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Research Article

The Effect of Coterie Relocation on Release-Site Retention and Behavior of Utah Prairie Dogs

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ABSTRACT Utah prairie dogs (*Cynomys parvidens*) have been extirpated in 90% of their historical range. Because most populations in Utah occur on private land, this threatened species is continually in conflict with landowners. The Utah Division of Wildlife Resources has been relocating Utah prairie dogs from private to public land since the 1970s, but relocations have been largely unsuccessful because of high mortality. Utah prairie dogs are highly social animals, but they are usually relocated without regard to their family group, or coterie. We predicted that relocating Utah prairie dogs with other coterie members would improve their survival rate and result in post-release behavior similar to non-relocated animals. We chose to investigate release-site retention as a measure of relocation success because we were unable to separate emigration from mortality. We relocated Utah prairie dogs from the Cedar Ridge Golf Course in Cedar City, Utah to 2 prepared sites near Bryce Canyon National Park, Utah in 2010 and 2011. We relocated prairie dogs as groups of coterie members or in a control group of individuals trapped with no regard to relatedness. Two months after relocation, we set traps to recapture animals to estimate release-site retention. We quantified activity budgets prior to and following relocation on study animals as well as from a previously established relocated prairie dog population on public land. The best predictor of release-site retention and recapture rate was the animal's weight at initial capture. Larger animals had high retention but low recapture rates. We found no differences in site retention or behavior between prairie dogs relocated with coteries and controls. Relocated individuals behaved more like prairie dogs on public lands than animals in the urban source population, but behaviors were still different from prairie dogs on public lands. We recommend relocating large, adult Utah prairie dogs rather than juveniles or relocating juveniles later in the trapping season to increase relocation success rate. We also suggest that future research should focus on developing additional release methods to reduce dispersal and increase site retention. © 2014 The Wildlife Society.

KEY WORDS behavior, coterie, *Cynomys parvidens*, family group, relocation, retention, translocation, Utah, Utah prairie dog.

Utah prairie dogs (*Cynomys parvidens*) occur only in southwestern Utah and have been extirpated in much of their historical range. In the 1920s, the population was estimated at 95,000 but declined to 3,300 animals by 1972 (Collier and Spillett 1973). Utah prairie dogs were listed as federally endangered in 1973 under the Endangered Species Act but reclassified as threatened in 1984 (U.S. Fish and Wildlife Service 2012). Population recovery has been slow because of sylvatic plague outbreaks and because Utah prairie dogs have low reproductive rates (Hoogland 2001, Slobodchikoff et al. 2009). The United States Fish and Wildlife Service considers populations only on federal or protected land (e.g., conservation easements, state wildlife management units) toward recovery goals because the Utah prairie dog will still be preserved on these lands following delisting. Foraging, burrowing, and their protected status create conflict between landowners and prairie dogs (2006*a*). In 2010, 83% of the prairie dogs counted during extensive annual surveys occurred on private land.

Since its listing in 1973, a recovery strategy has been to relocate Utah prairie dogs from agricultural fields and urban conflict zones onto public land throughout its extant range. During the period between 1972 and 2013, the Utah Division of Wildlife Resources and its partners relocated over 25,000 Utah prairie dogs. During the period of 2009–2012, 3,265 Utah prairie dogs from roughly 2 dozen source locations across 3 counties in southwest Utah were relocated to 11 different sites (J. Van Woeart, Utah Division of Wildlife Resources, personal communication). This annual effort led by the Utah Division of Wildlife Resources represents a massive undertaking involving many partners

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and funding sources. Relocation sites are prepared with artificial burrows and nest boxes prior to release and predator control is conducted following relocation. Although new complexes have been founded by these efforts and prairie dogs have been repatriated to areas where they were previously extirpated, many of these relocations have been unsuccessful because of high mortality (U.S. Fish and Wildlife Service 2012).

