

Fragmentation of sagebrush communities: does an increase in habitat edge impact pygmy rabbits?

J. E. Pierce¹, R. T. Larsen¹, J. T. Flinders¹ & J. C. Whiting²

¹ Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT, USA

² S.M. Stoller Corporation, Idaho Falls, ID, USA

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Correspondence

Randy T. Larsen, Department of Plant and Wildlife Sciences, Brigham Young University, Provo, Utah 84602, USA. Tel: 801-422-2322
Email: randy_larsen@byu.edu

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Abstract

Sagebrush (*Artemisia* spp.) communities are ecologically critical; however, these areas currently face severe threats from alteration and reduction. Pygmy rabbits *Brachylagus idahoensis* are sagebrush specialists that occupy the intermountain region of the USA. Little is known concerning how fragmentation of sagebrush and an increase in habitat edge may impact pygmy rabbits. From 2004 to 2009 in Utah, USA, we tested hypotheses concerning the influences of habitat edge on pygmy rabbits. We quantified the number of active pygmy rabbit burrows in relation to distance from habitat edge. At differing distances from habitat edge, we also deployed remote cameras at burrows and counted fecal pellets to document potential increases in the number of terrestrial predators and competitors. We classified activity of 528 burrows (284 active and 244 inactive). The proportion of active burrows was lower within 100 m of habitat edge ($r^2 = 0.502$, $P = 0.02$) compared with burrows located in control areas (>100 m from habitat edge). Photographs of pygmy rabbits decreased at burrows closer to habitat edge ($P < 0.01$). Photographs of predators increased near habitat edge, but was marginally insignificant ($P = 0.07$), and photographs of potential competitors [cottontail (*Sylvilagus* spp.), $P < 0.01$; jackrabbit *Lepus californicus*, $P < 0.01$] increased near habitat edge. Fecal pellet plots supported these patterns. Our results indicated that the proportion of active burrows and the relative abundance of pygmy rabbits were reduced near habitat edge. This reduction was associated with an increase in terrestrial predators and competitors near habitat edge. Consideration should be given to the influence of habitat edge on pygmy rabbits in order to conserve and manage this unique species.

Introduction

Sagebrush *Artemisia* spp. ecosystems are extremely important for many wildlife species; however, fragmentation, overgrazing, fire management practices, wildfires, and mechanical treatment have reduced sagebrush communities and impacted their associated fauna (Holechek, 1981; Knick, 1999; Knick *et al.*, 2003). Wildfires have increased in intensity and extent across the western USA since the early 1900s, leaving sagebrush communities fragmented (Knick, 1999; Westerling *et al.*, 2006; Brown & Thorpe, 2008). The frequency and intensity of wildfires is thought to be increasing due to climate change (Chambers & Pellant, 2008; Larrucea & Brussard, 2008c) and exotic plant invasions – particularly cheatgrass *Bromus tectorum* (D'Antonio & Vitousek, 1992; Billings, 1994). From 1990 to 2007, an estimated 16 million acres burned in the sagebrush-steppe regions of the Great Basin (Jones & Monaco, 2009). Along with increased intensity and extent of wildfires, sagebrush ecosystems are being chemically and mechanically treated by land managers to improve habitat for livestock and

wildlife (Gabler, Heady & Laundre, 2001). The scope and scale of these treatments have increased in recent years as land managers attempt to restore and improve degraded sagebrush habitats. These alterations to sagebrush ecosystems create fragmented habitats that may have profound impacts on sagebrush obligate species.

Habitat fragmentation and subsequent increases in edge can threaten biodiversity (Murcia, 1995; Lacerda, Tomas & Marinho, 2009). Edge effect is an ecological process resulting from fragmentation of habitat patches that produce interactions between two adjacent ecosystems separated by an abrupt edge. This increase in edge can have direct biological effects, which include changes in species abundance and distribution, because of alterations in overall conditions near edge (Murcia, 1995; Fletcher *et al.*, 2007). Additionally, an increase in edge can produce indirect biological effects, such as an increase in predation, parasitism, and competition (Asquith & Mejia-Chang, 2005; Lacerda *et al.*, 2009).

