Bryce Canyon National Park: Utah Prairie Dog Management and Conservation Strategy

Final report to Bryce Canyon National Park

By Dana H. Ikeda and Kirsten E. Ironside

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Merriam-Powell Center for Environmental Research
Northern Arizona University

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Summary

A management and conservation strategy for the Utah prairie dog (UPD) —a species federally listed as threatened—at Bryce Canyon National Park (BRCA) has been needed since 1974, when the animals were reestablished in the park. The UPD lives only in southern Utah, and BRCA is the only National Park Service unit in which the UPD is found. Since UPDs were reintroduced to BCNP, they have abandoned or colonized various meadows in the park. Of the 13 historically active colonies in BCNP, 7 colonies are currently active. Groups have filed suit against the U.S. Fish and Wildlife Service, claiming, in part, that federal agencies have not done enough to protect UPDs and recover the species on public lands.

Project Overview

This project inventoried park meadows that are currently occupied by UPDs or are areas of potential habitat, determined their condition and carrying capacity, and establish prescriptions for the management of these meadows as UPD habitat. This information will help park managers to set long-term population goals for UPD colonies.

The primary objectives and end results for the project are as follows:

1. A summary of the natural history of the prairie dog, with emphasis on the Utah prairie dog;
2. An environmental setting describing Bryce Canyon National Park;
3. A summary of the history of habitation of Bryce Canyon National Park by Utah prairie dogs and past reestablishment efforts;
4. A field assessment of all park meadows suitable for Utah prairie dogs, including their present characteristics and estimated carrying capacity, history of use, and recommended prescriptions for improvement as UPD habitat;
5. Management issues and recommendations;
6. Research needs and gaps in the current state of knowledge.

Natural History of the Prairie Dog

Prairie dogs (*Cynomys* spp.) are highly social rodents that form small to large colonies. They are herbivores that engage in extensive burrowing over large areas in grassland habitats also commonly inhabited by ungulates. Prairie dogs have experienced significant declines in populations across all species, mainly because of human extirpation efforts and a high susceptibility to outbreaks of plague. At the beginning of the 20th century there were an estimated 40 million ha of prairie dog habitat, but by 1960 there were just 600,000 ha remaining. Populations across all species are estimated to have declined by as much as 90 percent since 1900 (Marsh 1984), mainly owing to sylvatic plague (*Yersinia pestis*), a pathogen not native to North America, and human-related habitat alterations such as changes in fire regimes, destruction of habitat, and hunting/poisoning.

Prairie Dog Ecology

All species of Cynomys are restricted in range to areas with low-stature vegetation and open plant communities (Collier 1974, Crocker-Bedford and Spillet 1977). Prairie dogs are an integral part of the ecosystems they occupy and have been characterized as a “keystone species” (Miller et al. 1994) because of their importance as a prey species. For example, prairie dogs are a large component of the diets of ferrets, birds of prey, foxes, and badgers. Other species, such as plovers and burrowing owls, rely on prairie dog burrows for nesting areas. Prairie dogs have also been described as “ecosystem engineers” (Jones et al. 1994) because of their ability to alter vegetation characteristics, such as species biomass, productivity, diversity, height, and composition (Bonham and Lerwick 1976, Coppock et al. 1983, Archer et al. 1987, Slobodchikoff et al. 2009). These burrowing rodents have also been shown to modify vegetation physiognomy by preventing the establishment or spread of competitively dominant shrubs (Weltzin et al. 1997).

Foraging and burrowing activity by Gunnsion’s prairie dog (*Cynomys gunnisonii*) have been shown to affect plant diversity (Slobodchikoff et al. 1988), vegetation height and cover (Davidson 2005), and heterogeneity of landscape (Bangert and Slobodchikoff 2000). A study by Weltzin et al. (1997) examined the hypothesis that the decline of black-tailed prairie dog (*C. ludovicianus*) resulted in the subsequent increase of woody plants, particularly honey mesquite (*Prosopis glandulosa*). Their study demonstrated that the presence of herbivores can modify vegetation physiognomy by preventing the establishment or spread of competitively dominant shrubs. Prairie dogs have also been shown to affect not only animal community structure (Ceballos et al. 1999, Smith and Lomolino 2004, Collinge et al. in press), but also alter soil properties (Carlson and White 1987, Munn 1993), such as nutrient cycling (Whicker and Detling 1988).

There are a total of five species of prairie dogs, ranging in distribution from the northern Rocky Mountains down into Mexico. These five species fall into two distinct taxonomic groups characterized by their tail color: the white-tailed group and black-tailed group. The white-tailed group includes three species: Gunnison’s prairie dog, Utah prairie dog, and the white-tailed prairie dog (*C. leucurus*). The black-tailed group comprises the black-tailed prairie dog and the Mexican prairie dog (*C. mexicanus*). All three of the white-tailed species hibernate inside burrows during the winter, while the black-tailed group is active throughout the year (Harlow and Menkens 1986, Harlow and Frank 2001, Lehmer and Van Horned 2001). Two of the species, the Utah prairie dog and the Mexican prairie dog, have legal protection under the Endangered Species Act (Federal Register 35 FR 8491-8498 and 38 FR 14678).

All species of prairie dogs have experienced significant declines in populations throughout the past century, but the UPD has experienced some of the most considerable losses of both population and habitat. The distribution of the UPD has decreased by approximately 87 percent from the 1920s to the 1970s owing to the initiation of control programs. Original numbers were thought to be as high as 95,000 individuals in the 1920s. By the late 1970s, only 37 colonies were active, resulting in the species being classified as "endangered." After a short recovery effort, the species was down-listed to "threatened" in 1984. The population is currently thought to number only 6,000 individuals (Utah Division of Wildlife Resources, personal communication).

Today, approximately 75 percent of all UPDs reside on privately owned lands. Since 1972, land management agencies have been actively relocating *C. parvidens* from urban areas to public lands. Despite efforts to identify areas of suitable habitat, prairie dog transplants experience a 60–100 percent mortality rate. The successful relocation and subsequent conservation of the species requires a better understanding of the factors and constraints that make habitats suitable.

More research is needed to better understand UPD population dynamics associated with minimum viable population size, patch size, and connectivity. Mangle et al. (2008) found black-tailed prairie dogs colonies near urban environments were strongly associated with patch sizes with a mean of 21.8 ha, while smaller patches, with a mean of 5.6 ha, were unoccupied. Mangle et al. (2008) also found connectivity to be important in addition to patch size; prairie dog colonies were more likely to be found in large fragments with low-cost distances to large neighboring fragments. Mangle et al. (2010) reported local extinctions were most common in isolated colonies, and the distance of observed colonization events from colonized sites to the nearest neighboring prairie dog colony ranged from 13 m to 2,176 m (Mean: 665 m, SE=144.8).

Environmental Setting

Bryce Canyon National Park sits on the eastern edge of the Paunsaugunt Plateau in southeastern Utah. BCNP is the only National Park Service unit that UPDs currently inhabit. The park, which is small by national park standards at 14,556 ha^2 (56.2 square miles), ranges in elevation from 2,408 m (7,900 ft) to 2,778 m (9,115 ft). The meadows that might serve as prairie dog habitat within the park range between 2,343 and 2,430 m in elevation and are predominantly surrounded by ponderosa pine forests. Within meadow plant structure can be variable, ranging from predominantly shrub cover (*Artemisia* sp., *Chrysothamnus* sp.) to graminoid dominated communities (*Poa* sp., *Juncus* sp.). UPD colonies are primarily found within the shrub/grassland vegetation communities; however, one colony is located in a stand of ponderosa pine near Sunset Point. Because of the geographic location of the meadows and roads within the park boundaries, most prairie dog habitat is in close proximity to roads and other anthropogenic influences. One site in particular, the Mixing Circle, holds an extensive prairie dog colony whose main source of food comes from livestock feed. These interactions most likely have negative effects on UPD populations within the park, including (1) unnatural diets that derive from food provided by visitors, trash, and livestock feed; (2) shifts in avoidance response because of frequent human interaction; (3) shifts in reproduction and mortality rates owing to increased stress, and (4) lower diurnal predation rates because of human activity (Ashdown 1995).

History of Habitation at Bryce Canyon National Park

C. parvidens populations were high in the area within and surrounding BCNP at one point, but a combination of extirpation efforts, sylvatic plague outbreaks, and loss of suitable habitat because of drought and overgrazing (Collier 1975) drove the species out of the park and many of the surrounding areas. Data collected by park employees in 1958 and 1959 indicated that prairie dog populations in the East Creek Meadow were high but subsequently declined during the summer of 1959. Buchanan (1960) reported densities being as high as 1,000 animals in this area in the early 1950s but were reported to have declined substantially by late summer of 1959. Only one animal was spotted in 1962. Although these numbers reflect only the East Creek Meadow population, evidence indicates that this pattern has been observed in other areas of the park (Bryce Canyon monitoring database). The decline could have been attributed to a number of factors, namely (1) the use of sodium fluroacetate to poison prairie dogs, (2) drought, (3) shifts in plant composition due to removal of grazing practices, and (4) plague outbreaks. After the UPD was listed in 1974, efforts were made to reintroduce the species into BCNP, starting with translocation efforts in 1974 and 1975 (Elmore et al. 1976).

The initial reintroduction effort in August of 1974 brought in 38 animals from a colony located near Cedar City, Utah, and four prairie dogs from a colony near Bryce Canyon Airport (Elmore et al. 1976). The animals were active until mid-September, when it is thought that they commenced torpor for the winter but were not observed again. An excavation of the burrows in the spring of 1975 yielded no signs of animal remains and it is hypothesized that the animals relocated to a site 1.6 km from the original transplant site (Elmore et al. 1976). A subsequent effort in 1975 reintroduced 54 prairie dogs in the area currently known as Dave’s Hollow West, which is 200 m west of the visitor’s center, and 160 prairie dogs in East Creek Meadow. Within 1 week of the transplants, 88 percent of the prairie dogs had abandoned the augered holes and relocated to burrows that were historically occupied (Elmore et al. 1976).

Another introduction effort was conducted from 1984 to 1988 at various named and unnamed locations within the park (Figure 1). In 1992, when colony levels were high, some UPDs were removed from three sites and relocated outside of the park. The last removal was done in 2009 to remove one individual inside the lagoon barrier. A 2010 UPD census within the park found 59 individuals, but it is important to note that this is a conservative estimate because 50 percent of the population is thought to be below ground at any one time (Slobodchikoff et al. 2009). Currently, there are seven active colonies and five sites where UPDs were historically present in the park. One of the seven active sites is a small, recently established colony named Sunset Point, which shown in Figure 2. Because of the little information that is available for this colony it is not included in the colony summaries below.

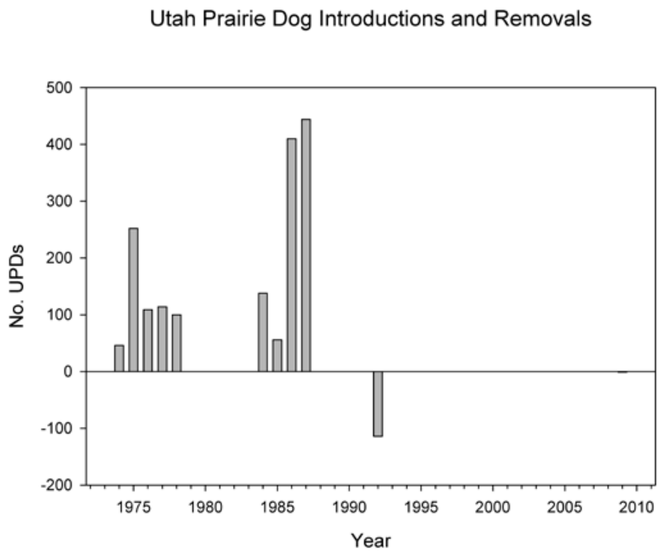


Figure 1. Record of Utah prairie dog introductions and removals within Bryce Canyon National Park.

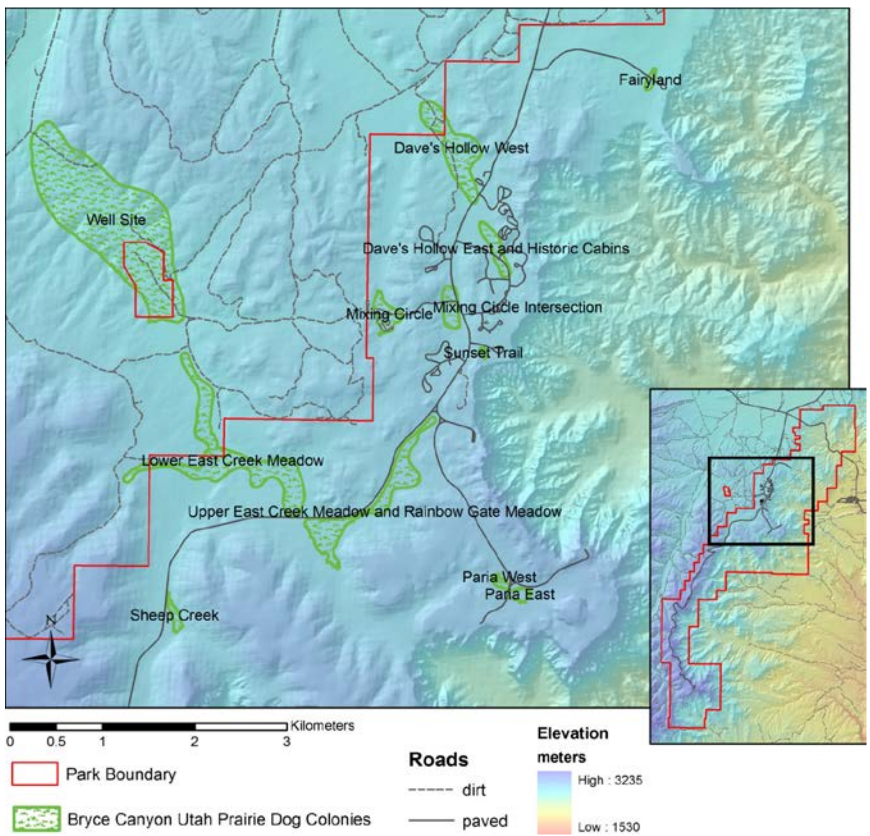


Figure 2. Location of currently active and formerly active Utah prairie dog colonies within Bryce Canyon National Park.

Currently Active Colonies

Dave's Hollow West

The colony commonly known as Dave's Hollow West, but also referred to in the past as the Visitor Center or Lagoon Colony, is located in the meadow to the west of the park's headquarters and visitor center. This area is adjacent to a sewer treatment lagoon and is part of a meadow system that extends outside of the park boundary that has historically been occupied by UPDs. Figure 3 identifies the location of UPD habitat within Dave's Hollow West, its location in relation to the other current and historic UPD colonies, and the surrounding environment displayed in aerial imagery. A barrier was constructed in 2001 around the sewer lagoon to prevent burrowing into the levies. Since the barrier was constructed, only one UPD has permeated the barrier and it was removed in 2009. Since 1978, when the park began monitoring the UPD populations by doing spring counts, the colony's population has varied from 0 to 50 animals. Following a decline in the population in 1983, 54 UPDs were introduced (Figure 4) without success In 1992, when the population was at its highest, 39 UPDs were removed from the colony. The colony count appears to be relatively stable for the period from 1995 to 2010, varying between 3 and 18.

The UPD habitat located in Dave's Hollow West shown in Figure 3 is approximately 264,133 m^2 and is configured with a relatively fair amount of core area (i.e., the ratio of perimeter (m) to area (m^2) is relatively small (Table 1)). The ratio of perimeter to area is a function of the size and shape of the UPD habitat and is used here to relate to the degree of openness of the site. Prairie dogs in general have been found to prefer large openings with a field of view in which they can detect the presence of predators. The closest active colony (0.6 km Euclidean distance) is the Historic Cabins Colony to the southeast. Using the survey counts over the monitoring record, which includes 1978 to the present (some years missing), the average UPD count is 15 animals. Other than being near the visitor center, the area only experiences a moderate amount of human activity relative to other colonies. UPDs have been introduced to the site several times in the 1970s and 1980s and been removed twice (Figure 4).

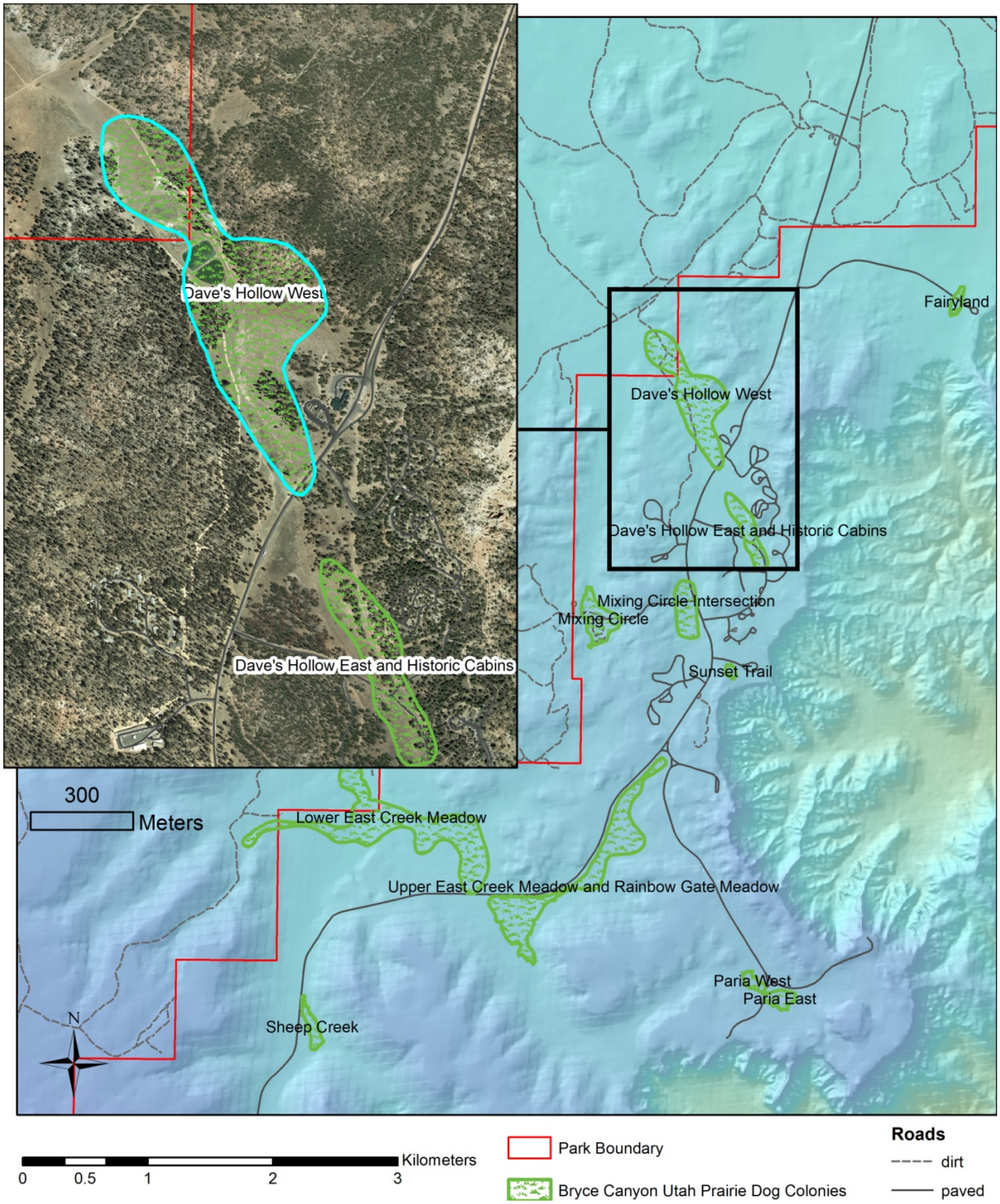


Figure 3. Location of the currently active colony known as Dave's Hollow West, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park.