Few studies have been conducted on the success of relocation of Utah prairie dogs, but some research has been published on factors that may improve or reduce relocation success of black-tailed prairie dogs (*Cynomys ludovicianus*). Black-tailed prairie dog relocation success was higher when animals were relocated in larger groups. Reduced emigration from and increased immigration to the site was attributed to a greater sense of security in the larger group and habitat patch sizes (Robinette et al. 1995). Translocation success may also depend on the relocated animals' experience with predators (Shier and Owings 2007). Captive juvenile black-tailed prairie dogs had higher translocation survivorship when reared with predator-experienced adults than captive juveniles reared without experienced adults. In a study of Utah prairie dogs, Ackers (1992) reported that relocated prairie dogs spent more time alert and moving than non-translocated resident prairie dogs. In the first 1–3 days following release, animals exhibited considerable alert and running behaviors, and rarely foraged. Dispersal was also high immediately post release. Relocating animals to sites with refuge from predators reduced dispersal and exploratory behavior.

Relocation success may also depend on the social structure of prairie dog colonies. Within each dog town, groups of closely related individuals, or coteries, maintain and defend territories containing separate burrow systems and associated food resources (Hoogland 1995). Prairie dog coteries typically contain several closely related females, young non-reproductive male offspring, and a single reproductive male. Individuals display increased anti-predator vigilance, performed by scanning the immediate vicinity and warning other individuals, when fewer family members are present (Manno 2007).

Although social structure is important for breeding and predator avoidance, Ackers (1992) found that relocated Utah prairie dogs did not maintain their social structure following relocation. Individuals behaved independently rather than displaying social behaviors and social units did not reform in the initial months following relocation. Behaviors such as exploring, vigilance, and burrow construction were observed more frequently than social behaviors. However, Shier (2006) reported that relocating coteries significantly improved relocation success in black-tailed prairie dogs over relocating animals with no regard to relatedness, particularly for adult females. Additionally, female black-tailed prairie dogs, specifically yearling females, relocated as a coterie showed increased reproductive success and juveniles relocated late in the season had higher survival than those relocated earlier in the summer.

The purpose of our study was to determine if relocating Utah prairie dogs with other coterie members improved translocation success. We defined release-site retention, the probability of relocated individuals remaining in the relocation study area, as a measure of relocation success because of our inability to separate emigration from mortality (Dullum et al. 2005). We predicted that Utah prairie dogs relocated with family groups would have higher retention rates than those not relocated as a coterie. A change in behavior post-relocation also may reduce site retention if animals die; therefore, we predicted that relocated prairie dogs would display more vigilant behavior and less foraging behavior than non-relocated animals. We also expected that individuals relocated with coterie members would spend more time foraging and less time displaying vigilance than animals relocated with no regard to kinship.

STUDY AREA

The study involved 4 areas. The first area contained the source population of Utah prairie dogs, which was on the Cedar Ridge Golf Course in Cedar City, Iron County, Utah. The course was roughly 1,780 m in elevation and received approximately 30 cm of precipitation annually (Western Regional Climate Center 2011*a*). Sprinkler irrigation provided supplemental water at the golf course. The course used a combination of bluegrass (*Poa* sp.) and bentgrass (*Agrostis* sp.) and the dominant soil type was loam (Soil Survey Staff 2012). Average maximum temperatures ranged from 5.7° C in January to 32.3° C in July (Western Regional Climate Center 2011*b*).

Our study included 2 relocation study areas. The first study area, Lime Kiln, was located 8 km northeast of Panguitch, Garfield County, Utah, and was managed by the United States Bureau of Land Management. In the Lime Kiln study area a 1-km^2 area of brush was removed and reseeded using a Great Basin Research Center (Ephraim, Utah) grass and forb seed mix in December of 2008. The site was determined suitable for prairie dog relocation in 2010 based on the recommended translocation habitat guidelines established for Utah prairie dogs (Utah Prairie Dog Recovery Team 2009). Dominant recorded plant species included Palmer's penstemon (*Penstemon palmeri*), blue grama (*Bouteloua gracilis*), Lewis flax (*Linum lewisii*), Indian ricegrass (*Achnatherum hymenoides*), needle-and-thread (*Hesperostipa comata*), big sagebrush (*Artemisia tridentata*), black sagebrush (*A. nova*), annual mustard, and an assortment of wheatgrass (*Elymus*) species. During the study, average plant height was 36 cm. Soils ranged from gravelly to very cobbly loam (Soil Survey Staff 2012). Panguitch received approximately 25 cm of precipitation annually (Western Regional Climate Center 2011*a*). Average maximum temperatures ranged from 4.0° C in January to 29.2° C in July (Western Regional Climate Center 2011*b*). Elevation at Lime Kiln was roughly 2,080 m.