Pygmy rabbits *Brachylagus idahoensis* are sagebrush specialists (Green & Flinders, 1980a; Thines, Shipley & Saylor, 2004) that occupy the intermountain region of the

USA (Larrucea & Brussard, 2008b). These specialized leporids prefer areas of relatively high sagebrush cover on loose, alluvial soils (Weiss & Verts, 1984; Flinders, 1999). Pygmy rabbits consume up to 99% big sagebrush *A. tridentata* ssp. during winter and 51% during summer (Green & Flinders, 1980b; Gahr, 1993). These rabbits rely on areas of contiguous sagebrush habitat throughout all phases of their life cycle and may be particularly sensitive to fragmentation and alteration of sagebrush communities (Weiss & Verts, 1984; Katzner & Parker, 1997; Thines *et al.*, 2004; Larrucea & Brussard, 2008b,c). Given the scope and scale of change occurring in sagebrush habitats, recent petitions have argued that pygmy rabbits warrant listing under the United States Endangered Species Act because these leporids may be declining across their range.

Pygmy rabbits may be particularly sensitive to indirect edge effects because predation—particularly mammalian predation—is a major source of mortality for these leporids (Sanchez, 2007; Crawford, 2008; Estes-Zumpf & Rachlow, 2009). Moreover, other leporid species may respond positively to edge and compete with or displace the smaller pygmy rabbits at burrows (Thines *et al.*, 2004). As alteration of sagebrush habitat continues across the Western USA, a need exists to understand the response of pygmy rabbits to fragmentation and an increase in habitat edge (Flinders, 1999; Larrucea & Brussard, 2008b).

Despite large-scale alterations in sagebrush communities, very little is known regarding the response of pygmy rabbits to these disturbances. Additionally, data are lacking regarding the response of predators and competitors to habitat edge. Large-scale mechanical treatment of sagebrush habitat in Utah, USA, provided a unique opportunity to study the influence of an increase in habitat edge on pygmy rabbits. We (1) quantified the number of active pygmy rabbit burrows in relation to habitat edge; (2) used remote cameras deployed at burrows to document the number of visits to burrows by pygmy rabbits, terrestrial predators, and potential competitors; and (3) counted fecal pellets near edge and in adjacent reference area. Given life-history characteristics of pygmy rabbits as sagebrush obligates that prefer dense stands of mature sagebrush, we predicted that: (1) the proportion of active burrows would decrease closer to habitat edge, indicating a potential edge effect; (2) an increase in occurrence of predators and competitors of pygmy rabbits would occur at burrows closer to habitat edge (*sensu* Lacerda *et al.*, 2009); (3) relative abundance as measured by fecal pellets would decrease for pygmy rabbits and increase for competitors of pygmy rabbits near habitat edge. Our results will provide important information regarding some of the influences of habitat fragmentation, which will aid with the conservation and management of this unique leporid.

Methods

Study area

Our study was conducted in Grass Valley of south-central Utah (38°16'N, 111°54'W, Fig. 1). This area receives



Figure 1 Areas of fragmented sagebrush (foreground) produced by mechanically treating sagebrush and control areas (>100 m from habitat edge, background) in Utah, USA. From 1997 to 2003, 5665 ha of sagebrush habitat were mechanically altered to increase production of grasses and forbs and restore sagebrush understory. Photo courtesy of K. Rasmussen.