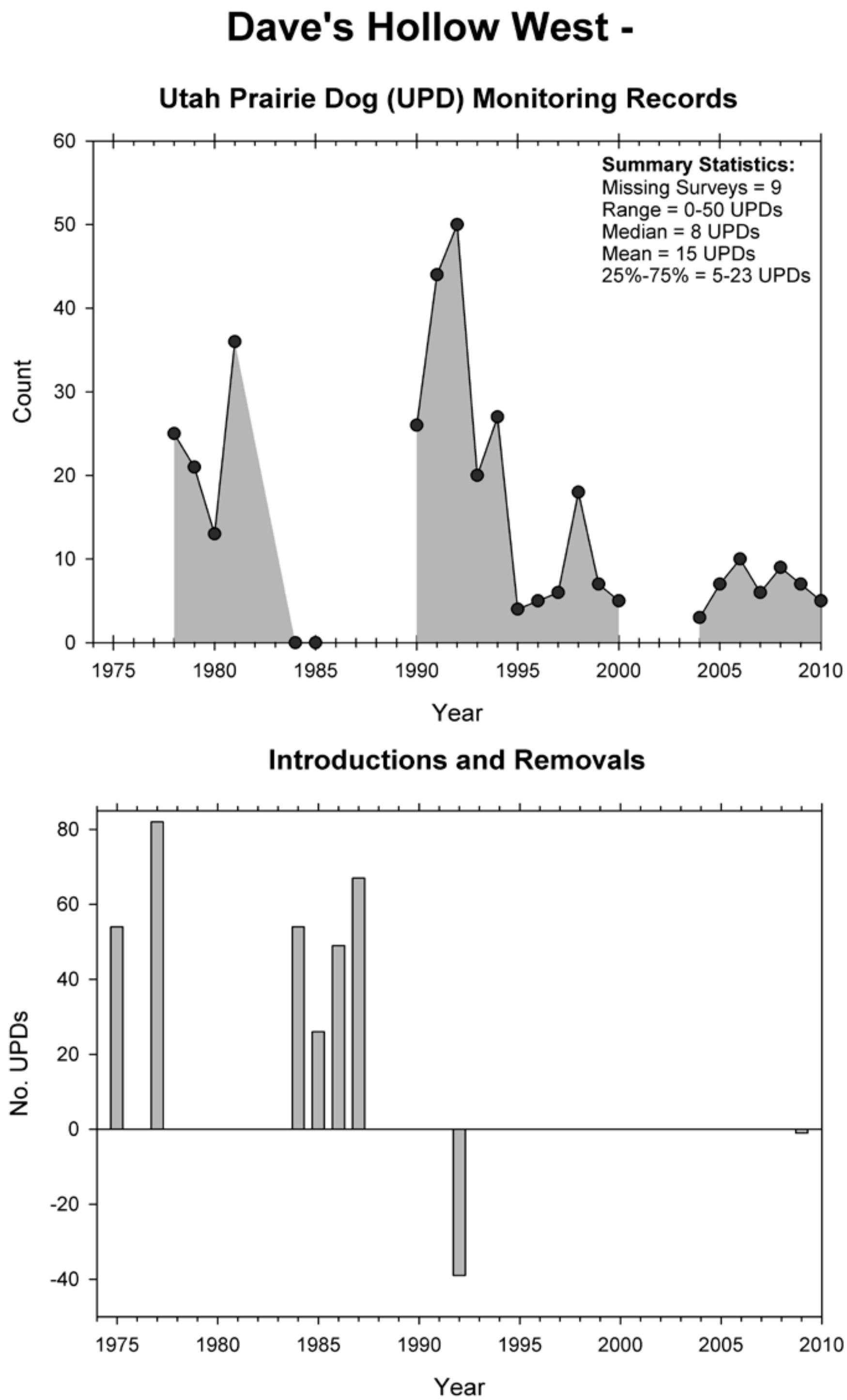


Figure 4. Utah prairie dog records for the Dave's Hollow West, including introductions and removals.

Dave's Hollow East and Historic Cabins

The Dave's Hollow East and Historic Cabins Colony occupies a small, wet meadow near many of the park's main public facilities and attractions. If it were not for the roads that bisect this meadow complex, Dave's Hollow West, Dave's Hollow East, and the Historic Cabins habitat patches would be one continuous habitat patch. Figure 5 shows the location of UPD habitat within Dave's Hollow, its location in relation to the other current and historic UPD colonies, and the surrounding environment displayed in aerial imagery. Since 1978, when the park began monitoring the UPD populations using spring counts, the population has varied from 0 to 45 animals. The colony reached the maximum colony count of 45 UPDs in 1993 and shortly after experienced a precipitous decline, and just 2 years later in 1995 no UPDs were found at the site. The site was recolonized in 1998 and currently has a small population (Figure 6).

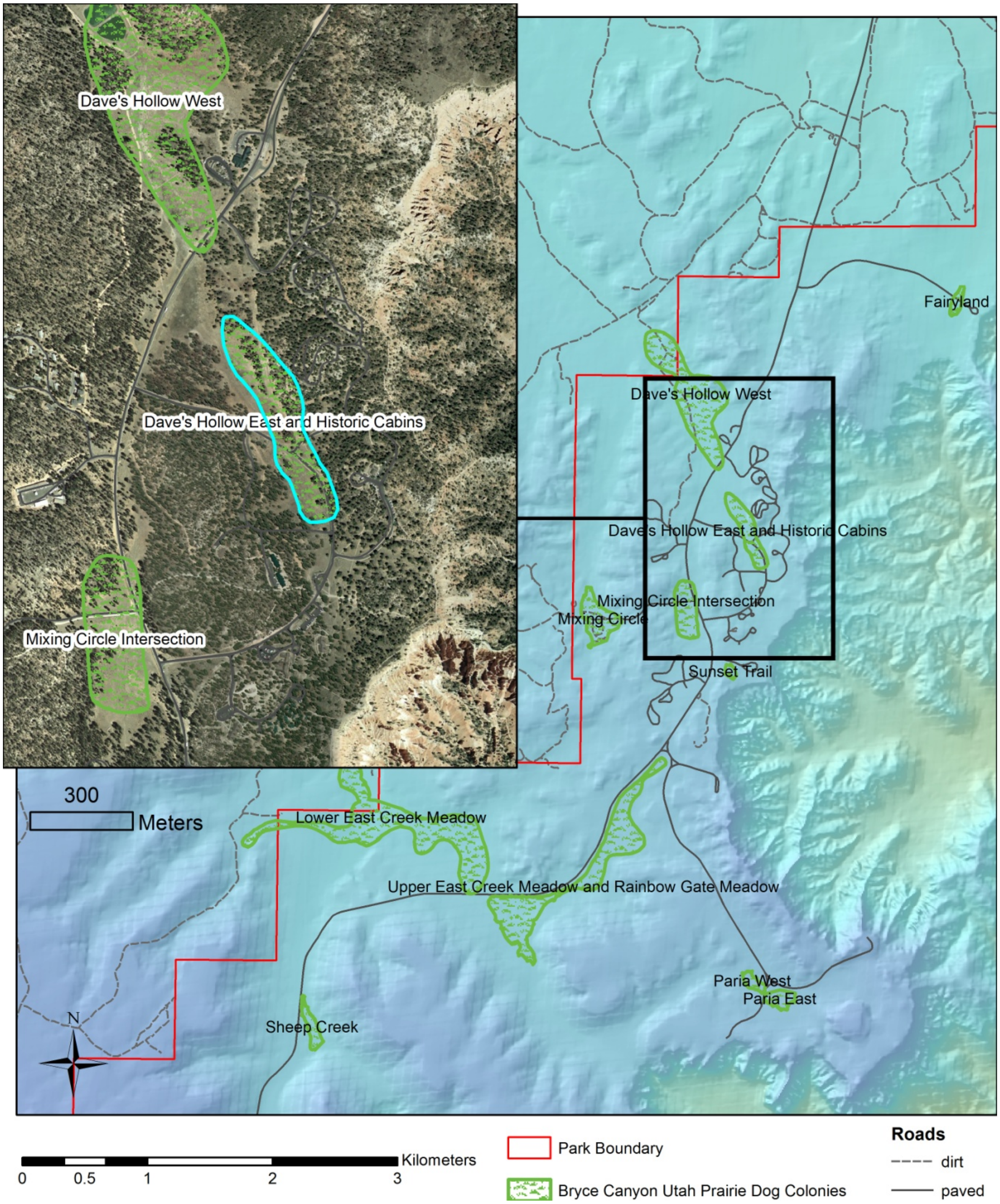


Figure 5. Location of the currently active colony known as the Dave's Hollow East and Historic Cabins Colony, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park.

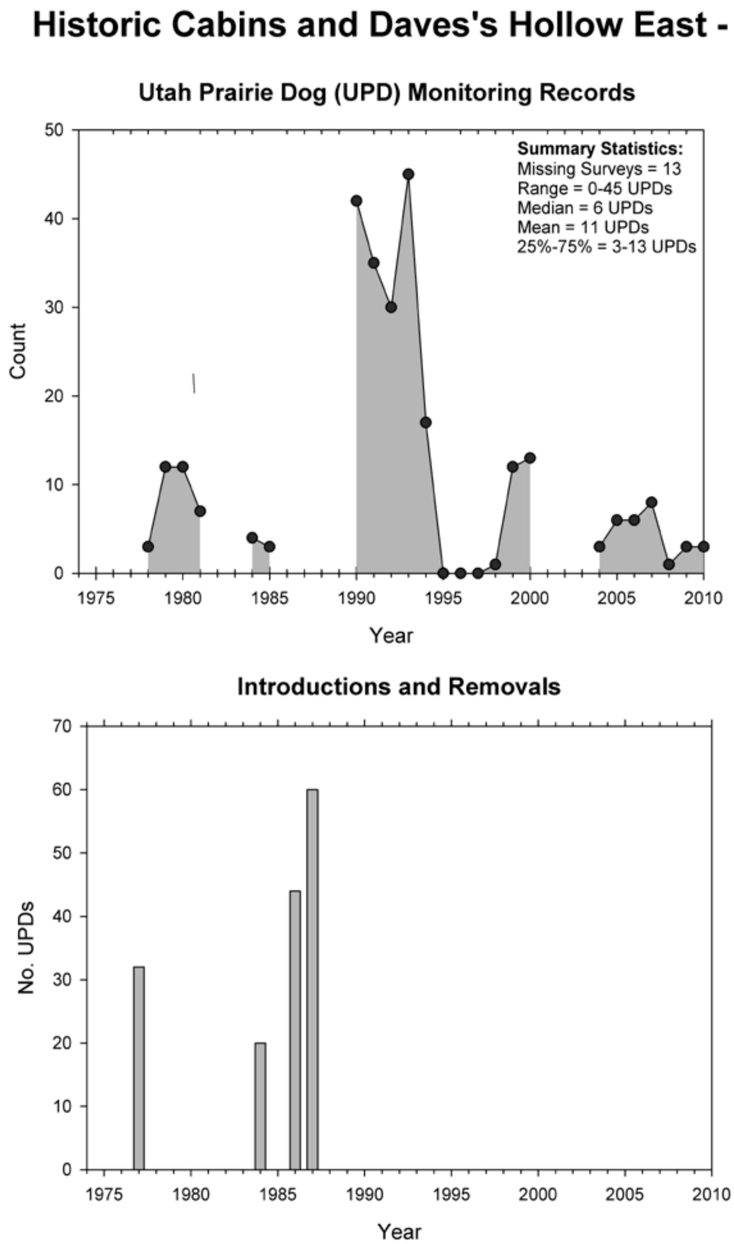


Figure 6. Utah prairie dog survey results for the Dave's Hollow East and Historic Cabins Colony, including four introductions.

Mixing Circle Intersection

The Mixing Circle Intersection Colony is located in a small meadow to the south of Dave's Hollow Meadow and to the east of the Mixing Circle Colony. The meadow is bisected by two roads, as shown in Figure 7, and UPDs have occupied the northern portion of the meadow where the roads intersect. This colony has been relatively stable over time, with UPDs present during every survey. The counts for this colony have ranged from 4 to 14 animals, with an average count of 9 UPDs (Figure 8). It is believed that this colony has a high degree of connectivity with the Mixing Circle Colony to the west.

The area identified as UPD habitat in Figure 7 is approximately 71,030 m^2 in size. Given the somewhat circular shape of the habitat and its small size, the ratio of area to perimeter is relatively large (Table 1). Survey counts average 9 UPDs. This site experiences a moderate to high amount of human activity in the surrounding vicinity, primarily via visitor vehicle traffic along the main road, park staff traveling to the facilities located at the Mixing Circle, and the trail riding concessioners, horses, and mules traveling between the night corrals at the Mixing Circle and day corrals near the Lodge. Sunset Campground is located to the south of the meadow.

Mixing Circle

The Mixing Circle Colony (Figure 9) is located near the park boundary to the west of the Mixing Circle Intersection Colony and to the east of a recently (2008) established colony named the East Fork Colony located on the Dixie National Forest. Survey counts have ranged between 2 and 75 UPDs and the average count is 30 UPDs. The UPD counts suggest the colony's population grew from 1978 to 2000 and has been declining over the last decade (Figure 10).

The area identified as UPD habitat in Figure 9 is approximately 75,032 m^2 in size, is rather circular, and has a relatively small ratio of area to perimeter (Table 1). This patch does provide a large opening with a field of view, though there are several structures located within this area. This site experiences a moderate to high amount of human activity within the colony, primarily via park staff using the facilities located at the Mixing Circle and the trail riding concessioners, horses, and mules housed at the corals. Additional food sources are available at this site, primarily alfalfa cubes, grain, and trash that are kept at this site. A camping ground is located to the south.

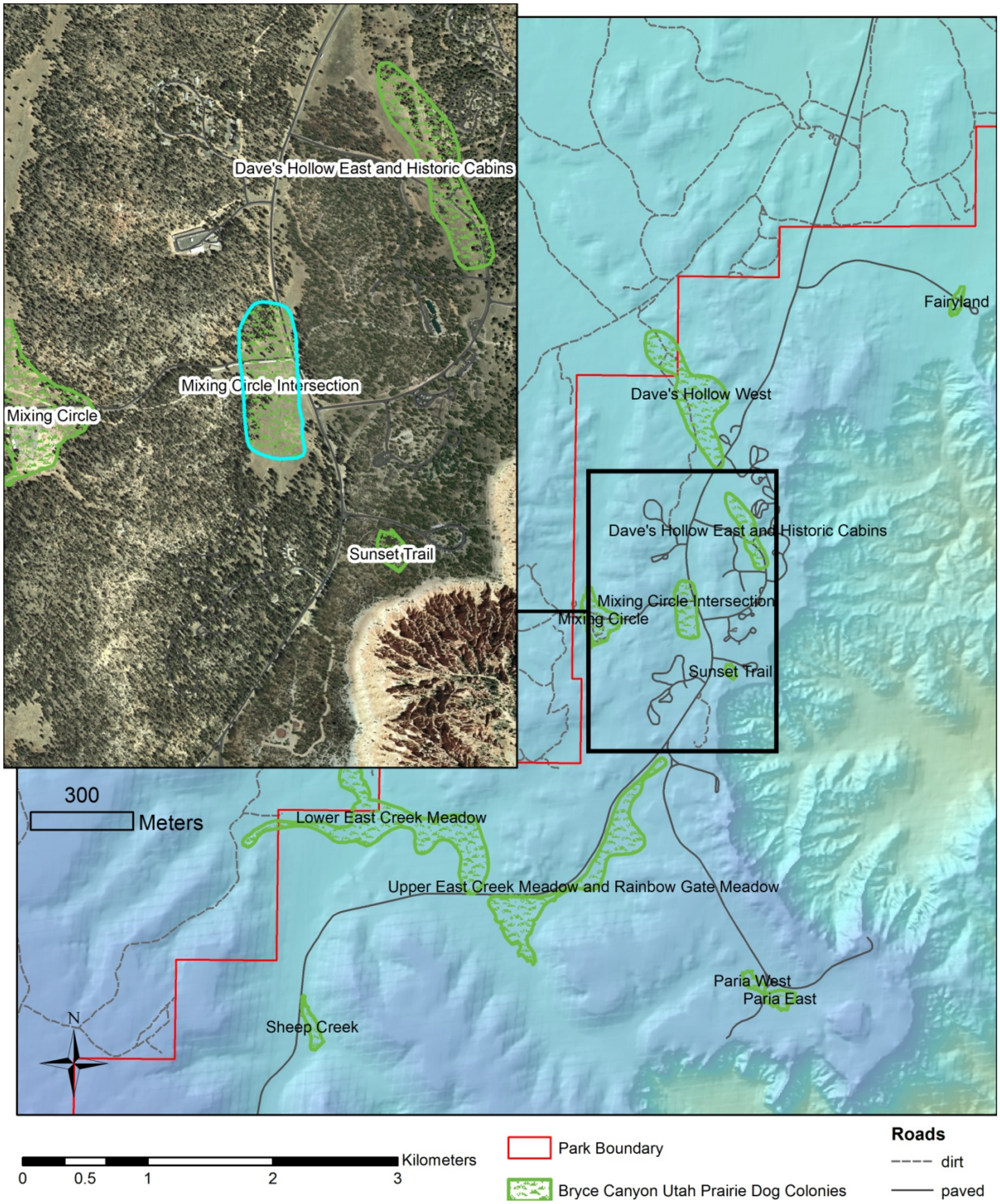


Figure 7. Location of the currently active colony known as the Mixing Circle Intersection Colony, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

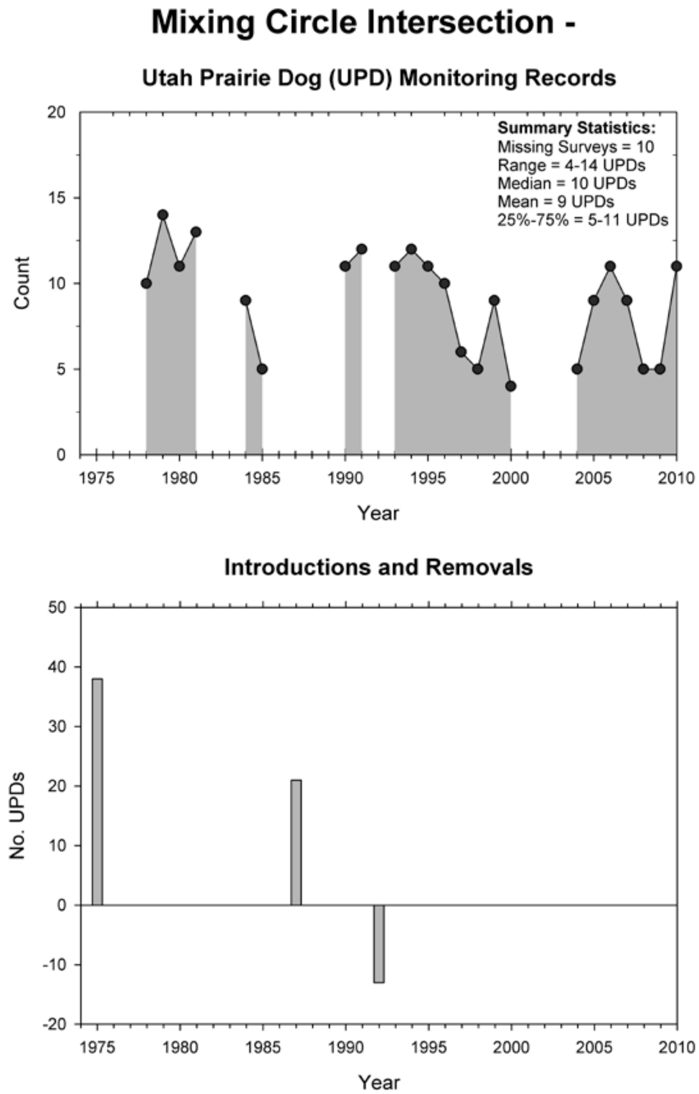


Figure 8. Utah prairie dog survey results for the Mixing Circle Intersection Colony, including one removal event in 1992 and two earlier introductions.