The second study area, Pat Willis, was located in John's Valley north of Bryce Canyon National Park, Garfield County, Utah, and was managed by the United States Forest Service. The study area was part of a long drainage of available habitat covering over 10 km^2. This area had wild

prairie dog colonies approximately 500 m to the south and southeast of the release sites, and had an additional release site constructed 1 km from our study area in 2011. The Pat Willis study area was historically reseeded and established with crested wheatgrass (*Agropyron christatum*). Additional plant species included needle-and-thread, big sagebrush, black sagebrush, rubber rabbitbrush (*Ericameria nauseosa*), broom snakeweed (*Gutierrezia sarothrae*), and sedges (*Carex* spp.). The average plant height was 27 cm, with silty to cobbly loam soils (Soil Survey Staff 2012). Bryce Canyon National Park, 17 km south of the study site, received approximately 40 cm of annual precipitation (Western Regional Climate Center 2011*a*); average maximum temperatures ranged from 1.4° C in January to 26.6° C in July (Western Regional Climate Center 2011*b*). The elevation at Pat Willis Wash was approximately 2,330 m.

The Utah Division of Wildlife Resources and Garfield County constructed artificial burrow systems in the relocation study areas. Each study area had 4 release sites greater than 200 m apart and each release site contained 5 burrows 4 m apart. A buried sprinkler box provided an underground nest chamber and tubing provided 2 entrances for each burrow. Corrugated, flexible plastic tubing was 10 cm in diameter and approximately 4 m in length. They placed the tubing in an arc reaching the rectangular sprinkling system valve box (30 cm × 45 cm × 30 cm) buried 1.8 m deep. They cut a hole large enough to accommodate the tubing in the middle of each long side of the valve box. They inserted 1 end of the tubing into each hole approximately 10 cm, cut it in 4 places, folded it back against the inside of the box and firmly affixed it to the box. The exit holes manufactured in the short ends and the bottom of the box were left open to allow prairie dogs to excavate their way out of the box. They cut 1 13-cm hole into the bottom of the tubing on either side of the box to allow the animals to expand the burrow. They firmly attached the lid to the box before they refilled the excavated area and tamped down the substrate (Utah Prairie Dog Recovery Team 2009).

We placed chicken-wire mesh cages over each burrow entrance to protect relocated animals from aerial and terrestrial predators (e.g., red fox [*Vulpes vulpes*], gray fox [*Urocyon cinereoargenteus*], bobcat [*Lynx rufus*], coyote [*Canis latrans*]). Cages were constructed of a rebar frame 0.9 m × 0.6 m × 0.5 m in size (Utah Prairie Dog Recovery Team 2009). The prairie dogs could readily burrow out from underneath the cages. We provided water at each site using a 3-gallon stainless steel poultry waterer. Within each study area, we used 2 release sites for the coterie relocation and 2 for non-coterie relocation (control) animals.

Predator removal of coyotes and badgers (*Taxidea taxus*) at or near release sites was conducted at both relocation study areas by the United States Department of Agriculture Wildlife Services but not at Cedar Ridge Golf Course or Berry Springs. Wildlife Services conducted predator removal for several weeks immediately prior to Utah prairie dog release. Subsequent to release, Utah Division of Wildlife Resources personnel periodically surveyed the area for evidence of predator activity. If they detected predator activity, Wildlife Services initiated a predator removal program as per their agency protocol. Because previous observation had determined that the presence of 1 badger could eliminate a relocation site population, the presence of even 1 predator was not tolerated during the relocation period.

We used the fourth study area, Berry Springs, also in Garfield County, to observe the behavior of a Utah prairie dog population on public lands. Berry Springs was a previously successful relocation site 6.5 km west of the Pat Willis study area. Utah prairie dogs were last released to the site in 2009. Elevation, precipitation, temperature, and species present in Berry Springs were similar to those at Pat Willis.