24.2 cm of precipitation annually, an average of 87.4 cm of snowfall, and temperatures range from -12.2 to 29.3 °C (Western Regional Climate Center, 2007). Grass Valley ranges in elevation from 2017 to 2208 m. Upper hillsides are dominated by juniper (*Juniperus* spp.), pinyon pine *Pinus edulis*, and aspen *Populus tremuloides*, whereas big sagebrush and other shrub-dominated communities along with wet grassy valley bottoms and agricultural fields occur at low elevations. Soil types are similar throughout the valley at a broad scale and pygmy rabbits occur throughout big sagebrush habitats in this area. Potential predators of pygmy rabbits occupying our study area included a suite of mammalian and avian predators (Lee *et al.*, 2010). Primary competitors of pygmy rabbits in our area were black-tailed jackrabbits *Lepus californicus* and cottontails (*Sylvilagus* spp.).

Between 1997 and 2003, land managers used a 435 horsepower tractor to pull a 13.1 m (7273 kg) or 8.2 m (3636 kg) wide Dixie Harrow once or twice over areas of sagebrush in order to restore grass and forb understory. During that time, 5665 ha of sagebrush habitat were mechanically altered (Greenwood, 2004). In mechanically treated areas, sagebrush islands and potential travel corridors for wildlife, usually along drainages, were left untreated producing a mosaic pattern of unaltered stands of sagebrush intermixed with areas cleared of sagebrush (Greenwood, 2004) (Fig. 1).

Classifying pygmy rabbit burrows

In conjunction with wildlife biologists from the Richfield, UT, office of the United States Bureau of Land Management, we surveyed for and marked burrow complexes of pygmy rabbits using a GPS unit in our study area from November 2004 to August 2009. We followed established protocol for locating and identifying pygmy rabbit burrows, which included walking survey routes in areas suspected to be occupied by pygmy rabbits (Ulmschneider *et al.*, 2004).

We classified burrows as used or unused based on the appearance of fecal pellets and characteristics of burrow entrances (Roberts, 2001; Rachlow & Witham, 2004; Sanchez *et al.*, 2009). We followed methodology of Sanchez *et al.* (2009) and considered burrows as used when they were included in the category of active or recent and as unused when they were included in the category of old or very old. We imported all burrow locations into ArcGIS® (ESRI, Redlands, CA, USA), and then used available tools to determine the distance of all burrows from habitat edge produced by mechanical treatment of sagebrush.

Estimates of home-range size for pygmy rabbits vary from 2.8 to 12.0 ha depending on season and sex (Sanchez & Rachlow, 2008). Pygmy rabbits are known to use more than one core area within their home range; however, these leporids spend much of their time within 30–100 m of burrow systems (Katzner & Parker, 1997; Heady & Laundré, 2005; Crawford, 2008). Given these small patterns of space use, and to test for a relationship between burrow activity and distance from habitat edge, we calculated the proportion of active burrows in 10 m increments from habitat edge up to 100 m into contiguous sagebrush. We considered all burrows located in areas >100 m from habitat edge as occurring in control areas, and we calculated a mean and 95% CI to compare the proportion of active burrows in control areas to that in areas near habitat edge. We then plotted these results and used simple linear regression to investigate the potential influence of distance from habitat edge on burrow activity in these areas. We chose this approach over logistic regression because we expected a threshold-type relationship between the response (proportion of active burrows) and explanatory variable (distance from habitat edge) where distance was a significant influence across some, but not all distances. Logistic regression assumes a constant linear relationship between the log-odds of the response and explanatory variable across all observed distances. As with linear models in general, this approach can give inaccurate results when threshold-type responses are present (Zuur *et al.*, 2009). In our case, we expected distance to influence the proportion of active burrows, but only across the initial distances (i.e. 0–100 m).

Remote cameras

Remote cameras have proven useful in efforts to document activity and distribution of pygmy rabbits (Larrucea & Brussard, 2008a,b, 2009; Lee *et al.*, 2010). We deployed Digital Ranger S600 SB CamTrak Cameras (CamTrak South Inc., Watkinsville, GA, USA) from May 2006 to August 2009 at 313 burrow complexes randomly selected from the list of all known complexes in our study area. Cameras were active for 24 h day⁻¹, and we placed cameras within 3 m of burrow systems for up to 4 weeks. We set cameras to focus on a single burrow and the surrounding area (Lee *et al.*, 2010). No scent lures were used in association with cameras.