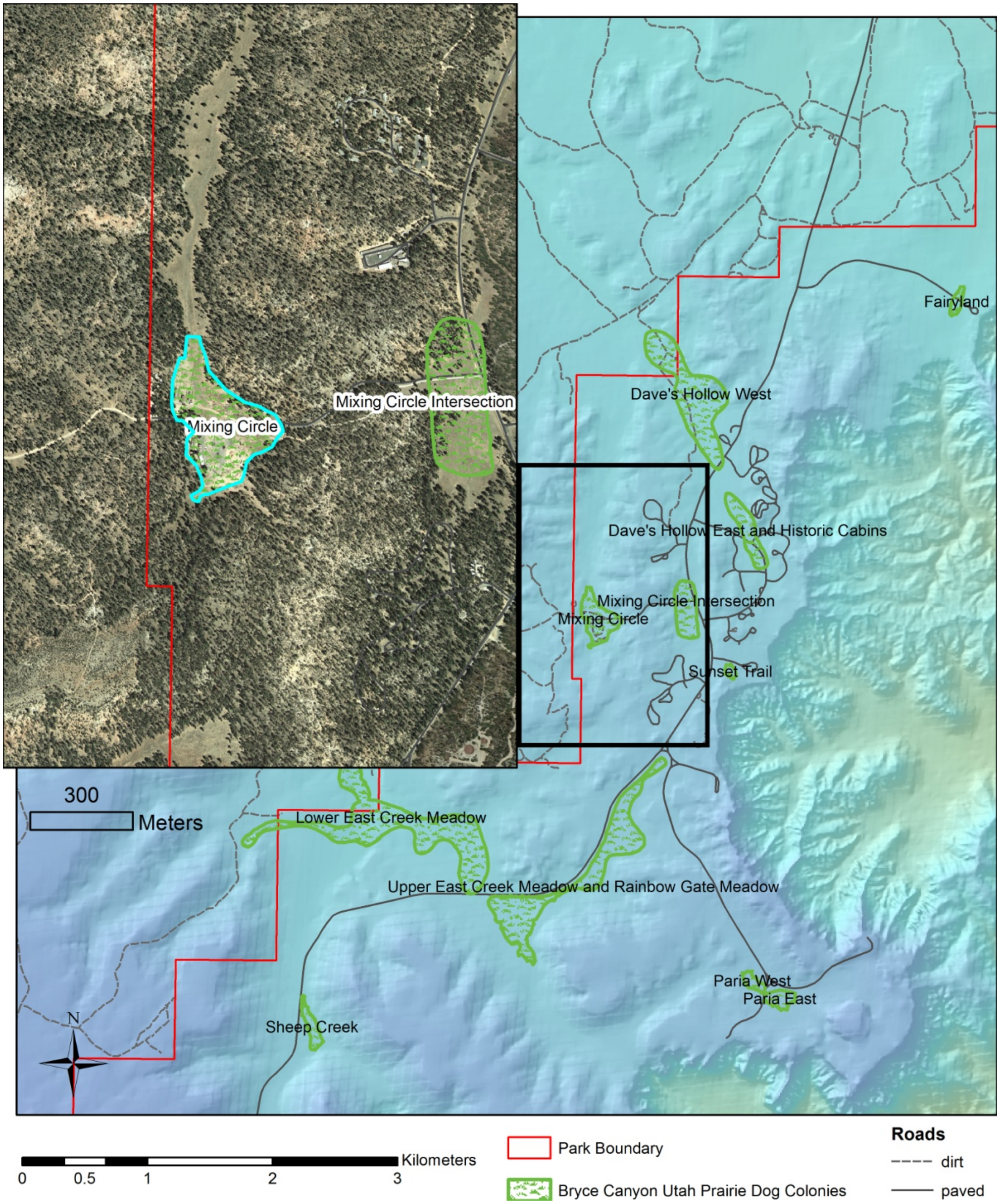


Figure 9. Location of the currently active colony known as the Mixing Circle Colony, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park.

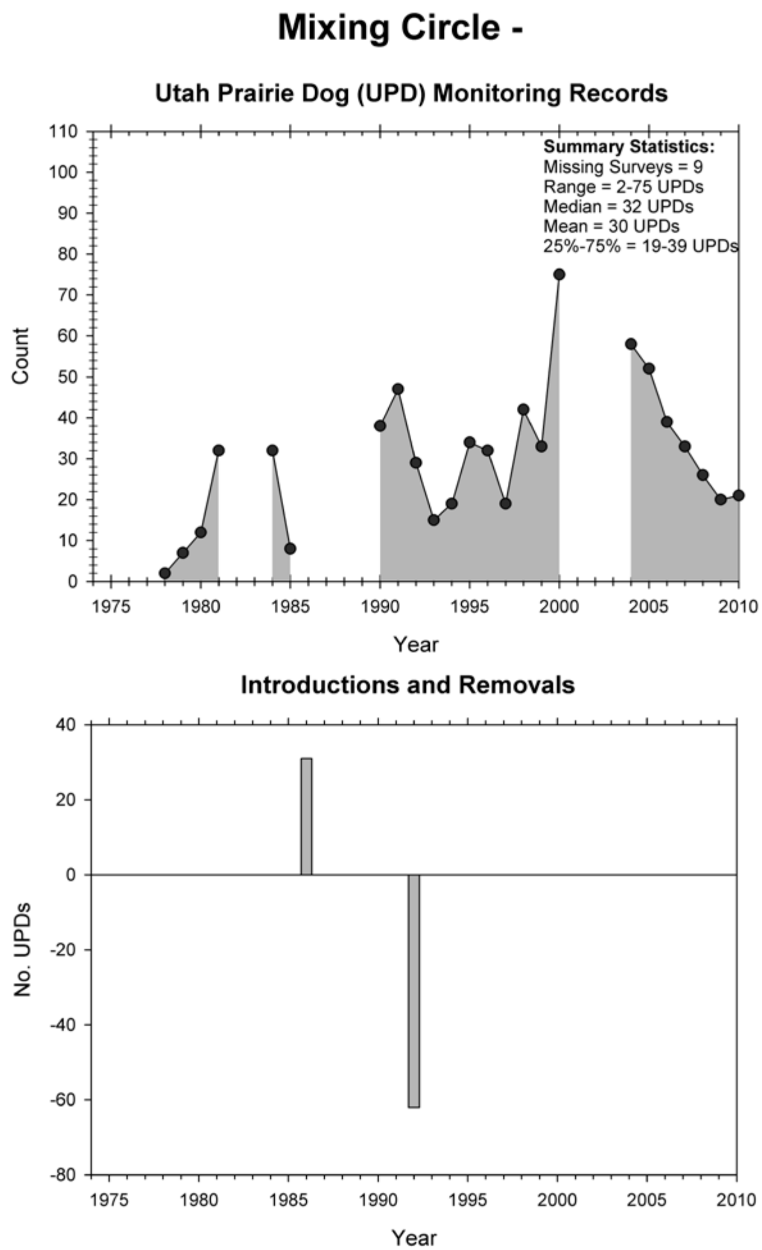


Figure 10. Utah prairie dog survey results for the Mixing Circle, including one introduction in 1986 and one removal event in 1992.

Lower East Creek Meadow and the Well Site

The colony referred to as the Lower East Creek Meadow Colony is located in the largest meadow complex within the park, which extends outwards into adjacent Dixie National Forest lands. An area known as the Well Site, which is park-owned land within the Dixie National Forest, is also included in the spring count surveys (Figure 11), but the UPD occurrences outside of these boundaries are not. Although the park began monitoring the UPD populations in 1978, the Lower East Creek populations were not surveyed until 1990, resulting in 15 missing surveys between 1978 and 2010 (Figure 12). Survey findings for this colony have also been the most variable of the colonies, ranging from 1 to 69 UPDs. Survey counts were at their highest in 1991 and 2008. The 2000 spring count resulted in only 1 UPD. The mean, 30 UPDs, and the median, 31 UPDs, are similar and there appears to be no trends in the count data other than that the colony varies substantially over time. Relative to the other colonies, there is little visitor traffic near the UPD colonies here and minimal use by park staff as well.

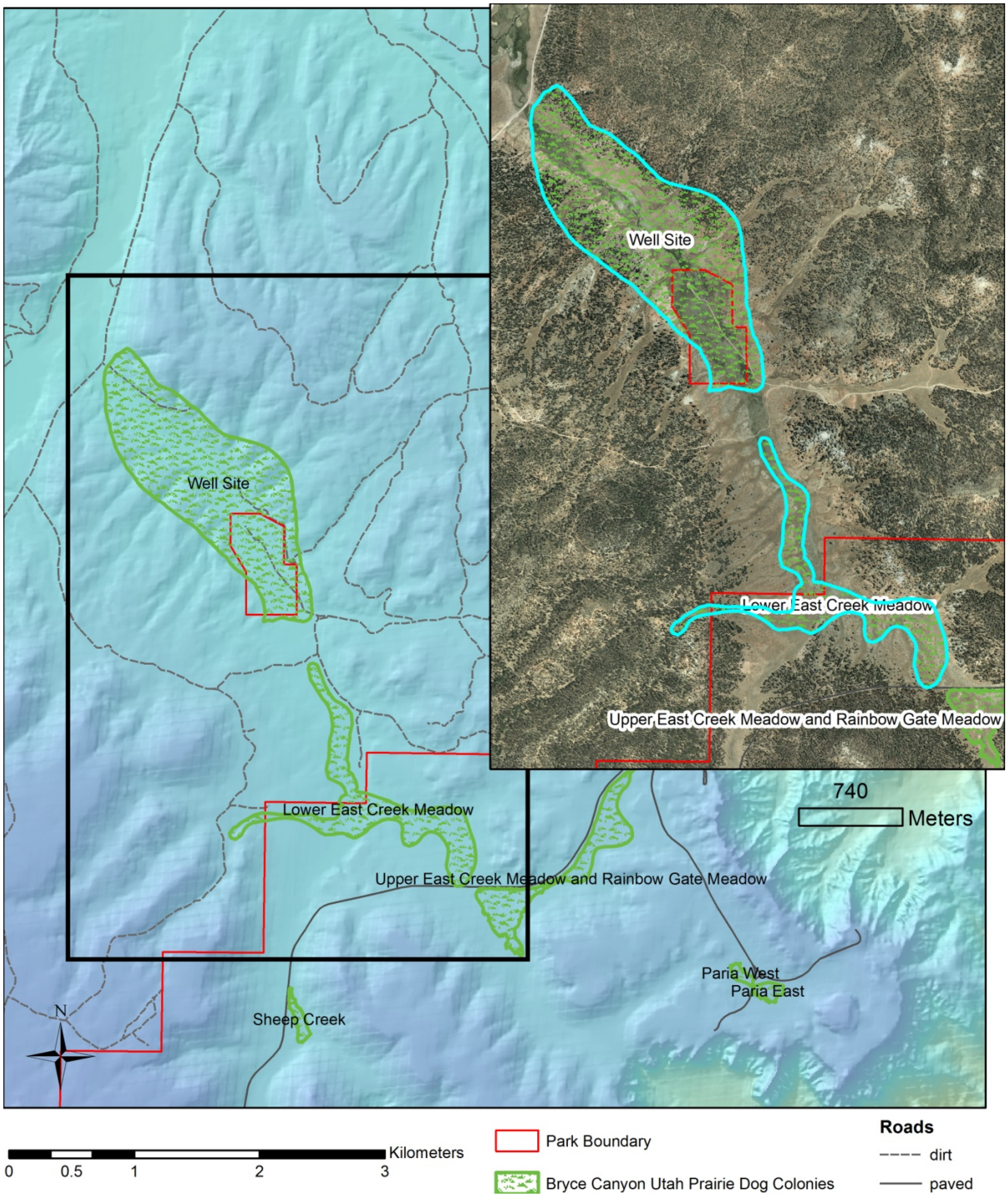


Figure 11. Location of the currently active colonies known as the Lower East Creek Meadow Colony and the Well Site Colony, which are shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

Lower East Creek Meadow and the Well Site -

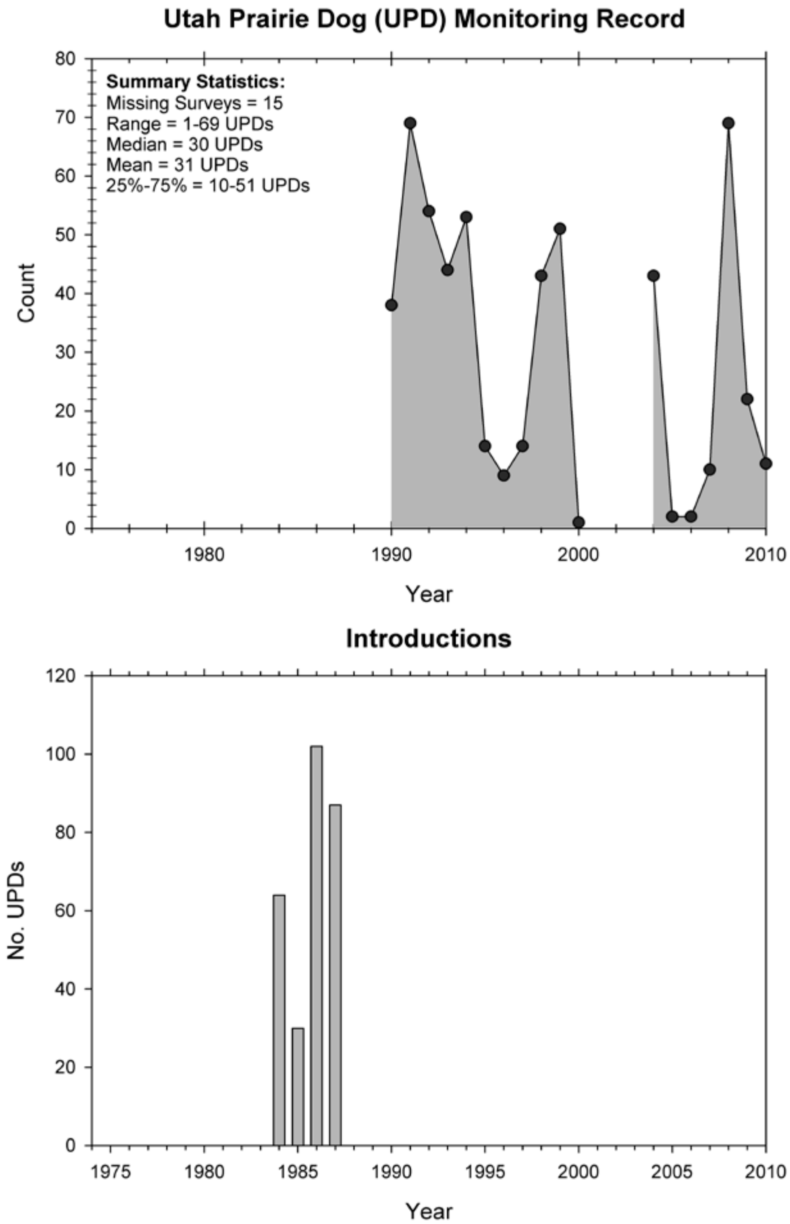


Figure 12. Utah prairie dog survey results for the Lower East Creek Meadow Colony, within the park boundaries, and the Well Site Colony including a series of introduction events in the 1980s.

Former Colonies

Upper East Creek Meadow and Rainbow Gate Meadow

The former colonies commonly known as the Upper East Creek Meadow and the Rainbow Gate Meadow Colonies are located to the east of Lower East Creek and, if it were not for the main road bisecting this meadow complex, would be one UPD habitat patch. Over time these two former colonies have been treated differently. Figure 13 shows the location of Upper East Creek Meadow, which the park recognizes as UPD habitat, and the former Rainbow Gate Meadow Colony documented by the Utah Division of Wildlife Resources colony data. From 1994 to 1999, the Upper East Creek Meadow and the Rainbow Gate Meadow's survey counts were treated as one colony but thereafter they were surveyed as separate colonies. UPD occupation of the Rainbow Gate Meadow has been sporadic and the last documented occurrence at this site was in 1993. From 1978 to 2009 the counts ranged from 0 to 10 UPDs (Figure 14). Similarly, the occupation at Upper East Creek Meadow has been sporadic and has ranged from 0 to 23 UPDs. The occupation was at its highest in 2000 but became inactive in 2007. The closest active colony (0.2 km Euclidean distance) is the Lower East Creek Meadow Colony, which just on the west side of the main road. Other than vehicle traffic along the road, the area only experiences a low amount of human activity.