METHODS

Determining the Coterie Pre-Release

In June 2010, we observed Utah prairie dogs for 2 weeks prior to trapping. During this time, juveniles were active aboveground and most, if not all, individuals were weaned. We monitored social interactions to determine coterie boundaries and marked estimated boundary locations on a map (Roe and Roe 2004). Next, we placed single door Tomahawk wire box-traps (18 cm × 18 cm × 50 cm; Tomahawk Live Trap Company, Hazelhurst, WI) near the burrow entrances and baited them with a mixture of peanut butter and sweet oats. We checked traps each hour to reduce stress to captured animals. We marked trapped prairie dogs with commercial hair dye to identify family group. Although prairie dogs are traditionally marked with Nyanzol-D branding dye (Greenville Colorants, Greenville, SC), we chose to use human hair dye because it is less caustic and we needed the mark to last for only the few weeks we collected post-relocation dispersal data. In 2010, we placed the dye on a small patch of fur; the color and location of the mark designated the coterie. We then released marked animals back into their burrow system.

We continued behavioral observations for another 2 weeks to determine if the estimations of social group were accurate and if our marking method was effective. Following the 2-week period, the Utah Division of Wildlife Resources trapped Utah prairie dogs to relocate them to the 2 relocation sites; relocated individuals represented a subset of all previously trapped and marked prairie dogs. All Utah prairie dog trapping and marking was conducted with the Utah Division of Wildlife Resources. Methods were approved by the Institutional Animal Care and Use Committee at Utah State University (IACUC # 1427).

Prairie Dog Relocation

In July of 2010 and 2011, we relocated Utah prairie dogs to the 2 relocation study areas. The trapping was similar to that described above; however if we captured a prairie dog, we labeled the trap with its location to identify the coteries before moving prairie dogs to a central processing location. We placed trapped prairie dogs in a shaded area for processing to reduce heat stress (Roe and Roe 2004).

We identified the sex of animals and weighed them to the nearest 50 g using a spring balance to classify prairie dogs by age and to ascertain that juveniles met the minimum weight threshold. We classified any animal 750 g or heavier as an adult, comprised of yearlings and older, as per Utah Division of Wildlife Resources protocol; we classified smaller prairie dogs as juveniles, or young of the year. In 2010, we relocated prairie dogs as small as 400 g. In 2011, all relocated prairie dogs were 550 g or larger. We attached ear-tags to trapped prairie dogs, placing a different number in each ear. Double tagging reduced the chance of not being able to identify an animal if a tag was lost. We transported prairie dogs the same day to their relocation sites immediately after we processed all animals trapped on a given morning. We closed and removed traps from the course by noon each day to reduce the amount of time animals spent in the traps and to transport trapped prairie dogs to the relocation site before the daily temperature reached its peak. A maximum of 10 individuals (Utah Prairie Dog Recovery Team 2009) comprised each relocated group to avoid overcrowding in the artificial burrows and nest-boxes. Groups typically contained 1 adult male, 2 or 3 adult females, and the remaining individuals were juveniles of both sexes to mimic the social structure described by Manno (2007). We assigned each coterie group to a burrow system within a relocation site. We placed coteries that were neighbors at the golf course in the same release site to mimic their established colonial structure.

In 2011, we remapped clusters of burrows and observed interactions to verify coterie boundaries. We trapped some areas of the golf course in the second season but not the first. In these cases, we mapped burrows and observed interactions as before but did not have the prior season's observations for verification of coterie boundaries. Trapping methods in the second season were the same as used the prior year except that we marked all prairie dogs alphanumerically with commercial black hair dye to allow the group and individual to be distinguished using binoculars following release. We trapped control animals using the same methods as treatment animals. Upon capture, we randomly assigned control prairie dogs to a group. We took these individuals to the release site and released them in numbers approximately corresponding in size to coterie groups.

We conducted mortality surveys at least twice a week in the release sites and surrounding areas. Beginning at the center of each release site, we scanned for carcasses while walking concentric circles around the site until we were 100 m away. We hoped to identify prairie dog carcasses to separate the individuals missing because of mortality from those that dispersed from the release sites.

Release-Site Retention and Recapture Rates

In mid-September of 2010 and 2011, the Utah Division of Wildlife Resources recaptured and released animals using the same methods as in previous trapping efforts to determine release-site retention. They set 25 traps at each release site for a total of 100 traps per study area. They trapped for 8 days at each study area (two 4-day sessions) and alternated between study areas each week. When they trapped animals, they read ear tags to identify the trapped animals and measured weights to 50 g using a spring balance.

