidophoridae	Camel Cricket	1	0.01%
Canis latrans	Coyote	6	0.07%		Gymnorhinus cyanocephalus	Pinyon jay	1	0.01%

Figure 1. Above are images of pygmy rabbits from photographs taken in our study areas in south-central Utah by Digital Ranger S600 SB CamTrak Cameras.

Dataset 1 **Dataset 2**

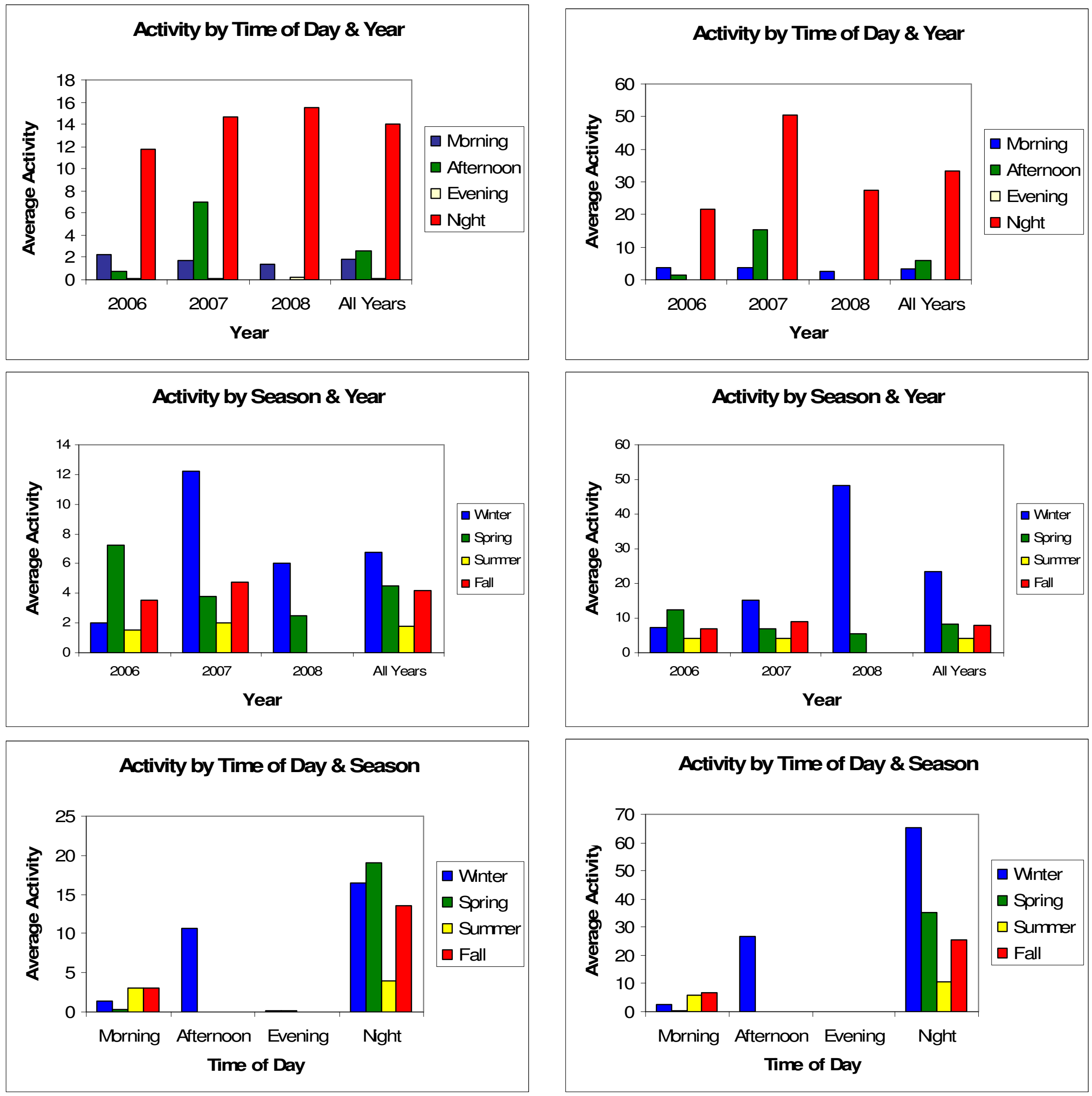

Figure 2. We documented the following activity patterns for pygmy rabbits in our study areas for 2006-2008. Activity level is defined as the number of photographs divided by effort (the number of remote cameras in operation) within a site. Summer and fall data has yet to be collected and/or analyzed for 2008 and were not included in this analysis. Note the different scales on each graph.