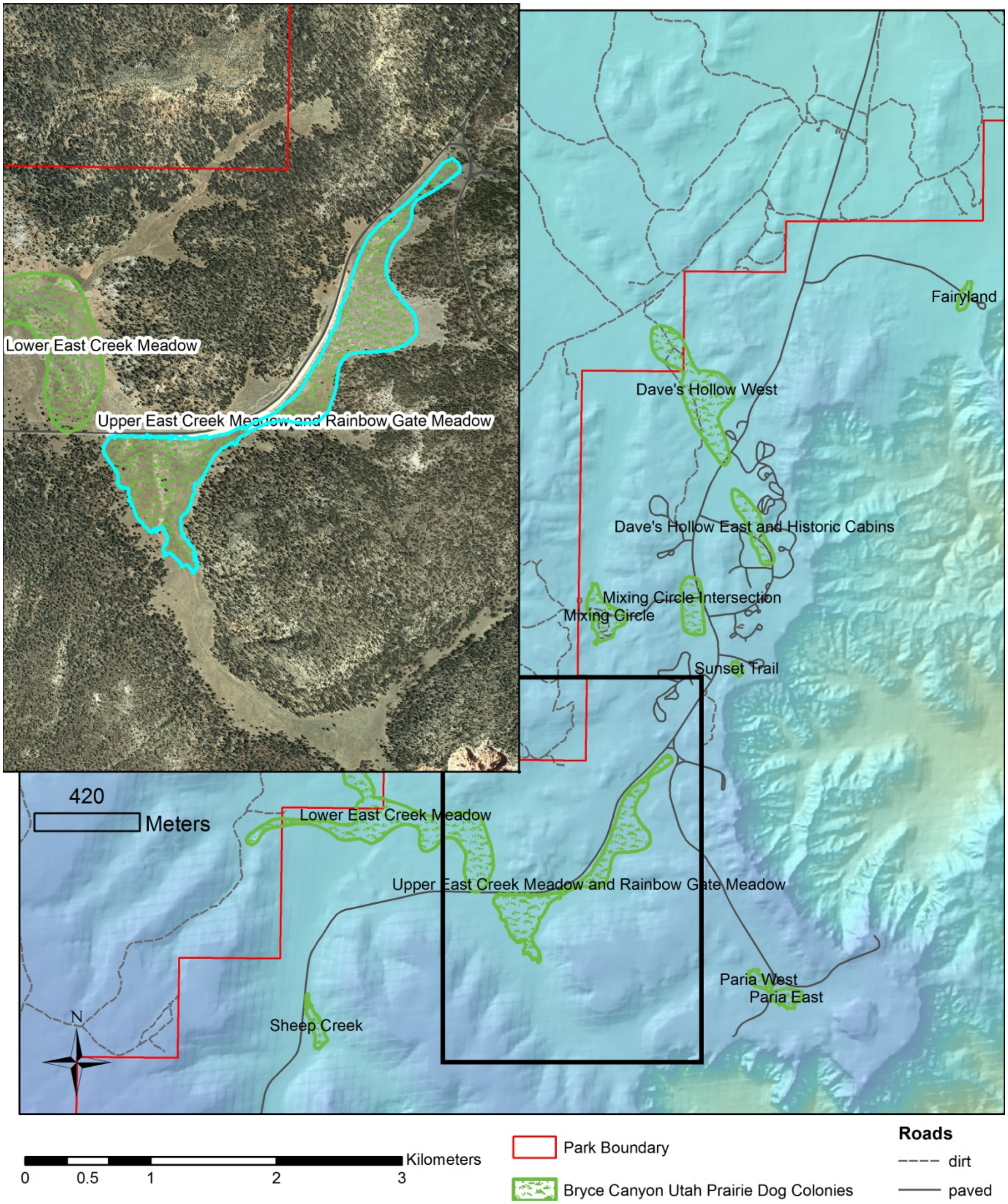


Figure 13. Location of the currently inactive colonies known as the Upper East Creek Meadow Colony and the Rainbow Gate Meadow Colony, which are shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

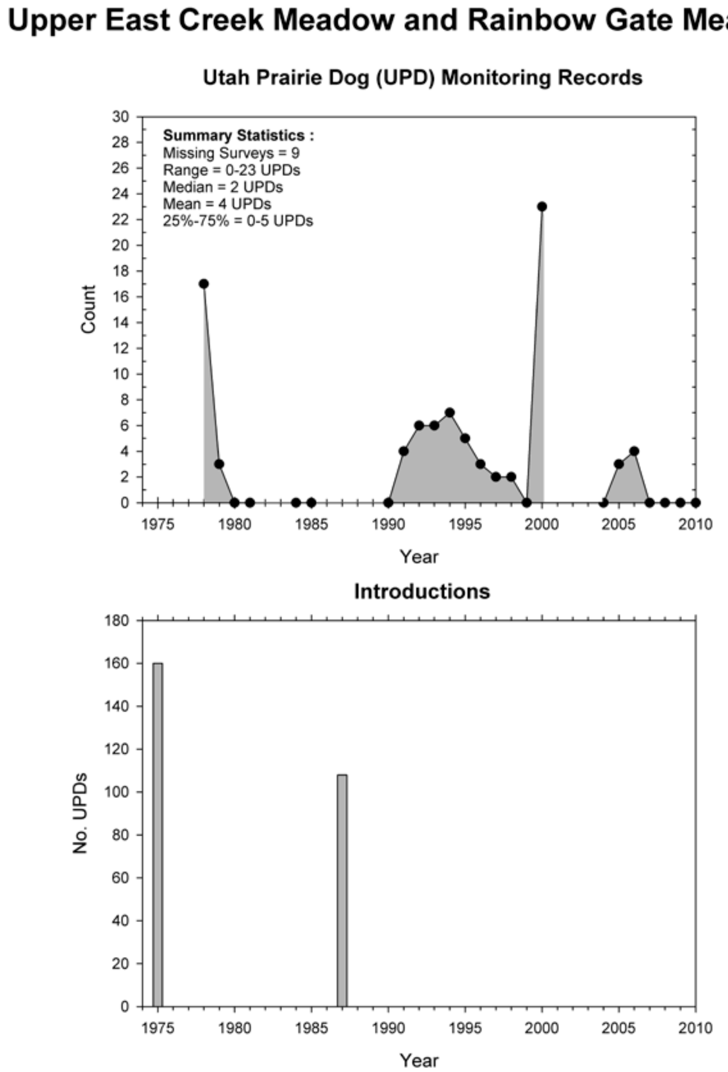


Figure 14. Utah prairie dog survey results for the Upper East Creek Meadow Colony and the Rainbow Gate Meadow Colony.

East and West Paria View

The former colonies commonly known as the East and West Paria View Colonies are located to the east of East Creek Meadow and, if it were not for a road bisecting the meadow, would be one UPD habitat patch. Figure 15 shows the location of the Paria View former colonies. Surveys for these sites did not begin until 1990 (Figure 15). West Paria View is a very small habitat patch and has only had 1 UPD occurrence from 1990 to 2010. The initial survey count for East Paria View was 6 UPDs and was followed by a steady decline until 2006 when no more UPDs were found to occupy this site. Summary statistics were only calculated for the East Paria View site and resulted in a mean of 1 UPDs and a median of 0 UPDs over the survey record.

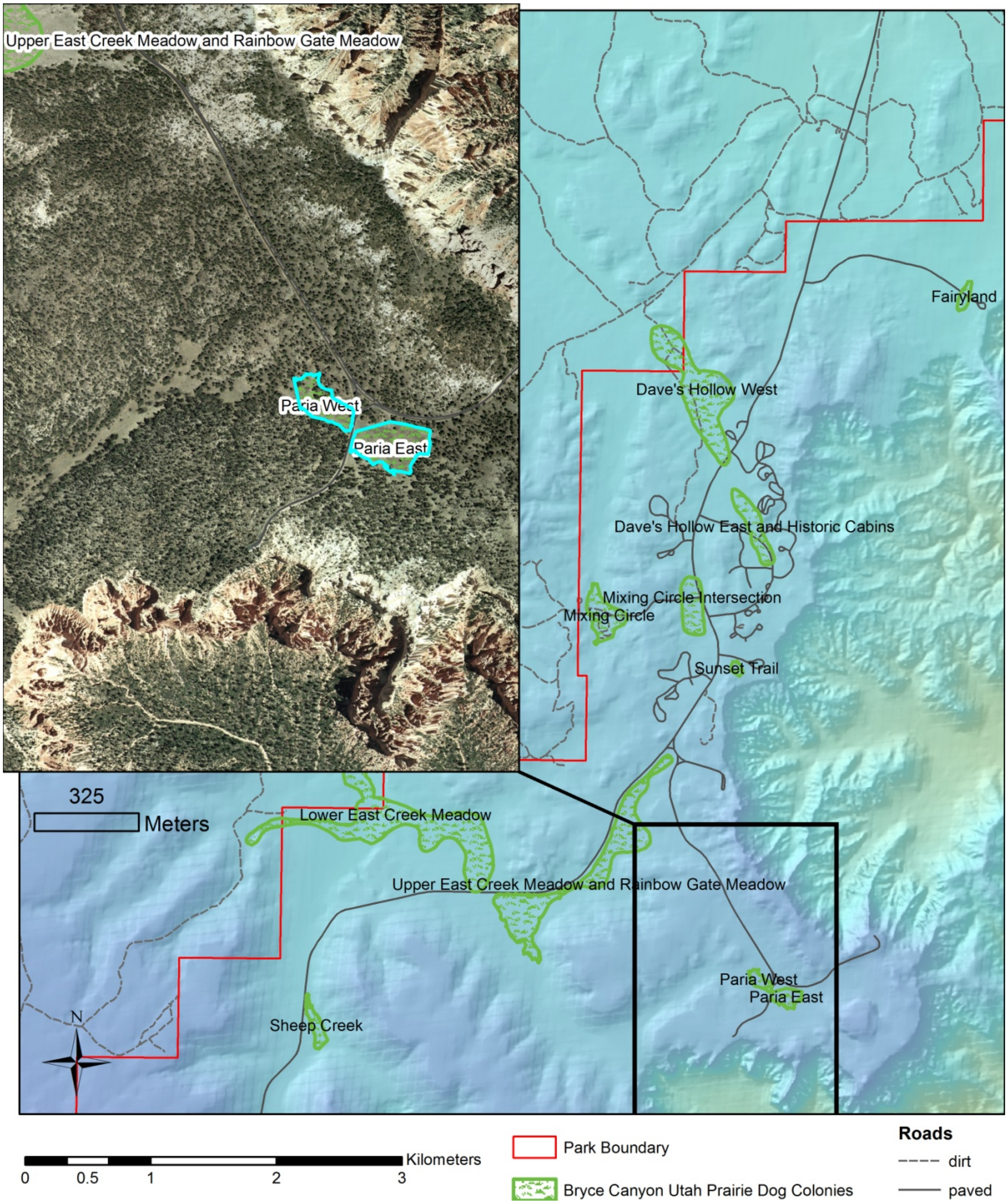


Figure 15. Location of the currently inactive colonies known as the East and West Paria View Colonies, which are shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

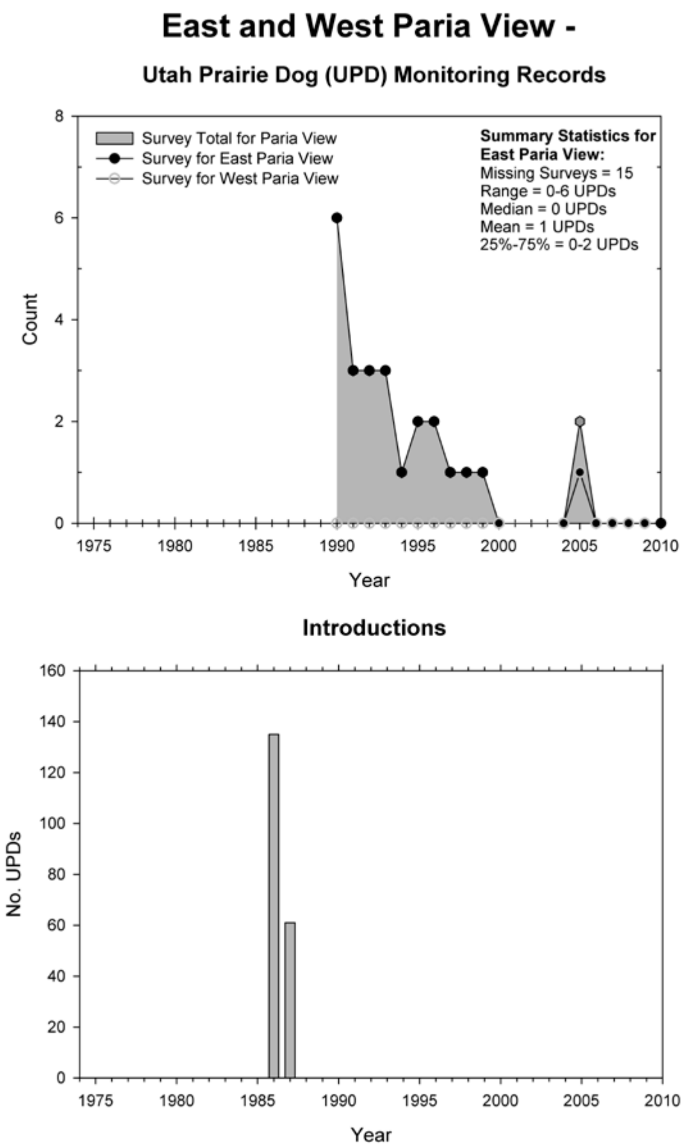


Figure 16. Utah prairie dog survey results for the East and West Paria View Colonies. Because the West Paria View Colony has documented the occurrence of only one Utah prairie dog during a single year, summary survey statistics were calculated only for the East Paria View survey data. Two introductions occurred in 1986 and 1987.

Sheep Creek Trail

The currently inactive Sheep Creek Colony is the southernmost UPD colony within the park and would be connected with the Lower East Creek Meadow habitat patch, if the main park road did not bisect this meadow complex (Figure 17). UPD occupation of the Sheep Creek Trail site has been sporadic over time; 1 UPD was documented in 1979, but there was no further occupancy documented until 1993, when the maximum recorded count was 4 UPDs. From 1993 to 2000 there was a steady decline in the survey counts. The last time occupancy was document was in 2005, when 2 UPDs were detected. Summary statistics resulted in a mean of 1 UPDs and a median of 0 UPDs over the survey record (Figure 18).

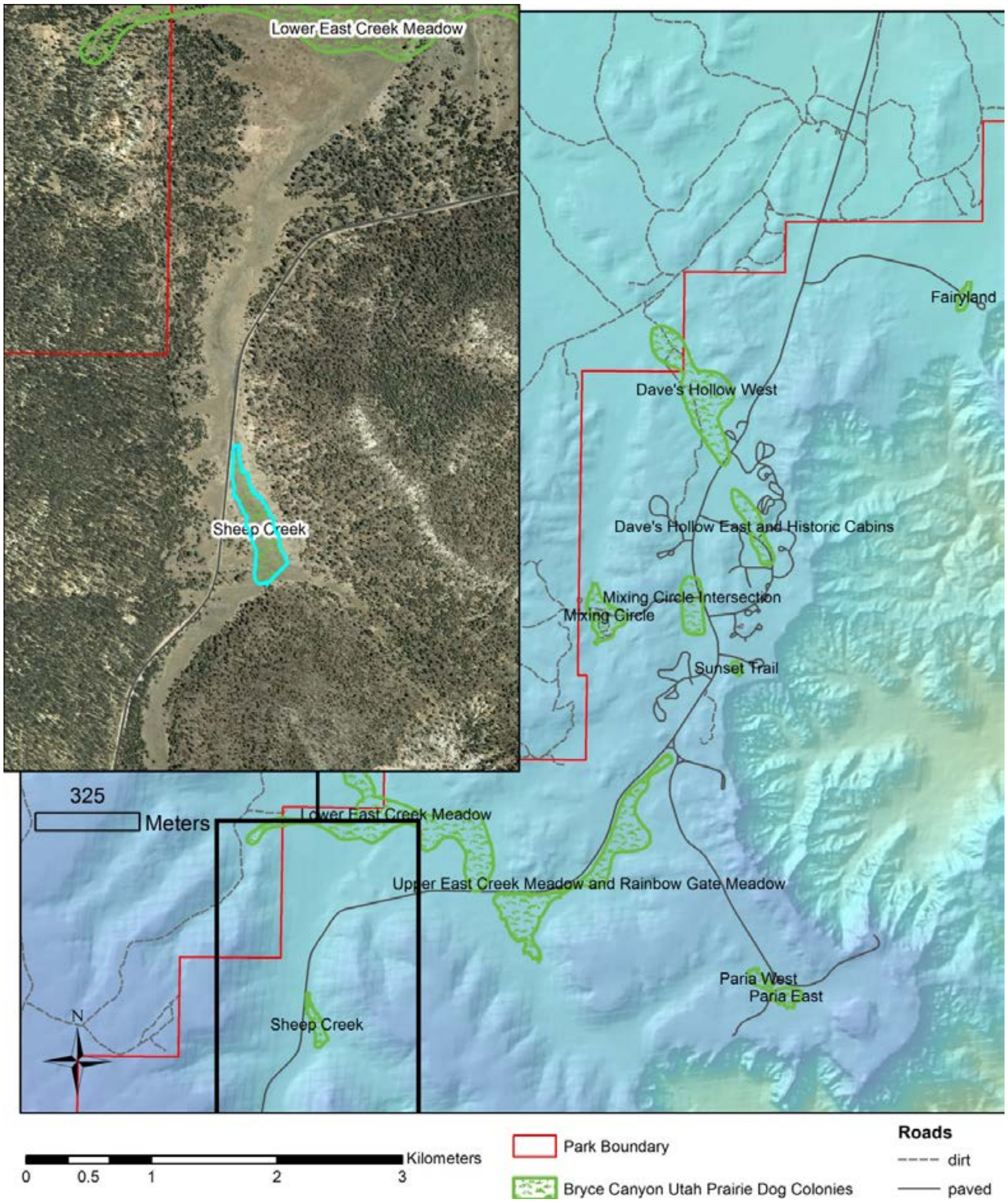


Figure 17. Location of the currently inactive colony known as the Sheep Creek Trail Colony, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

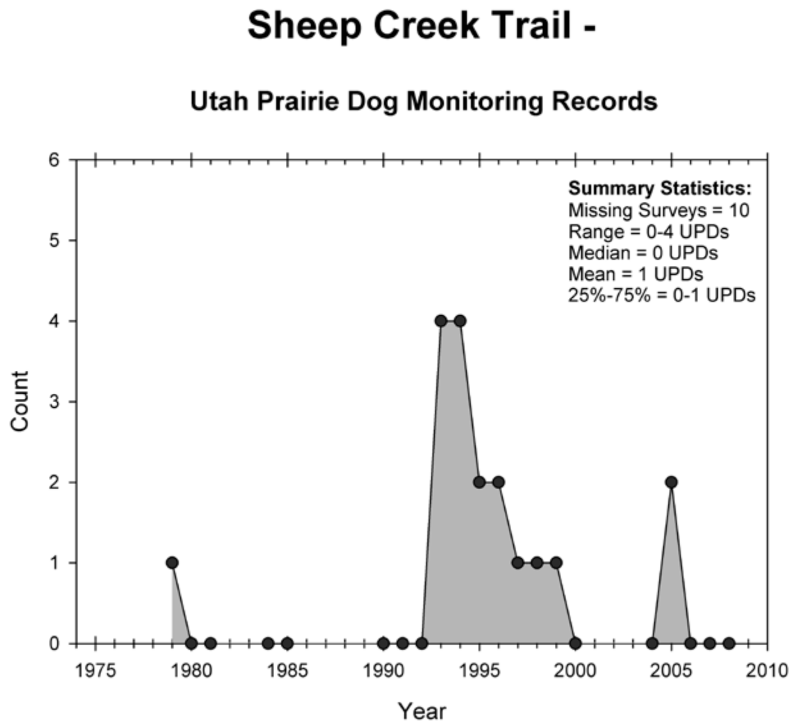


Figure 18. Utah prairie dog survey results for the Sheep Creek Trail Colony. This site was primarily occupied during the 1990s and has no record of being an introduction or removal site.