We considered the following species as terrestrial predators of pygmy rabbits: badgers *Taxidea taxus*, bobcats *Lynx*

rufus, coyotes *Canis latrans*, feral house cats *Felis catus*, long-tailed weasels *Mustela frenata*, and red foxes *Vulpes vulpes* in order to analyze the potential increase in relative abundance of terrestrial predators in relation to distance from habitat edge. For this analysis, we pooled the number of photographs for all mammalian predators during each camera's sampling period. For our analyses, we considered black-tailed jackrabbits and cottontails (Thines *et al.*, 2004) as leporids that could compete with or displace pygmy rabbits at burrows. These species were the only other leporids in our study area.

Analyzing photographs can be problematic because this information is technically considered count data. Although counts are a common ecological response of interest, they often do not conform to assumptions of normality required for traditional linear regression. In this scenario, use of the Poisson or negative binomial distribution is recommended. The negative binomial distribution in particular has been suggested as a flexible alternative for analysis of count data (White & Bennetts, 1996). We used the negative binomial distribution to model photo counts as a function of elapsed sampling time and distance from habitat edge given its flexibility and the characteristics of our dataset. We included elapsed sampling time in the linear model to account for its influence, but we were primarily interested in distance to habitat edge. We then used the fitted model (coefficients) to plot and predict the expected number of photographs of pygmy rabbits, cottontail rabbits, black-tailed jackrabbits, and predators of pygmy rabbits in relation to distance from habitat edge. We used the `pscl` (Zeileis, Kleiber & Jackman, 2007) and `MASS` (Venables & Ripley, 2002) libraries in version 2.7 of program R (R Development Core Team, 2007) to perform these analyses.

Fecal pellet plots

From 2005 to 2007, we established plots to monitor deposition of fecal pellets as an index of habitat use by pygmy rabbits, cottontails, and black-tailed jackrabbits in relation to habitat edge. We identified pellets based on size, shape, and color (Rachlow & Witham, 2004; Ulmschneider *et al.*, 2004; Sanchez *et al.*, 2009). Counts of fecal pellets have been used extensively to measure rabbit and hare day-use occurrences, population abundance, and activity (Forsy & Humphrey, 1997; Sugimura & Yamada, 2004). These counts have also been used to verify the presence of pygmy rabbits (Rachlow & Witham, 2004; Ulmschneider *et al.*, 2004; Sanchez *et al.*, 2009). To decrease biases caused by lack of experience (Neff, 1968), the same researchers counted pellets each month, and all individuals were trained to identify each species pellet by size, shape, and color (Rachlow & Witham, 2004; Ulmschneider *et al.*, 2004; Sanchez *et al.*, 2009).

To understand the use of habitats near edges, we randomly selected active burrows in areas of sagebrush that were within 15 m of a habitat edge. From that active burrow, we randomly selected a point around the burrow complex (within 10 m) to initiate a sampling plot. We then established a 30 m transect perpendicular to the habitat edge

that extended from the selected point, across the area of sagebrush and habitat edge, and into the area that was mechanically treated. We divided this 30 m transect into thirds, and within each 10 m segment established 0.25 m² square quadrats at 3, 6, and 9 m. Three of those quadrats were oriented within areas of sagebrush, while the remaining six quadrats extended into areas that were mechanically treated. We established plots at 13 different locations and counted and cleared all pygmy rabbit, cottontail, and black-tailed jackrabbit fecal pellets monthly at each quadrat from June to October 2005, March to October 2006, and April to October 2007. Plots were separated by an average distance of 453 m.