We used an information-theoretic approach for explaining release site retention and recapture rates using a live recaptures (Cormack-Jolly-Seber) model (White and Burnham 1999) in Program MARK (Version 7.1, warnercnr.colostate.edu/~gwhite/mark/mark, accessed Sep 2013) and ranked models using Akaike's Information Criterion corrected for small sample sizes (AIC_c; Burnham and Anderson 2002). We simultaneously modeled retention and recapture in each model. We used retention in place of the survival parameter because we were unable to distinguish between mortality and emigration. We computed the Akaike weights for each model, which represents the strength of evidence that each model was the best of the set of models we considered (Burnham and Anderson 2002). We selected models with a $\Delta AIC_c < 1.0$. We included age, sex, year, and weight at relocation as covariates a posteriori to analyze their effect on retention rate. We conducted a biserial correlation to assess the relationship between the weight and age covariates. We also assessed the effect of treatment and the covariates on recapture rate. We determined the first time-step interval by calculating the average number of days elapsed between relocation and the first trap day at that study area. Our analysis included site retention from only the first 2 months following relocation because of the small sample size of relocated prairie dogs trapped a year after relocation. We addressed the effect of release site characteristics on site retention in a concurrent study (Curtis and Frey 2013).

Activity Budgets

To assess changes in behavior, we determined activity budgets for the Utah prairie dogs prior to and following relocation. Additionally, we determined activity budgets for the previously established Berry Springs population for comparison. We collected observational data on prairie dogs at Cedar Ridge Golf Course prior to relocation based on the methodology of previous studies of black-tailed prairie dogs (Magle et al. 2005, Foster-McDonald et al. 2006). We randomly selected a section of the site to observe within the study site. This was especially important at the golf course, where only a portion of the population was visible at any given location. After arriving on site, we allowed 15 minutes for the prairie dogs to habituate and return to normal behavior before collecting observations. When attempting to randomly select unmarked individuals, we temporarily assigned numbers to all visible aboveground individuals and then randomly selected a number. Movement of unmarked animals possibly allowed some individuals to be double counted, although we consciously tried to avoid this. To start the observations, we randomly selected a Utah prairie dog and observed it for 5 minutes, recording its activity every 15 seconds from a pre-defined list of behaviors (Table 1). We selected a new individual for each 5-minute observation session and observed each animal no more than once per day (Foster-McDonald et al. 2006). We considered observations of the same animal on separate days to be

Table 1. Commonly observed Utah prairie dog behaviors.

Vigilant	Animal stands on its hind legs, apparently searching for danger. Animal may forage in vigilant posture.
Semi-vigilant	Animal lifts its head for 1–5 seconds, apparently examining its surroundings. Animal may forage while semi-vigilant.
Peeking	Animal peeks head out of burrow without completely entering or exiting.
Out of view	Animal not visible to observer. Typically inside burrow.
Moving	Walking or running, not in conjunction with aggressive or evasive behaviors.
Foraging	Foraging, but not engaging in any vigilant behavior.
Other	Animal involved in activity not listed above. Includes burrowing, friendly exchanges, grooming, calling, playing, chasing, or fighting with other prairie dogs.

independent. We collected observations in 2-hour time intervals from 0600 to 2200 hours during the 2010 study season. In the 2011 season, we conducted observations from 0800 to 2000 hours in 2-hour intervals because of the absence of prairie dog activity in the early morning and late evening (R. Curtis, Utah State University, personal observation; Hoogland 2009). After the 2-hour time period was over, the observer moved to another section of the study area and repeated the process, continuing throughout the day or until all visible prairie dogs had been observed that day. Following relocation, we randomly selected release sites and conducted behavioral observations using the same methodology as pre-relocation.