Fairyland

The currently inactive Fairyland Colony is the northernmost UPD colony within the park and is comprised of two habitat patches because a road bisects the meadow at this site (Figure 19). The former colony was primarily located at the southern end of the UPD habitat identified in Figure 18. UPD occupation of Fairyland was fairly consistent from 1978 to 2000, generally varying between 1 and 7 UPDs, but occupation of the site ceased by 2004. Summary statistics resulted in a mean of 3 UPDs and a median of 2 UPDs over the survey record (Figure 20).

The closest active colonies are both approximately 2 km away (Euclidean distance), one being Dave's Hollow West to the southwest and the other outside of the park boundary to the north near Bryce Canyon City, Utah. The colonies at Bryce Canyon City are rather large containing ~ 100 UPDs currently (S. Haas, National Park Service, personal communication). The area experiences some vehicle traffic along the road and visitor parking at the view point, which results in a relatively low to moderate amount of human activity at this location.

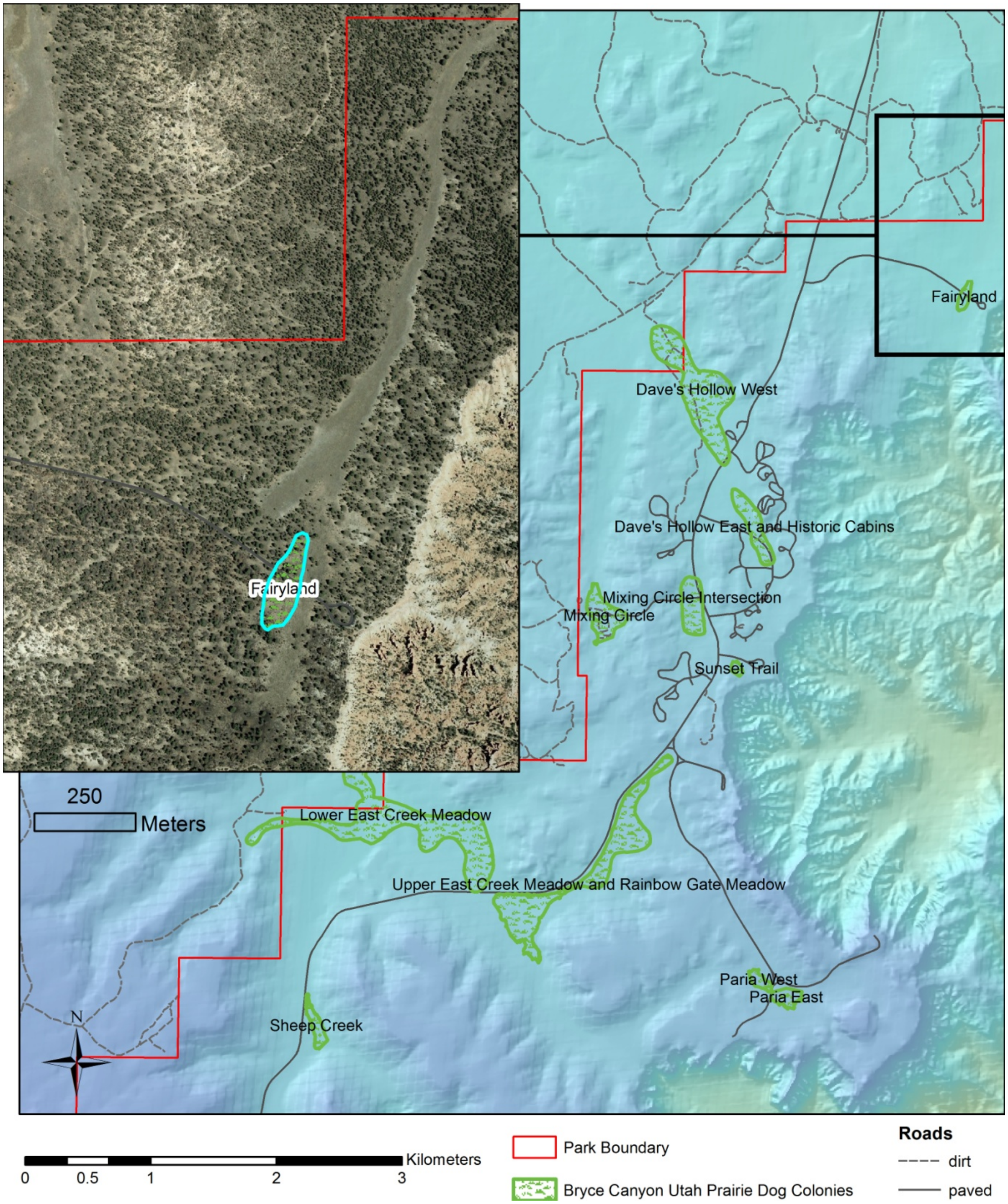


Figure 19. Location of the currently inactive colony known as the Fairyland Colony, which is shown in relation to other Utah prairie dog colonies within Bryce Canyon National Park and the surrounding area.

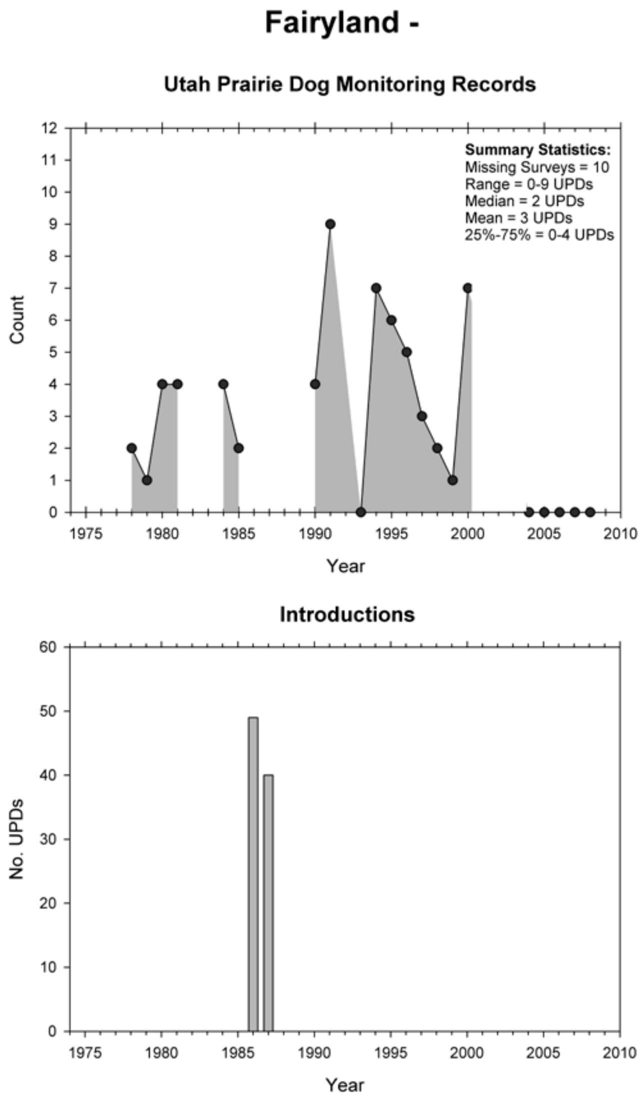


Figure 20. Utah prairie dog (UPD) survey results for the Fairyland Colony. Except for one survey, this site was occupied until 2004. UPDs were introduced twice at this location in the 1980s.

Comparisons of Currently Active Colonies to Inactive Colonies

Size and Shape of Habitat Patches

The size and configuration of available habitat at a site is strongly related to the number of UPDs it can support. Table 1 below shows the size of UPD habitat at each of the BCNP sites and their current status. In an effort to capture how the size and shape of the habitat patches relates to the ability of UPDs to occupy the site over time, the ratio of area to perimeter was calculated. The larger the ratio, the more open a site is as a result of being large and/or relatively round in shape. The smaller the ratio, the smaller the habitat patch and/or irregular in shape (less open).

Table 1. Table indicating the current status of the colonies, active or inactive, the size of the Utah prairie dog (UPD) habitat associated with the colony, road density for each colony as a measure of human activity in the vicinity, and distance to nearest active colony as a measure of connectivity for population source/sink dynamics.

Colony Name	UPD Occupation (2010 AD)	Area (sq. m.)	Perimeter (m.)	Road Density (km/sq. km.)	Distance to Active Colony (km.)	Avg. UPD Count	Location Source
Mixing Circle	Active	75032	1367	3.9	0.4	30	Bryce Canyon NPS Staff Delineations of UPD Habitat
Dave's Hollow West	Active	264133	2918	2.9	0.2	15	Utah Division of Wildlife Resources 2007 UPD Colony Data
Well Site*	Active	1580067	6053	1.0	0.3	31	Utah Division of Wildlife Resources 2007 UPD Colony Data
Dave's Hollow East and Historic Cabins	Active	70564	1466	3.5	0.2	11	Utah Division of Wildlife Resources 2007 UPD Colony Data
Mixing Circle Intersection	Active	71030	1139	4.2	0.3	9	Utah Division of Wildlife Resources 2007 UPD Colony Data
Lower East Creek Meadow*	Active	519867	7609	1.4	0.3		Utah Division of Wildlife Resources 2007 UPD Colony Data
Sunset Trail**	Active	7338	350	3.4	0.3	3	Utah Division of Wildlife Resources 2007 UPD Colony Data
Sheep Creek	Inactive	27732	1095	0.6	1.3	1	Bryce Canyon NPS Staff Delineations of UPD Habitat
Paria West	Inactive	16542	639	0.7	2.2	0	Bryce Canyon NPS Staff Delineations of UPD Habitat
Paria East	Inactive	26799	754	0.7	2.5	1	Bryce Canyon NPS Staff Delineations of UPD Habitat
Fairyland	Inactive	14762	569	0.9	1.9	3	Utah Division of Wildlife Resources 2007 UPD Colony Data
Upper East Creek Meadow and Rainbow Gate Meadow	Inactive	298599	5479	1.0	0.2	4	Bryce Canyon NPS Staff delineations of UPD Habitat for Upper East Creek Meadow and UDWR delineation of Rainbow Gate Meadow merged

Degree of Anthropogenic Influence

To assess the potential for anthropogenic factors that may relate to the occurrence of UPDs at a site, a road density layer was created as a surrogate measure for the amount of human activity at various sites throughout the park (Figure 21). Road density, the number of roads per km^2, was calculated using both dirt and paved roads for the area of interest using a search radius of 1,120 m, resulting in a road density scaled between 0 and 4.5 roads per km^2 across the study area. The colony polygon centers were used to estimate the road density for each colony shown in Table 1.

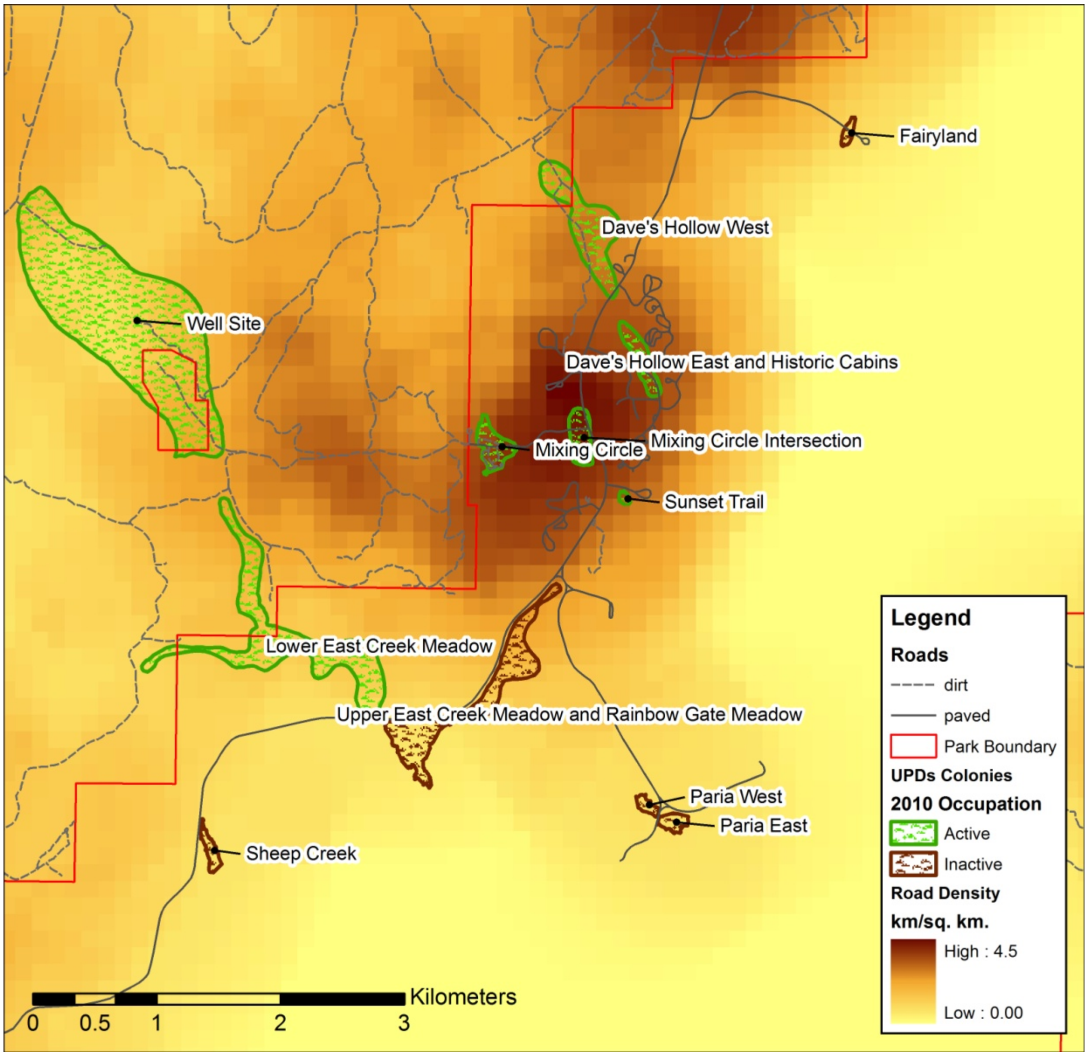


Figure 21. Road density (both dirt and paved road classes) surrounding the Utah prairie dog (UPD) colonies at Bryce Canyon National Park. Road density was calculated as a surrogate measure of the relative degree of human activities within and surrounding the park's UPD colonies.

Connectivity

Metapopulation dynamics can play an important role in the ability of organisms to occupy habitat patches. Population source and sink dynamics are a function of connectivity between habitat patches. To assess how the location of UPD colonies in terms of connectivity to other colonies may influence the ability of UPDs to occupy a site over time, a simple distance measure (straight line aerial distance, Euclidean distance) was estimated in GIS to the nearest active colony. Distances between colonies were found to vary from 0.02 to 2 km to a currently active colony.

Low sample size and the various factors likely influencing the colonies makes statistical testing of individual factor's influences on the occurrence of UPDs difficult. Active versus inactive colonies were compared using a nonparametric test, the Mann-

Whitney test, for significant differences in median patch area to perimeter ratios. The median ratio for active colonies was found to be significantly larger than inactive colonies (significant at 0.0370) (Figure 22). Small patch sizes likely support small colonies that make them susceptible to predators, disease, inbreeding depression, and other issues associated with the theory of minimum viable population sizes.

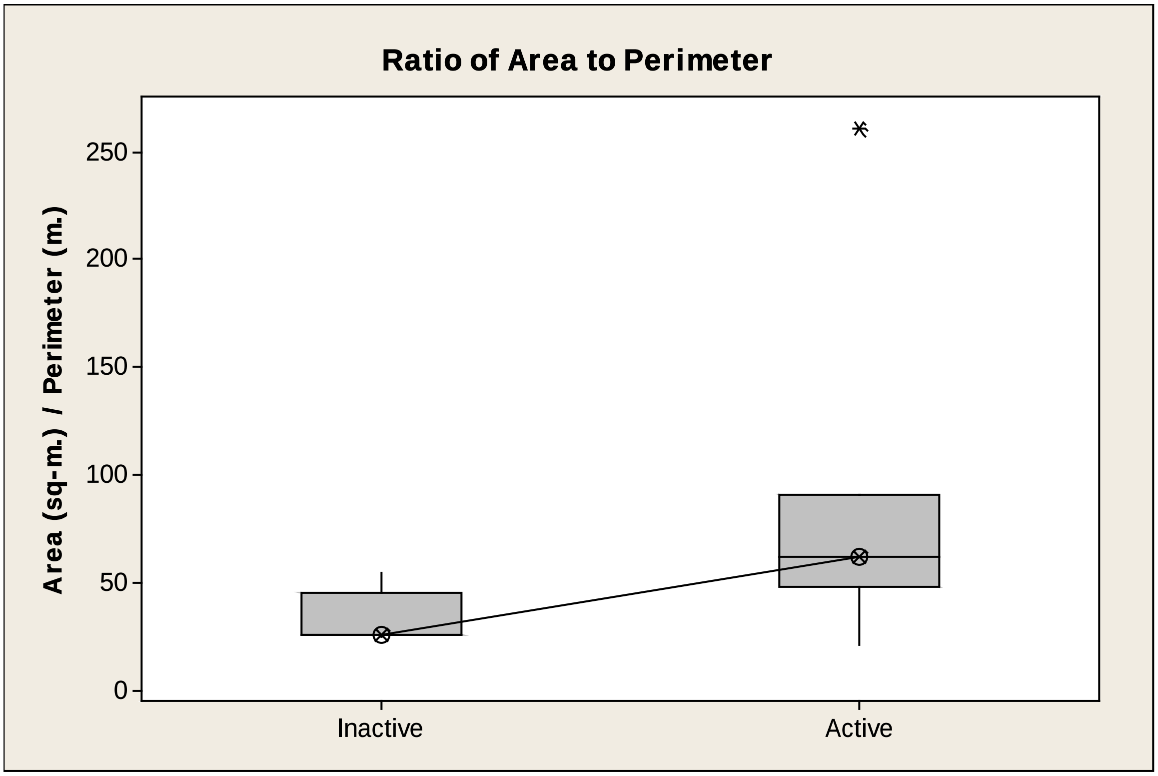


Figure 22. Boxplot showing the range, quartiles, and median patch perimeter to area ratio for active versus inactive colonies. Though not statistically significant, the findings suggest smaller and/or irregularly shaped habitat patches are less likely to contain active colonies.