To establish plots in control areas (>100 m from habitat edge), we followed similar protocol for selection of active burrows, but required they be >100 m from habitat edge (\bar{x} distance = 4916 m, s_D = 5879 m, range = 112–13 508 m). We then placed 0.25 m² fecal pellet quadrats in similar fashion. We established 13 of these plots to mirror sampling in areas near habitat edge. We counted and cleared all pygmy rabbit, cottontail, and black-tailed jackrabbit fecal pellets at each quadrat during the same dates indicated previously. Plots were separated by an average distance of 2028 m. To assess differences in the number of fecal pellets deposited by leporid species, we calculated means and 95% CIs for number of fecal pellets by species in areas near habitat edge that were located in sagebrush (i.e. within sagebrush up to 7 m from habitat edge), in areas that were devoid of sagebrush (i.e. from habitat edge up to 19 m into areas that were mechanically treated) and in control areas (>100 m from habitat edge).

Results

Classifying pygmy rabbit burrows

We classified activity level of 528 burrows (284 active and 244 inactive) during our study. A significant positive relationship existed for burrow activity regressed on distance from habitat edge up to 100 m ($\hat{y} = 0.0343x + 0.347$, $r^2 = 0.502$, $P = 0.02$, Fig. 2), indicating that burrows located closer to edge were more likely to be classified as inactive compared with burrows farther from treatment edges and in control areas (>100 m from habitat edges). In control areas, 61% of burrows were classified as active (Fig. 2). Mean (\pm SD) distance of pygmy rabbit burrows from habitat edge in control areas was 1873 m (\pm 2984 m, range = 100–13 623 m).

Remote cameras

Coefficients from models of photo count as a function of elapsed sampling time and distance from habitat edge indicated strong influences for both effects (Table 1). Photo counts of pygmy rabbits decreased at burrows as distance to habitat edge decreased ($P < 0.01$). Conversely, photo counts of predators of pygmy rabbits increased with decreasing distance from habitat edge, but was marginally insignificant ($P = 0.07$). Photo counts of jackrabbits ($P < 0.01$) and cottontails ($P < 0.01$) increased as distance to habitat edge

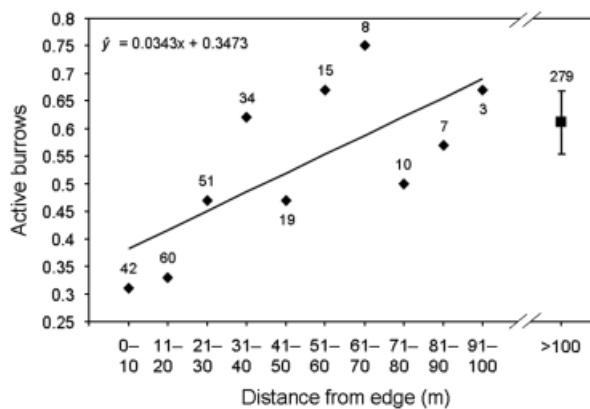


Figure 2 Proportion of active burrows (sample size near points) regressed on distance from habitat edge, and mean (\pm 95% CI) for all burrows located in control areas (>100 m from habitat edge) for pygmy rabbits *Brachylagus idahoensis* in Utah from 2004 to 2009. Burrows located closer to habitat edge were more likely to be classified as inactive compared with burrows in control areas.

Table 1 Coefficients and statistical estimates from models of photo counts for pygmy rabbits *Brachylagus idahoensis*, cottontails *Sylvilagus* spp., black-tailed jackrabbits *Lepus californicus*, and predators of pygmy rabbits as a function of camera sampling time and distance from habitat edge