We did not collect pre-relocation data in 2011 because of the large amount of data collected on this group in 2010. Preliminary analysis on our first year of data showed that in 2010 we collected 25,399 instantaneous behavior samples on pre-relocation animals, and 11,884 samples following relocation because of the small number of observable prairie dogs at the release sites. We decided that we should focus our resources on increasing the behavior observations for relocated prairie dogs. In 2011, we also observed established wildland Utah prairie dogs in Berry Springs. We presumed urban prairie dog behavior would be non-typical compared to prairie dogs in a wildland habitat. Because we were relocating prairie dogs from urban areas to wildland areas, we attempted to separate which behaviors may have been caused by stress from relocation from behaviors that are normal in non-urban environments.

We calculated activity budgets of common behaviors by determining the percent of time each prairie dog spent engaged in each behavior. We grouped any behavior that accounted for less than 1% of prairie dog activity into an "other" category or combined it with similar behaviors to simplify analysis. We assessed differences in behavior by combining the activity budgets of prairie dogs observed in the pre- and post-relocation and wildland groups, and comparing the activity percentages of each group. We used a multi-response permutation procedure in Blossom statistical software (Version W2008.04.02, www.fort.usgs.gov/Products/Software/Blossom, accessed 10 Mar 2012), because of the non-normal distribution of percentage data.

RESULTS

Release-Site Retention and Recapture Rates

We trapped and marked 779 Utah prairie dogs in the 2 years of the study (Table 2). Weights ranged from 400 g to 1,700 g. Of the 779 relocated Utah prairie dogs in 2010 and 2011, the Utah Division of Wildlife Resources recaptured 50 at the release sites during the fall trapping periods. The average number of days between release and retrapping was 56 days (SD: 8.89). Of the 379 prairie dogs relocated in 2010, only 3 were recaptured the following year; 2 adult females were recaptured in Pat Willis in September 2011 and 1 male in Lime Kiln was caught and released from a predator-deterrent cage in August 2011.

We recovered very few prairie dog carcasses despite extensive searches. We found 3 individuals dead and scavenged near the release sites. We lost additional prairie dogs to predators; we found bones around the sites and around raptor perches but without ear tags, we were unable to identify the individual.

Dispersal was evident in both study areas. We observed individuals moving away from release sites within 24 hours of their release. We saw several individuals over the course of a few days using natural burrows progressively farther from their release site until we lost sight of them completely. We

Table 2. Number of Utah prairie dogs relocated by treatment and study area in 2010 and 2011, Garfield and Iron Counties, Utah. The number of prairie dogs recaptured 2 months following relocation are provided in parentheses.

	Treatment		Study area		Year		Sex		Age	
	Control	Coterie	Lime Kiln	Pat Willis	2010	2011	Female	Male	Adult	Juvenile
Control			186 (13)	200 (11)	186 (15)	200 (9)	198 (11)	188 (13)	135 (11)	251 (13)
Coterie			188 (13)	205 (13)	193 (14)	200 (12)	200 (14)	193 (12)	161 (13)	232 (13)
Lime Kiln					174 (16)	200 (10)	189 (15)	185 (11)	147 (13)	227 (13)
Pat Willis					205 (13)	200 (11)	209 (10)	196 (14)	149 (11)	256 (13)
2010							206 (18)	173 (11)	113 (11)	266 (18)
2011							192 (7)	208 (14)	183 (13)	217 (8)
Female									103 (8)	295 (17)
Male									193 (16)	188 (9)
Total	386 (24)	393 (26)	374 (26)	405 (24)	379 (29)	400 (21)	398 (25)	381 (25)	296 (24)	483 (26)

observed 2 prairie dogs nearly 2 km away from their release site within a few weeks of their release. We observed ear-tagged individuals in the Pat Willis site intermixed with wild prairie dogs in a neighboring colony.

Movement was evident within the relocation colony as well. Eight of the 50 recaptured prairie dogs were trapped in different release sites than the sites where they had been originally relocated. Dispersing prairie dogs may have used other release sites coincidentally, happening upon them as they moved across the landscape. The only evidence we saw of fidelity to family group was 2 juvenile males dispersing together. Also, at the Lime Kiln site, 2 individuals from 1 coterie were recaptured in the same non-original site. We were able to observe ($n = 16$) or recapture ($n = 8$) very few dispersing animals.