A 2-sample t-test was used to compare the road density at active versus inactive colonies. Active colonies were found to have significantly higher road densities (p-value = 0.004) than inactive colonies. This suggests UPDs may benefit from human activity within the park (Figure 23). Further research is needed to better understand why this may be. Some possible explanations may be buffering UPDs from predation and the availability of human food sources.

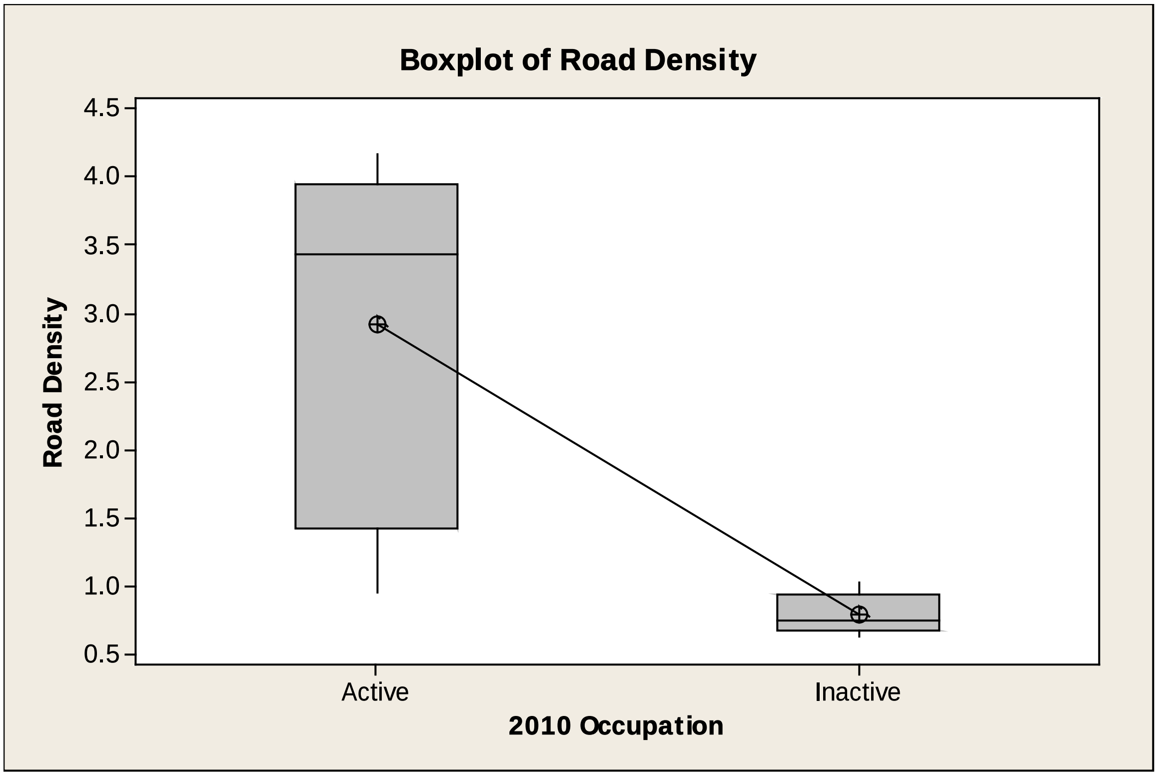


Figure 23. Boxplot showing the range, quartiles, mean, and median road densities for active and inactive colonies. A parametric test showed that road density for active colonies is significantly greater than at currently inactive colonies. This result suggests Utah prairie dogs may benefit in some way from human activities within the park.

A 2-sample t-test was used to compare the distance to the nearest active colony for both active and inactive colonies. Active colonies were found to have significantly shorter distances to a nearby active colony and inactive colonies tend to be more isolated (p-value = 0.031). Connectivity between habitat patches has been found to be important for several species and appears to also be important for UPDs (Figure 24).

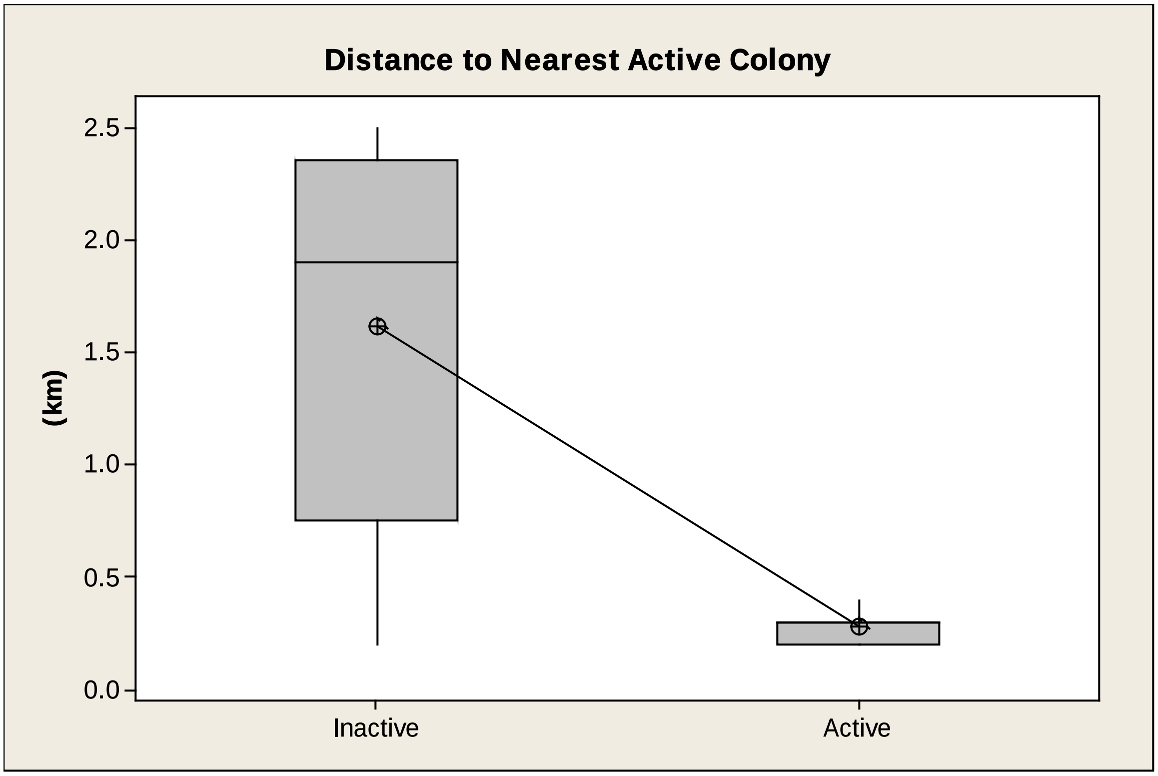


Figure 24. Boxplot showing the range, quartiles, mean, and median distance of a colony to a currently active colony. This graph suggests Utah prairie dogs (UPDs) are more likely to maintain occupancy of a site when there are currently active UPD colonies nearby.

Field Assessment

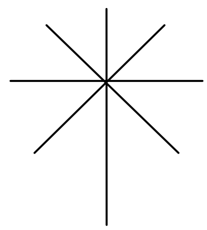
Two different methods were used to assess the quality of habitat within BCNP. A vegetation survey of the meadows within the park was conducted to assess the suitability of habitat within the park. This study sought to determine (1) if there are differences in species composition between meadows with and without prairie dogs, (2) if vegetation differs as distance from prairie dog colonies increases, (3) if there are species that are indicative of the presence of UPDs, and (4) if there are abiotic factors that explain the presence or absence of prairie dogs. In addition to the field component, a species distribution model called MaxEnt (Phillips et al. 2006) was used to identify areas of habitat that may be suitable sites for reintroduction within the park's boundaries. Using these suitable habitat classifications and the annual counts from Bryce Canyon National Park, the potential carrying capacity for each meadow was estimated. Lastly, study results are summarized and recommendations are made for improving UPD habitat within the park.

Methods

Data Collection

Surveys were conducted in the summer of 2009 to assess the habitat suitability of the BCNP meadows. The first survey, to capture cool-season grasses and forbs, was conducted between May 25 and June 14, 2009. A repeat survey was conducted from July 27 through August 3 to capture the emergence of vegetation associated with the monsoon season. The vegetative sampling design used to survey and inventory BCNP meadows for UPD habitat was developed in conjunction with park staff and in consultation with the UPD recovery team, the U.S. Fish and Wildlife Service, and the Utah Division of Wildlife Resources.

Since the area being sampled was of small extent, transect lines were hand drawn on the basis of vegetation and elevation. We began by extracting contour intervals of 3 m from a digital elevation model and overlaid the contour layer with an image layer that clearly delineated meadows from tree coverage. Transects were drawn through the meadows by picking lines that were perpendicular to as many contour lines as possible. From that first transect line, three other lines were drawn: one at 90° from the line and two at 45°. The resulting pattern formed a star shaped pattern illustrated below:



The transect intercepts were centered on the largest area or center of the meadows. For example, if the meadow was the widest at the northern end, then the additional transects were drawn there. Transects were oriented to provide semi-equal sample sizes of vegetation types, hydrological aspects of the meadows, slope, and aspect.

Sample points were placed at the transect ends, the intercepts, and wherever a contour line intercepted a transect (Figure 25). Data that was gathered at each point included a fixed area (1 m^2) vegetation sample (count, absolute cover, average height estimates of each species, % litter, % bare ground, and % rock), slope, aspect, surface soil texture, distance to nearest prairie dog burrow, potential for burrow flooding, and distance to the nearest tree.

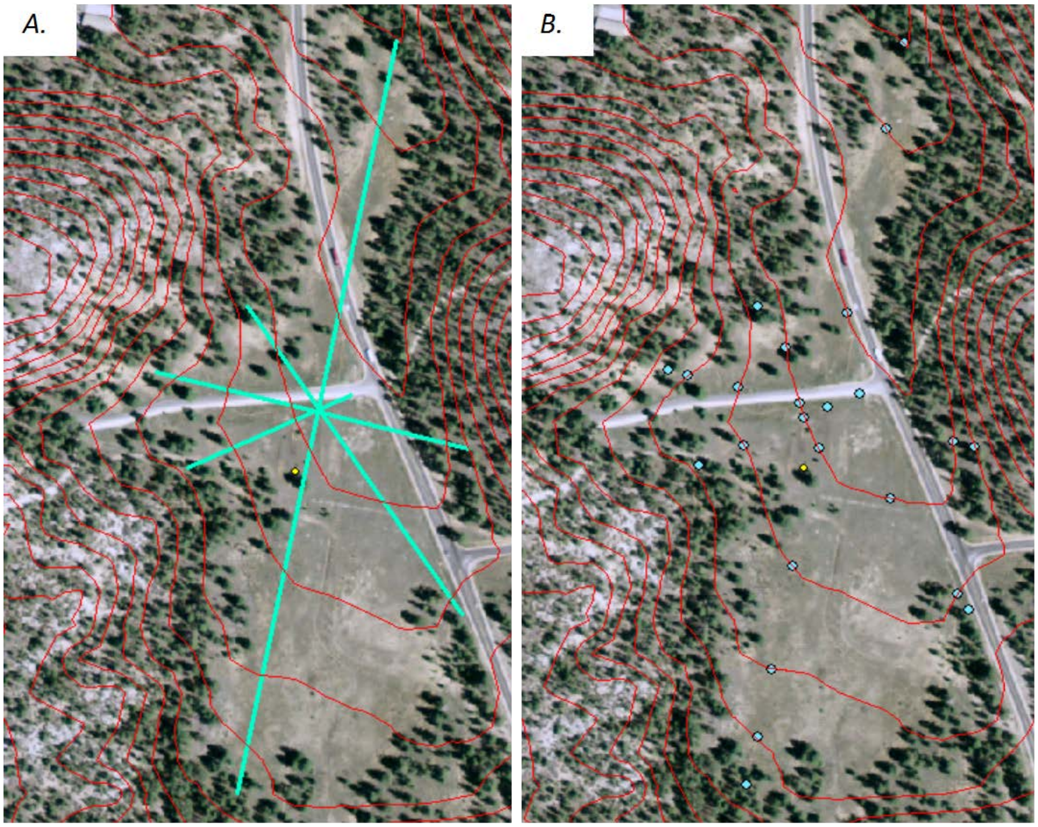


Figure 25. Transects and the derived sampling points. The red lines are the contours derived from the digital elevation map. *A*., Transects are in green and the yellow point is a Utah prairie dog colony. *B*., Sample points derived from the intersection of transects and contour lines.

Systematically placed transects were created in a GIS that ran perpendicular to the hydraulic and elevation gradients at each site. Along these transects, 1 m^2 quadrat locations were stratified to optimize the number of quadrats that represent each of the following environmental variables present at the study sites: distance to nearest tree species, surface soil texture, geology, aspect, slope, and hydrologic position (areas prone to flooding or not).

Sampling was conducted in May and June to capture cool-season plant species production following the start of the growing season and resurveyed in July and August to capture the peak production of warm-season plant species associated with the monsoon season. A permanent rebar stake was placed at the center point of all transects. Pin flags were placed at the location of each quadrat for ease of relocation for the second survey. The location of the stake and flags was documented with the Trimble GeoXT for submeter accuracy. Bearing direction of all transects were measured using a compass in the field. Pin flags were removed after the second survey session.

Cover of species, litter, bare ground, and height were recorded. Clonal plants were difficult to count, so 500 counts were given to species that exhibited clonal reproduction and were too clustered to count as individuals. Other measurements included distance to the nearest tree and distance to the nearest active colony (if present on study area), as depicted in the Utah Prairie Dog Habitat Evaluation Guide (Toombs 2007). A total of 245 plots were sampled.

Statistical Analyses

For the first part of the analysis, meadows were analyzed on a plot-by-plot basis based on distance to the nearest prairie dog colony to determine if there were indicator species that were linked to either the presence or absence of prairie dogs. In the second part of the analysis, sites within meadows were classified as either present or absent, depending upon the presence of an active colony of prairie dogs. R for Mac OS X GUI 1.35 was used for the indicator species analyses and NMDS ordinations, and SPSS (SPSS 15.0 for Windows, SPSS Inc., 2006) was used for all ANOVAs.

There were a total of seven meadows with prairie dogs present and six without. The meadows with prairie dogs were: Dave's Hollow East, Dave's Hollow West, Well Site, Mixing Circle, Mixing Circle Intersection, Lower East Creek, and Sunset. Meadows without prairie dogs encompassed the Fairyland, Upper Mixing Circle, Rainbow Gate, Upper East Creek, Paria, and Sheep Creek. Plants were grouped into three functional groups: shrubs, forbs, and grasses. Groups were determined from the U.S. Department of Agriculture classification of growth habit (see Appendix A for the full list of species recorded and their functional group). Functional groups were averaged together across transects and within meadows to analyze for differences between meadows with and without prairie dogs using height, cover, and count.

Identifying Current Suitable Utah Prairie Dog Habitat

Prairie Dog Colonies

C. parvidens colonies collected by the Utah Division of Wildlife Resources for the past 26 years were used for this study. Currently active colonies were selected from "complexes," which are groups of colonies separated by less than 10 km with no geographic barriers (Roberts et al. 2000), and complex centroids were generated to represent occurrences. For the analysis, 42 complexes were used as occurrence points.

Environmental Variables

A total of 26 environmental variables were used and included climate, vegetation, landform, and soil data. Present climatic variables were from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) 4 km grid cell resolution dataset between 1970 and 2000 (Daly et al. 1994) (www.prism.oregonstate.edu). Variables were averaged by month across the 30-year span and further grouped into seasons based upon similarities in precipitation and temperature ranges. Seasons were created by averaging the following months together: winter (December, January, and February), spring (March and April), early summer (May and June), monsoon (July, August, and September) and fall (October and November). Non-climatic variables included were vegetation (existing vegetation height and cover) from LANDFIRE (http://gisdata.usgs.net/website/landfire/), landform and vegetation type from ReGAP (Manis et al. 2001), and soil (SSURGO).

Soil data were downloaded from SSURGO (http://soildatamart.nrcs.usda.gov) and variables included were depth to any restrictive layer (e.g., bedrock), depth to lithic bedlayer, and percent clay, sand, and silt. The first two variables reflect the availability of soil for burrowing, while percent clay, silt, and sand summarize soil texture and stability for burrowing. Datasets were re-sampled to a common 30-m resolution grid using bilinear interpolation with PRISM and cell majority with STATSGO, LANDFIRE, and ReGAP.

Model Calibration and Evaluation

MaxEnt version 3.3.3 was used to identify current suitable UPD habitat within the boundaries of Bryce Canyon National Park. Maximum entropy (MaxEnt) estimates species distribution by finding the distribution with the maximum entropy subject to constraints by environmental variables chosen *a priori* (Phillips et al. 2006, Phillips and Dudik 2008). Studies have shown MaxEnt performs well using presence-only data (Elith et al. 2006, Evangelista et al. 2008, Kumar et al. 2009). Output format was specified to a logistic form for easy interpretation. Thirty percent of the occurrences were used for model evaluation. The random seed option was selected whereby different presence points were randomly chosen to train the model for each of the 500 runs (Phillips et al. 2006). To compare suitable and unsuitable habitats, the upper most threshold value was specified wherein the fixed cumulative value was equal to 1.

Model fit was evaluated using AUC values (Area Under the receiver operator characteristic Curve) (Guisan and Zimmermann 2000, Pearce and Ferrier 2000, Araújo et al. 2005). Variable importance was assessed using a jackknife analysis (Phillips et al. 2006). Linear, quadratic, hinge, or categorical response functions were also examined, which depict the relationship between species occurrence and environmental factors (Phillips et al. 2006).