| Coefficients | Estimate | SE | z-statistic | P |
|--------------------------|----------|--------|-------------|-------|
| Pygmy rabbits | | | | |
| Intercept | 2.488 | 0.3076 | 8.115 | <0.01 |
| Sampling time | 0.014 | 0.0093 | 1.550 | 0.12 |
| Distance edge | 0.001 | 0.0004 | 2.743 | <0.01 |
| Cottontails | | | | |
| Intercept | 1.371 | 0.3235 | 4.24 | <0.01 |
| Sampling time | 0.027 | 0.0098 | 2.79 | <0.01 |
| Distance edge | -0.001 | 0.0005 | -2.98 | <0.01 |
| Black-tailed jackrabbits | | | | |
| Intercept | 0.573 | 0.3143 | 1.823 | 0.07 |
| Sampling time | 0.030 | 0.0095 | 3.200 | <0.01 |
| Distance edge | -0.002 | 0.0005 | -4.371 | <0.01 |
| Predators | | | | |
| Intercept | 0.107 | 0.5580 | 0.192 | 0.84 |
| Sampling time | -0.003 | 0.0171 | -0.187 | 0.85 |
| Distance edge | -0.002 | 0.0009 | -1.817 | 0.07 |

decreased (Table 1). Further, predicted number of photographs based on fitted models showed strong patterns in all cases with changes occurring for pygmy rabbits, cottontails, jackrabbits, and predators between 100 and 350 m from habitat edge (Fig. 3).

Fecal pellet plots

We cleared all plots seven times in 2005 (control = 3, near habitat edge = 4), 14 times in 2006 (control = 7, near habitat edge = 7), and 12 times in 2007 (control = 6, near habitat edge = 6). During the study, we collected 34 207 fecal pellets

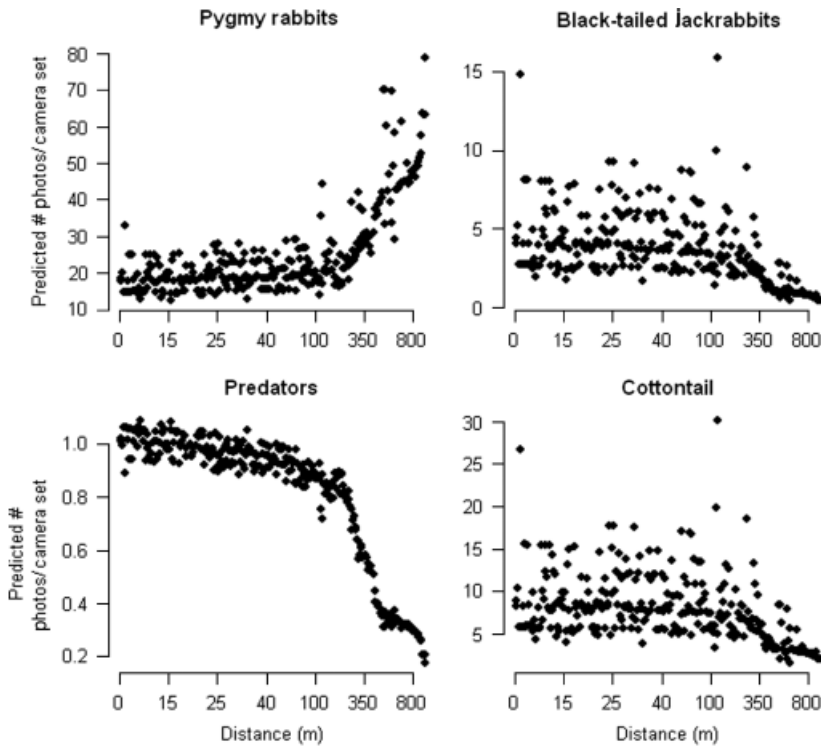


Figure 3 Predicted number of photographs for pygmy rabbits *Brachylagus idahoensis*, cottontail rabbits *Sylvilagus* spp., black-tailed jackrabbits *Lepus californicus*, and predators of pygmy rabbits based on models derived from observed photograph counts at varying distances from habitat edge (x-axis). Patterns show reduced photo counts for pygmy rabbits near habitat edge with increasing counts beyond 100 m, whereas predators and competitors showed the inverse pattern of higher counts near habitat edge.

of pygmy rabbits, 15 926 fecal pellets for cottontails, and 16 328 fecal pellets for black-tailed jackrabbits. In areas of sagebrush within 7 m of habitat edge, mean number of pygmy rabbit pellets was lower across all quadrats compared with number of pygmy rabbit pellets in control areas (Fig. 4). Within treatment areas, mean number of pellets for pygmy rabbits was significantly lower than in control areas and areas of sagebrush within 7 m of habitat edge (Fig. 4). Also in treatment areas, mean number of pellets for jackrabbits and cottontails was significantly higher compared with control areas and areas of sagebrush within 7 m of habitat edge (Fig. 4).