Results

Summary of All Meadows

The Sunset area was removed from the analysis because significant differences in plant community structure when compared to the remaining sites. Since there were no statistical differences between early summer and late summer sampling efforts, the two surveys were averaged together by plot number. More than 120 species were recorded across the two sampling periods. The five most abundant species according to count were *Poa fendleriana*, *Elymus elemoides*, *Poa compressa*, *Juncus articus*, and *Poa* species. The least abundant species according to count were *Oenothera longissima*, *Oenothera caespitosa*, and *Lupinus sericeus*. A species accumulation curve indicated that this study adequately sampled the understory community (Figure 26).

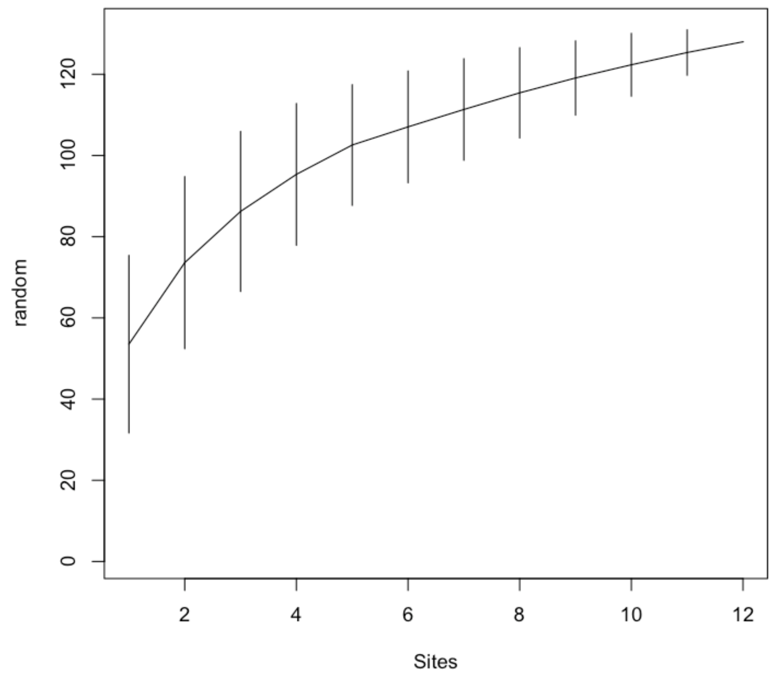
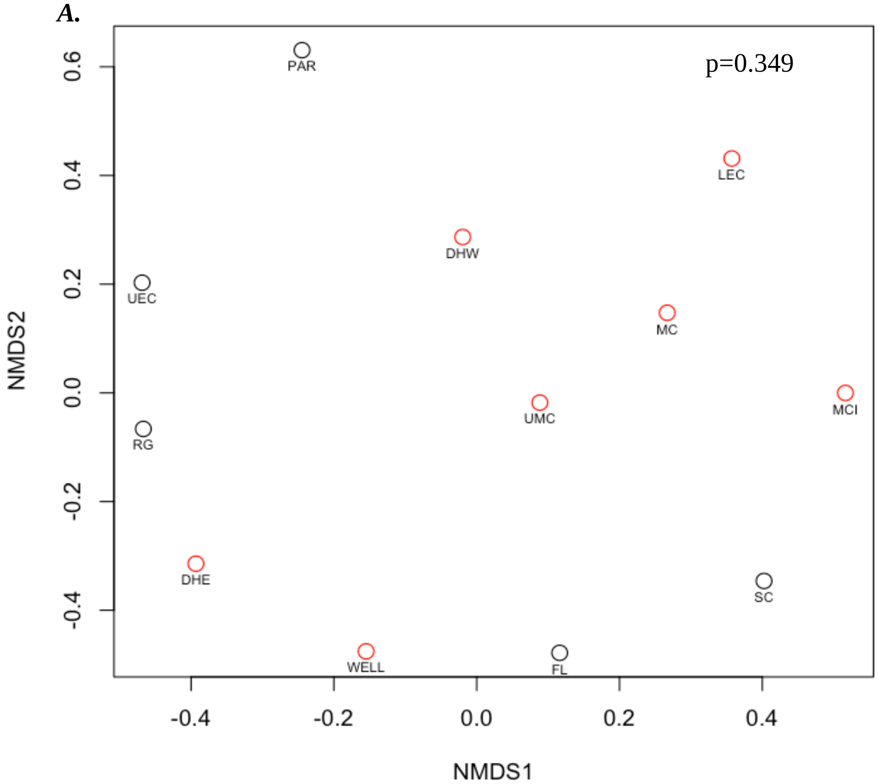


Figure 26. Species accumulation curves indicate that the sampling intensity of this study was adequate to capture the vegetation within the meadows.

Differences between Meadows With and Without Prairie Dogs

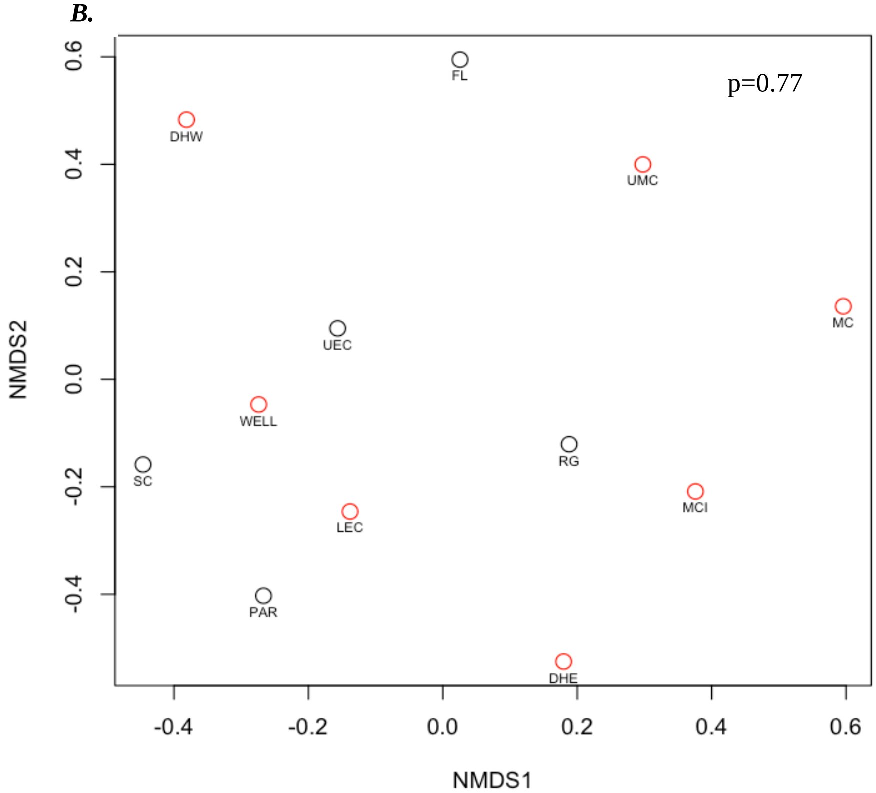
To assess for differences in species composition between meadows with and without prairie dogs, a series of Nonmetric Multi-Dimensional Scaling (NMDS) was conducted using the adonis function in R to test for differences between meadow vegetation types, which is analogous to a MANOVA test. Meadow averages of all species and meadow averages of functional groups were used to test for differences between cover, count, and height. No significant patterns were found (Figure 27), with p-values ranging from 0.45 to 0.09.

A.



p=0.349
PAR
LEC
DHW
UEC
MC
UMC
MCI
RG
DHE
SC
WELL
FL
NMDS2
NMDS1

B.



p=0.77
FL
DHW
UMC
MC
UEC
WELL
RG
SC
MCI
LEC
PAR
DHE
NMDS2
NMDS1

C.

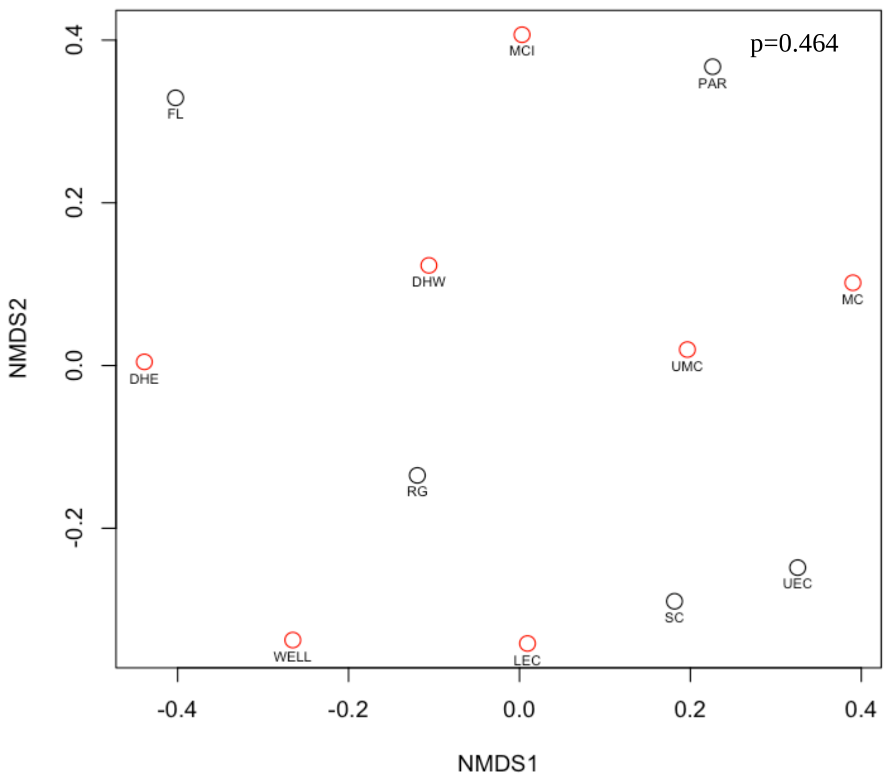


Figure 27. NMDS plots indicate no pattern between meadows with and without prairie dogs. Plots (meadows) close together indicate more similarity than plots further apart. (*A*.) Vegetation cover, (*B*.) vegetation height, and (*C*.) vegetation count.

There were some fundamental differences between meadows with and without prairie dogs in terms of vegetation structure (height, cover, and count) on a species-by-species basis. An ANOVA of the functional groups showed that in terms of height, one shrub species (*Artemesia nova* (p=0.05)), two grasses (*Carex rossii* (p=0.041) and *Elymus lanceolatus* (p=0.0001)), and three forbs (*Artemisia frigida* (p=0.022), *Erigeron speciosus* (p=0.040), and *Leptodactylon pungens* (p=0.036)) were significantly greater in meadows without prairie dogs than with. Only three forb species showed differences in cover between the two meadow types: *Artemsisia frigida* (p=0.027), *Euphorbia brachycera* (p=0.050), and *Leptodactylon pungens* (p=0.045). One grass (*Elymus lanceolatus* (p=0.0001)) and three forbs (*Euphorbia brachycera* (p=0.045), *Leptodactylon pungens* (p=0.018), and *Oenothera howardii* (p=0.034)) had different counts between meadows.

An indicator species analysis further distinguished differences between meadows with and without prairie dogs. Four forb species were correlated with the presence of Utah prairie dogs: *Achnatherum pinetorum* (p= 0.0344), *Hymenoxys acaulis* (p=0.0248), *Leptodactylon pungens* (p=0.0008), and *Linanthus caespitosus* (p=0.0522). Nine species of a mixture of shrubs, forbs, and grasses were indicators of meadows without prairie dogs: *Artemisia nova* (p=0.0254), *Bromus anomalus* (p=0.0206), *Eriogonum racemosum* (p=0.0030), *Erigeron speciosus* (p=0.0094), *Festuca saximontana* (p=0.0036), *Hes-*

perostipa comate (p=0.0528), *Oenothera* sp. (p=0.0030), *Potentilla concinna* (p=0.0146), and *Solidago simplex* (p=0.0058).

Abiotic factors were analyzed for differences between the two meadow types and no patterns emerged. The abiotic factors included distance to nearest tree species, surface soil texture, geology, aspect, slope, and hydrologic position (areas prone to flooding or not).

Distance from Prairie Dog Colonies

Plots were grouped into three distance classes (50 m, 100 m, and 200 m) based on distances from the nearest UPD colonies. An indicator species analysis of the count data was performed to determine if certain species were indicative of the presence of prairie dogs. At the 50 m distance, three species were correlated with the presence of prairie dogs: *Carex* sp. (0.0116), *Elymus trachycaulus* (0.0058), and *Leptodactylon pungens* (0.0124). At the 100 m distance the following species were indicative of the presence of prairie dogs: *Artemisia frigida* (0.0378), *Elymus trachycaulus* (0.0086), *Iris missouriensis* (0.0136), *Koeleria macrantha* (0.0290), *Leptodactylon pungens* (0.0460). At the 200 m distance, six species were indicative of the presence of prairie dogs, including *Artemisia tridentata* (0.0082), *Chamaesyce fendleri* (0.0412), *Elymus lanceolatus* (0.0002), *Elymus trachycaulus* (0.0444), *Leptodactylon pungens* (0.0006), and *Linanthus caespitosus* (0.0492).

Identifying Current Suitable Utah Prairie Dog Habitat

The model generated in MaxEnt produced “excellent” AUC scores (AUC=0.965) and identified approximately 7 ha (18 acres) of suitable habitat within BCNP boundaries (Figure 28). Suitable habitat in hectares by meadow from greatest to least was as follows: Rainbow Gate and Upper East Creek (2.06), Sheep Creek (0.97), Lower East Creek (0.95), Dave’s Hollow West (0.41), Dave’s Hollow East (0.39), Mixing Circle Intersection (0.23), Mixing Circle (0.36), Paria (0.27), Sunset (0.27), and Fairyland (0.009). The jackknife analysis indicated that minimum and maximum temperature were the predominant factors in predicting suitable habitat, but differences in vegetation type were likely the drivers of differences in habitat suitability within Bryce Canyon National Park (Figure 29).

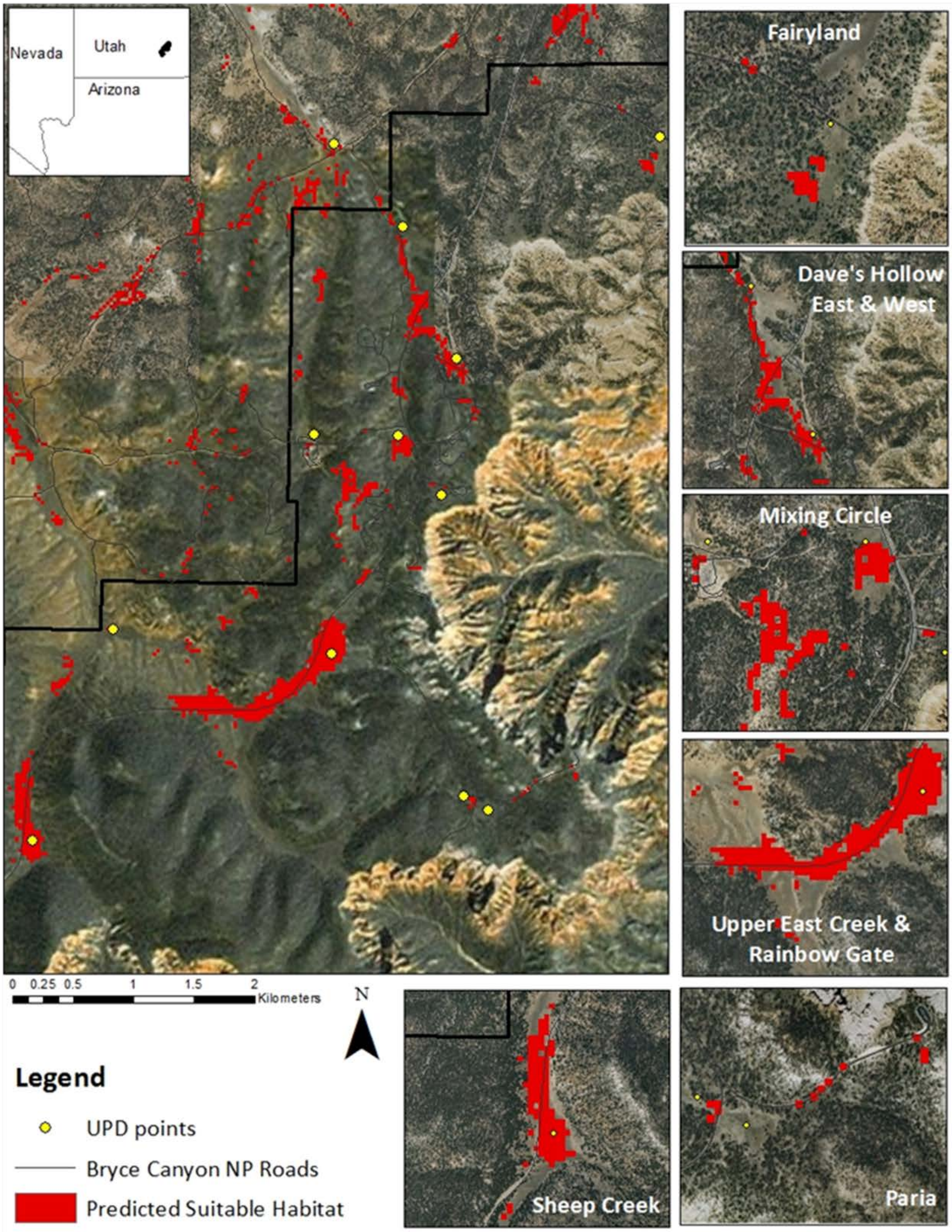


Figure 28. Predicted current suitable habitat of Utah prairie dogs within Bryce Canyon National Park generated from the MaxEnt output.