Discussion

Our results indicated that the proportion of active burrows, photo counts, and mean number of fecal pellets for pygmy rabbits decreased significantly near habitat edge. Increases in habitat edge can produce direct biological effects, which can include changes in species abundance, because of alterations in overall conditions near edge (Murcia, 1995; Fletcher *et al.*, 2007). Habitat fragmentation and subsequent increases in edge can be major threats to biodiversity (Lacerda *et al.*, 2009), and a need exists to understand the response of pygmy rabbits to disturbance of sagebrush ecosystems (Flinders, 1999; Larrucea & Brussard, 2008c). Our results hold important conservation implications, because wildfires and mechanical treatment of sagebrush are increasing in frequency and intensity, and these disturbances produce an increase in habitat edge (Larrucea & Brussard, 2008c). When conserving or managing habitat for pygmy

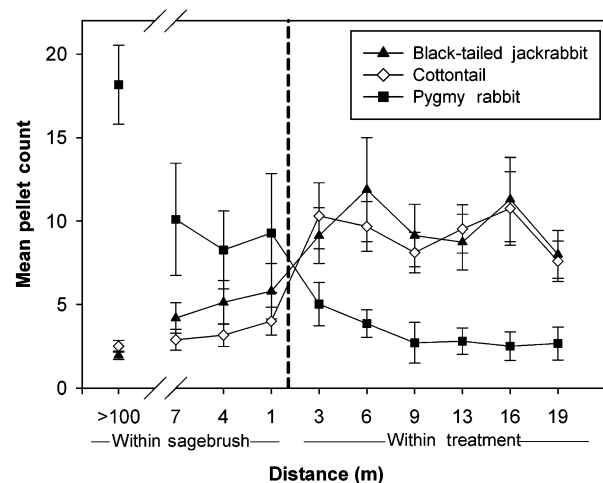


Figure 4 Mean pellet counts (\pm 95% CIs) by leporid species in control areas (> 100 m within sagebrush), within sagebrush (7 m to 1 m) near habitat edge (dashed vertical line), and within mechanically treated areas devoid of sagebrush (3 m to 19 m). Counts of pygmy rabbit *Brachylagus idahoensis* pellets were much higher in control areas and decreased near habitat edge and into areas devoid of sagebrush, whereas the converse was true for jackrabbits *Lepus californicus* and cottontails *Sylvilagus* spp.

rabbits, wildlife managers and conservationists need to consider the reduction in active burrows and relative abundance of pygmy rabbits we observed near habitat edges.

We documented an increase in the photo counts of terrestrial predators at pygmy rabbit burrows closer to

habitat edge, with a decrease in such photographs at burrows farther from edge. These results provide support for our prediction that an increase in occurrence of predators would occur near habitat edge. Indeed, an increase in habitat edge can produce indirect biological effects, such as an increase in predation (Murcia, 1995; Asquith & Mejia-Chang, 2005; Lacerda *et al.*, 2009). Predation, especially by terrestrial predators, is a major source of mortality for pygmy rabbits (Green & Flinders, 1980a; Sanchez, 2007; Crawford, 2008; Estes-Zumpf & Rachlow, 2009). Additionally, we documented an increase in relative abundance (fecal pellets) of jackrabbits and cottontails near habitat edge and in areas devoid of sagebrush adjacent to habitat edge, indicating that these leporids responded positively to a reduction of sagebrush. We hypothesize that an increase in other leporid species may support an increase in predators near habitat edge. These ideas potentially explain the decrease in proportion of active burrows we observed within 100 m of habitat edge.