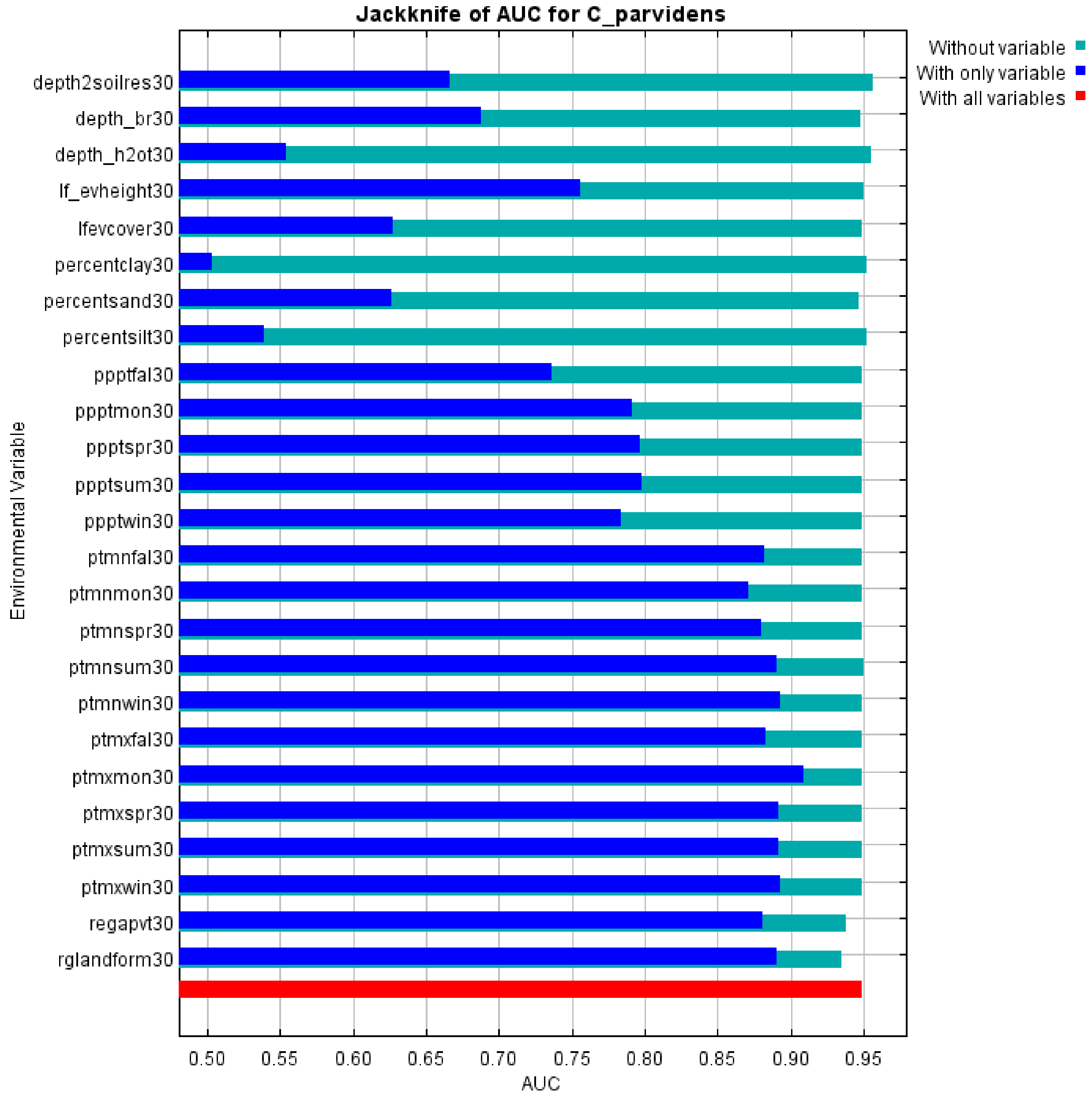


Figure 29. Jacknife analysis indicating variable importance based on each variables contribution to the overall model fit (AUC score). See Table 2 for abbreviations of variable names.

Table 2. Variables and their abbreviations used in the MaxEnt model.

Variable Name	Variable Name
Depth to bedrock (depth_br)	Precipitation Summer (pptsum)
Depth to water table (depth_h2ot)	Precipitation Monsoon (pptmon)
Depth to restrictive layer (depth2soilres)	Minimum Temperature Fall (ptmnfal)
Landform vegetation height (lf_evheight)	Minimum Temperature Winter (ptmnwin)
Landform vegetation cover (lfevcover)	Minimum Temperature Spring (ptmnspr)
Regap vegetation type (regapvt)	Minimum Temperature Summer (ptmnsum)
Rangelandform (rglandform)	Minimum Temperature Monsoon (ptmnmon)
Percent sand (percentsand)	Maximum Temperature Fall (ptmxfal)
Percent silt (percentsilt)	Maximum Temperature Winter (ptmxwin)
Percent clay (percentclay)	Maximum Temperature Spring (ptmxspr)
Precipitation Fall (pptfal)	Maximum Temperature Summer (ptmxsum)
Precipitation Winter (pptwin)	Maximum Temperature Monsoon (ptmxmon)
Precipitation Spring (pptspr)	

Discussion

Characteristics of Meadows within Bryce Canyon National Park

This study is one of the first to use field surveys and species distribution modeling to assess the habitat requirements of the Utah prairie dog. The results of the field survey indicate that differences in prairie dog habitat within the park are driven mainly by vegetation differences and not by abiotic factors, such as slope, aspect, and soil composition. Although these factors are known to be important in the establishment and success of burrows (Wagner and Drickamer 2004), there may not have been enough variation between the meadows to explain differences between those with and without prairie dogs. Furthermore, the method used by this study to qualifying soil texture was extremely coarse, and a method using a lab analysis might give different results.

The literature on the effects of prairie dogs on the surrounding habitat has generally supported the idea that prairie dogs alter the habitat surrounding their burrows, acting as "ecosystem engineers" (Bonham and Lerwick 1976, Archer et al. 1987, Davidson and Lightfoot 2008). Contrary to these studies, this study did not find significant differences in the overall vegetative community structure between meadows with and without prairie dogs (Figure 27). Although all meadows differed from each other according to vegetation count, height, and cover, as indicated by the NMDS plot in Figure 27, the differences were not driven by the presence or absence of prairie dogs. As shown in Figure 27, meadows whose plots are closer together indicated more similar vegetation communities, while meadows whose plots are farther apart indicate less similar communities.

However, this study identified a few species that differed between meadow types (presence and absence) in terms of cover, count, and height. One species in particular, black sagebrush (*Artemesia nova*), had significantly different height measurements between meadows with and without prairie dogs. Since cover and count did not differ between the two meadow types, prairie dogs may either be browsing the black sagebrush to keep the height low or selecting habitat characterized by low shrub height. Black sagebrush has been hypothesized to be one of the drivers of the decline of the Utah prairie dog (Collier and Spillett 1975). In addition, Lehmer and colleagues (2009) found that Utah prairie dogs typically avoided consuming the shrub, even though their habitat was dominated by the species.

The indicator species analysis of the vegetation data classified by distance from prairie dog colonies indicated that prairie dogs very likely structure the landscape at a smaller scale than by meadows. At a 50 m distance, there were two grasses (*Carex species* and *Elymus trachycaulus*) and one forb (*Leptodactylon pungens*) that were indicative of the presence of prairie dogs. At both the 100 m and 200 m distances, the presence of prairie dogs was correlated with the presence of both forbs and grasses. These results are consistent with other studies on the vegetation community structure surrounding active colonies. Herbaceous species, the primary food of prairie dogs, tend to decrease with increasing densities of highly competitive, xerophytic species (Ellison 1960, Collier and Spillett 1973, Tueller and Blackburn 1974).

Together, these results indicate that although there are differences in cover, count, and height of some species, the differences are not great enough to create a signature on the vegetation community of meadows with and without prairie dogs. This is consistent with a study by Grant-Hoffman and Detling (2006), which found no significant difference in biomass and vegetation cover between *C. gunnisoni* prairie dog towns and the surrounding grassland. One of the most likely explanations for this finding is that prairie dog densities are not high enough to significantly alter the vegetative community of an entire meadow, and prairie dogs are selecting habitat with certain characteristics (e.g., low shrub height).

Estimated Carrying Capacities

Using the available habitat suitability estimates for each meadow from the MaxEnt model in addition to reported carrying capacities for Cynomys species reported in the literature, general predictions can be made regarding the potential carrying capacity of the meadows within Bryce Canyon National Park (Table 3). Data from published literature on the carrying capacity per hectare of *Cynomys ludovicianus* was used for estimates of *C. parvidens*. Estimates range from an average of 13 colonies per hectare (King 1955) to a minimum density of 10 prairie dogs per hectare (Lewis et al. 1979) and a maximum density of 40 prairie dogs per hectare (O'Meilia et al. 1982, Crosby and Graham 1986, Archer et al. 1987, Clippinger 1989). Rainbow Gate and the Upper East Creek Meadow have the greatest potential for an increase in density. Unsurprisingly, the Mixing Circle Colony has approximately 43 more prairie dogs per hectare of available natural habitat, indicating that the supplemental feed is keeping the colony size artificially high. Together, the results summarized in Table 3 indicate that while there is some available habitat for a reintroduction or established colony growth, the meadows within Bryce

Canyon National Park are already close to the mean carrying capacity reported for other Cynomys species.

Table 3. Estimated carrying capacities for each meadow with three different densities (10, 25, and 40 Utah prairie dogs (UPDs) per hectare).

Meadow name	Hectares	Count (Mean)	UPDs/ hectare	Possible number of UPDs for introduction		
				10/ha	25/ha	40/ha
Rainbow Gate and Upper East Creek	2.06	4	1.94	8	23	38
Sheep Creek	0.97	1	1.03	9	24	39
Lower East Creek	0.96	31	32.46	-22	-7	8
Dave’s Hollow West	0.41	15	36.34	-26	-11	4
Dave’s Hollow East	0.39	11	28.31	-18	-3	12
Mixing Circle Intersection	0.23	9	38.34	-28	-13	2
Mixing Circle	0.36	30	83.29	-73	-58	-43
Paria	0.27	1	3.69	6	21	36
Sunset	0.27	?	?	?	?	?
Fairyland	0.01	3	336.96	-327	-312	-297

Habitat Improvement

Based on the results reported in this study, there are a number of recommendations to increase the suitability of the habitat within the meadows of Bryce Canyon National Park. Decreasing the height and cover of black sagebrush would be among the first recommendations. Historically, grazing within the park may have acted to keep shrubs densities low and grass and forb densities high. When grazing within the park began to phase out (1931–37) and were eventually terminated in 1947, the meadows saw a turnover to a predominately shrub communities with grasses in the wetter sections of the meadows. In a reintroduction study of Utah prairie dogs, Player and Urness (1982) found that some sort of vegetation treatment was needed when prairie dogs were transplanted back onto old colonies with high densities of shrub cover. Reducing the cover and height of shrubs, such as black sagebrush, may act to increase the abundance of grasses and forbs. Second, to identify areas of suitable natural habitat, the MaxEnt results reported in Figure 28 should be used, ignoring the small areas in the trees identified as suitable habitat. Furthermore, much of the suitable habitat identified by the model results is on the slope at the outer edges of the meadows, where prairie dogs are likely to have a good vantage point to spot predators. Lastly, some of the most successful colonies are associated with human use (Mixing Circle and Sunset), and while these colonies may not be considered “natural,” they represent possible source populations for other colonization events.

Management Issues and Recommendations

This study sought to determine the influence of anthropogenic factors on the Utah prairie dogs within the park’s boundaries and how to improve the habitat quality for this species. A comparison between currently active and inactive colonies showed that active colonies (1) occupied larger habitat patches, (2) were closer to roads, and (3) had higher connectivity with other active colonies than inactive colonies. Although the ideal solution would be for prairie dogs within the park to be completely isolated from anthropogenic influences, this is not a realistic goal for BCNP because of the park's small area and the number of roads and lookouts that traverse suitable prairie dog habitat. Because of these factors, we recommend leaving the colonies that are associated with anthropogenic factors (e.g., Mixing Circle Intersection, Mixing Circle, and Sunset) intact, as they represent a large portion of the overall population and can act as source populations for colonization events.

Regarding improving the habitat quality of meadows in Bryce Canyon National Park, our primary recommendation would be to decrease the height and cover of black sagebrush in active colonies. For selecting habitat for the introducing of prairie dogs into new areas, we recommend selecting habitat based on the MaxEnt model output and using a vegetation treatment to decrease the cover of black sagebrush, if needed. This should act to not only increase the number of prairie dogs per colony, but also to opening up suitable habitat to future colonization events.

Research Needs

There are a number of research questions that still need to be addressed. First, the relationship between active colonies anthropogenic factors is not fully understood. Two possible hypotheses to explain the positive relationship between colony success and human activity might be that colonies close to high-impact areas experience low predation rates or that these colonies have access to supplemental feed. The first hypothesis may explain the persistence of the Mixing Circle Intersection Colony, while the later hypothesis might explain the success of the Sunset population (and certainly the Mixing Circle Colony). Second, while soils are known to be an integral factor in the success of colonies (Wagner and Drickamer 2009), the soils data used by this study was too coarse to be able to differentiate between soils in the meadow versus those surrounding prairie dog colonies. Lastly, future research should center on identifying suitable habitat for the Utah prairie dog under various climate change scenarios. If temperatures within Bryce Canyon National Park are expected to exceed those which normally characterize suitable habitat by the end of the century, then it will likely become a management priority to begin to designate other areas as reintroduction sites.

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Appendix A

USDA Species	Species	Growth Habit	USDA Species	Species	Growth Habit
2FA	Unknown forb	Forb	ERIGE2	Erigeron sp.	Forb
2GB	Unknown grass	Grass	ERIOG	Eriogonum sp.	Forb
ACHY	Achnatherum hymenoides	Grass	ERRA3	Eriogonum racemosum	Forb
ACLE9	Achnatherum lettermanii	Grass	ERSP4	Erigeron speciosus	Forb
ACMILO	Achillea millefolium L. var. occidentalis	Forb	EUBR	Euphorbia brachycera	Forb
ACPI2	Achnatherum pinetorum	Grass	FESAS	Festuca saximontana	Grass
AGCR	Agropyron cristatum	Grass	GERAN	Geranium sp.	Forb
AGST2	Agrostis stolonifera	Grass	GUSA2	Gutierrezia sarothrae	Shrub
ALLIU	Allium species	Grass	HECOC8	Hesperostipa comata	Grass
AMUTU	Amelanchier utahensis var. utahensis	Shrub	HOJU	Hordeum jubatum	Grass
ANRO3	Antennaria rosulata	Forb	HYACA2	Hymenoxys acaulis	Forb
ANSE4	Androsace septentrionalis	Forb	HYFI	Hymenopappus filifolius	Forb
ARFEG	Arenaria fendleri	Forb	HYFO7	Hypericum formosum	Forb
ARFR4	Artemisia frigida	Forb	HYRIF	Hymenoxys richardsonii	Forb
ARLUL	Artemisia ludoviciana	Shrub	IPAG	Ipomopsis aggregata	Forb
ARNO4	Artemisia nova	Shrub	IRMI	Iris missouriensis	Grass
ARPU9	Aristida purpurea	Shrub	JUAR2	Juncus arcticus	Grass
ARPY2	Artemesia pygmaea	Shrub	KOMA	Koeleria macrantha	Grass
ARTRV	Artemisia tridentata	Shrub	LEMO4	Leucocrinum montanum	Forb
ASAM5	Astragalus amphioxys	Forb	LEMOC5	Lepidium montanum	Forb
ASARP	Astragalus argophyllus	Forb	LEPU	Leptodactylon pungens	Forb
ASCO12	Astragalus convallarius	Forb	LICA36	Linanthus caespitosus	Forb
ASCOC9	Astragalus columbianus	Forb	LIIN2	Lithospermum incisum	Forb
ASHUH2	Astragalus humistratus	Forb	LIKI2	Linum kingii	Forb
ASKE	Astragalus kentrophyta	Forb	LINUM	Linum sp.	Forb
ASMEP	Astragalus megacarpus	Forb	LIPEL3	Linum lewisii	Forb
ASMIO	Astragalus miser	Forb	LUAR3	Lupinus argenteus	Forb
ASTRA	Astragalus sp.	Forb	LUSES4	Lupinus sericeus	Forb
BASA3	Balsamorhiza sagittata	Forb	LYAR2	Lygodesmia arizonica	Forb
BOGR2	Bouteloua gracilis	Grass	MUAN	Muhlenbergia andina	Grass
BRAN	Bromus anomalus	Grass	MUHLE	Muhlenbergia sp.	Grass
BRIN2	Bromus inermis	Grass	MUPU2	Muhlenbergia pungens	Grass
CAAND	Castilleja angustifolia	Forb	OECAC3	Oenothera caespitosa	Forb
CALA38	Calylophus lavandulifolius	Forb	OECO2	Oenothera coronopifolia	Forb
CALI4	Castilleja linariifolia	Forb	OEHO2	Oenothera howardii	Forb
CALYL	Calylophus sp.	Forb	OELO	Oenothera longissima	Forb
CANU3	Calochortus nuttallii	Forb	OENOT	Oenothera sp.	Forb
CARO5	Carex rossii	Grass	PAMU11	Packera multilobata	Forb
CASP	Carex sp.	Grass	PASM	Pascopyrum smithii	Grass
CASTI2	Castilleja sp.	Forb	PECAD2	Penstemon caespitosus	Forb
CHDE2	Chrysothamnus depressus	Shrub	PECE	Pedicularis centranthera	Forb
CHDO	Chaenactis douglasii	Forb	PECO5	Penstemon comarrhenus	Forb
CHFE3	Chamaesyce fendleri	Forb	PENST	Penstemon sp.	Forb
CHPAH2	Chrysothamnus parryi	Shrub	PHLO2	Phlox longifolia	Forb
CHVIL6	Chrysothamnus viscidiflorus	Shrub	POA	Poa sp.	Grass
CIAR3	Cirsium arizonicum	Forb	POCO	Poa compressa	Grass
CRAB2	Cryptantha abata	Forb	POCOB	Potentilla concinna	Forb
CRRUG	Crepis runcinata	Forb	POCR4	Potentilla crinita	Forb
DRSU	Draba subalpina	Forb	POFE	Poa fendleriana	Grass
ELCA4	Elymus canadensis	Grass	PUTR2	Purshia tridentata	Shrub
ELEL5	Elymus elymoides	Grass	ROWO	Rosa woodsii	Shrub
ELHI4	Elyleymus hirtiflorus	Grass	RUSAM	Rumex salicifolius	Forb
ELLA3	Elymus lanceolatus	Grass	SEMU3	Senecio multilobatus	Forb
ELPS	Elymus pseudorepens	Grass	SENEC	Senecio sp.	Forb
ELTR7	Elymus trachycaulus	Grass	SESPS2	Senecio spartioides	Forb
ELYMU	Elymus species	Grass	SOLID	Solidago sp.	Forb
EQLA	Equisetum laevigatum	Forb	SOSI3	Solidago simplex	Forb
ERAS2	Erysimum asperum	Forb	SOVE6	Solidago velutina	Forb
ERCA14	Erysimum capitatum	Forb	STCO6	Streptanthus cordatus	Grass
ERDI4	Erigeron divergens	Forb	SYOR2	Symphoricarpos oreophilus	Shrub
EREA	Erigeron eatonii	Forb	TAOF	Taraxacum officinale	Forb
ERFL	Erigeron flagellaris	Forb	TECA2	Tetradymia canescens	Shrub