Our results indicated that photo counts of jackrabbits and cottontails increased significantly at burrows located closer to habitat edge. These results are consistent with the idea that an increase in habitat edge may lead to an increase in competitors (i.e. indirect biological effects) (Murcia, 1995; Asquith & Mejia-Chang, 2005; Lacerda *et al.*, 2009). Cottontails do not dig their own burrows, but these leporids may compete with or displace pygmy rabbits at burrows (Thines *et al.*, 2004; Larrucea & Brussard, 2008b). We hypothesize that this potential increase in competitors near edge and in areas devoid of sagebrush adjacent to habitat edge contributed to the decrease in burrow activity of pygmy rabbits we documented.

The spread of infectious diseases, coupled with habitat loss and climate change, can contribute to extinctions of species and is an important issue in wildlife conservation (Smith, Acevedo-Whitehouse & Pedersen, 2009). Diseases and parasites are common among leporids (Morner & Addison, 2001; Samuel, Pybus & Kocan, 2001; Harrenstien *et al.*, 2006). Jackrabbits and cottontails are susceptible to numerous diseases, which cause periodic population die-offs (Flinders, 1999). Our results indicated that jackrabbits and cottontails increased use of areas near edge. These results could have serious impacts for pygmy rabbits with regard to the transmission of diseases among these sympatric leporids. Jackrabbits and cottontails occupy much larger, continuous areas that overlap the fragmented areas of sagebrush occupied by pygmy rabbits. As more jackrabbits and cottontails occupy areas devoid of sagebrush adjacent to areas used by pygmy rabbits near habitat edges, we hypothesize that diseases and parasites contracted by jackrabbits and cottontails may spread much easier and faster, and therefore could be more detrimental to pygmy rabbits in fragmented sagebrush.

Alteration and fragmentation of sagebrush could limit the size and stability of pygmy rabbit populations due to potentially low capabilities for dispersal of this species across unsuitable habitat (Katzner & Parker, 1997; Larrucea & Brussard, 2008c). Pygmy rabbits use shrubs for cover and

large open spaces may act as a barrier to movement (Weiss & Verts, 1984; Estes-Zumpf & Rachlow, 2009). Movement by pygmy rabbits, however, can be facilitated when animals are able to use corridors or stop in residual clumps of sagebrush that are interspersed among unsuitable habitat (Weiss & Verts, 1984; Katzner & Parker, 1998; Estes-Zumpf & Rachlow, 2009). Additionally, dispersing pygmy rabbits may be more susceptible to predation as they travel from sagebrush stands and cross areas that are devoid of sagebrush (Estes-Zumpf & Rachlow, 2009). When mechanically reducing sagebrush habitat, predation may be minimized and genetic exchange maintained by providing corridors for dispersal to other areas of suitable pygmy rabbit habitat.

Pygmy rabbits rely on areas of contiguous sagebrush habitat throughout all phases of their life cycle (Weiss & Verts, 1984; Thines *et al.*, 2004). These leporids are designated as a Category 2 species by the United States Fish and Wildlife Service with one population in Washington, USA, considered critically endangered. As big sagebrush habitat obligates, the amount of available habitat for these leporids is reduced over the short term when their critical habitat is removed by large-scale disturbances that reduce or eliminate the dominance of mature big sagebrush. Our results indicate that the proportion of active burrows, photo counts, and mean number of fecal pellets of pygmy rabbits were reduced near habitat edges, produced by mechanical alteration of sagebrush communities. We hypothesize that the reduction in burrow activity and relative abundance of pygmy rabbits we observed near edge was caused by an increase in terrestrial predators and competitors and suggest further work to test this hypothesis. When and where mechanical treatment of sagebrush does occur, we recommend that a buffer of at least 100 m around burrow systems be left in order to conserve and manage areas used by this unique species.

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