We evaluated multiple models to explain release-site retention and recapture rates (Table 3). The highest ranked model indicated that release-site retention and recapture were both dependent on prairie dog weight at initial capture (Figs. 1 and 2). The top 4 models (ΔAIC_c values <1) in the candidate set included the weight covariate. Models considering retention and recapture rates dependent on both weight and age were highly ranked (Table 3). However, because we classified age using a weight threshold, the age covariate is a representation of weight ($r_b = 0.956$).

Behavior

We obtained 2,377 separate animal observation sessions that generated 47,508 instantaneous observations of behavior. We did not find a difference in the post-relocation behavior between 2010 and 2011 (standardized test statistic (sts) = -0.100, $P = 0.159$), so we pooled these data for additional analyses.

Activity budgets for pre-relocation Utah prairie dogs were different from relocated coterie (sts = -301.288, $P \leq 0.001$), relocated control (sts = -272.460, $P \leq 0.001$), and wildland prairie dogs (sts = -114.242, $P \leq 0.001$). Wildland prairie dog behavior differed from that of relocated coteries (sts = -13.246, $P \leq 0.001$) and relocated controls (sts = -11.217, $P \leq 0.001$). We did not find a difference between relocated coterie and control activity budgets (sts = 0.682, $P = 0.725$; Fig. 3).

DISCUSSION

Release-Site Retention and Recapture Rates

The most parsimonious model indicated both retention and recapture rates were dependent on the animal's weight at initial capture. We found no evidence of a retention benefit to relocating Utah prairie dogs in groups of coterie members. Daily retention rate increased as weight increased; the difference in daily retention rate between the smallest and largest prairie dogs was approximately 2%. The lesser retention of smaller animals may have been caused by mortality due to poorer body condition, rather than dispersal. Most relocated adults lost weight in the 2 months between relocation and recapture. Weight loss may be due to stress from relocation, difficulty finding food, or reduced forage time. Smaller animals may not have the fat stored to survive heavy weight loss. High elevation sites have short growing seasons and any weight reduction could reduce overwinter survival (Elmore and Messmer 2006*b*). This may be a

Table 3. Utah prairie dog relocation models created using a live recaptures (Cormack-Jolly-Seber) model in Program MARK ranked by corrected Akaike's Information Criterion (AIC*c*). We simultaneously modeled retention (probability of relocated individuals remaining in the relocation study area) and recapture in each model. We conducted relocations in 2010 and 2011 to 2 relocation sites in Garfield County, Utah.

Model						
Retention	Recapture	AIC*c*	ΔAIC_c	AIC_c weight	Model likelihood	Parameters
Weight	Weight	851.315	0.000	0.252	1.000	4
Constant	Weight	851.828	0.513	0.195	0.774	3
Weight + age	Weight + age	851.857	0.543	0.192	0.762	6
Constant	Weight + age	852.047	0.732	0.174	0.693	4
Constant	Weight + sex + age	853.730	2.415	0.075	0.299	5
Weight + sex	Weight + sex	855.215	3.901	0.036	0.142	6
Weight + sex + age	Weight + sex + age	855.717	4.402	0.028	0.111	8
Weight × sex × age	Weight × sex × age	856.131	4.816	0.023	0.090	8
Constant	Sex	859.566	8.251	0.004	0.016	3
Constant	Year	860.536	9.221	0.003	0.010	3
Age	Age	860.599	9.284	0.002	0.010	4
Sex	Sex	861.205	9.890	0.002	0.007	4
Constant	Age	861.776	10.461	0.001	0.005	3
Age	Constant	862.333	11.018	0.001	0.004	3
Year	Year	862.340	11.026	0.001	0.004	4
Constant	Constant	862.788	11.473	0.001	0.003	2
Weight + age	Constant	863.896	12.581	0.000	0.002	4
Weight	Constant	864.276	12.961	0.000	0.002	3
Year	Constant	864.308	12.994	0.000	0.002	3
Sex	Constant	864.683	13.368	0.000	0.001	3
Coterie treatment	Constant	864.696	13.381	0.000	0.001	3
Constant	Coterie treatment	864.754	13.439	0.000	0.001	3
Weight + sex + age	Constant	865.907	14.592	0.000	0.001	5
Weight + sex	Constant	866.289	14.975	0.000	0.001	4
Coterie treatment	Coterie treatment	866.648	15.333	0.000	0.001	4

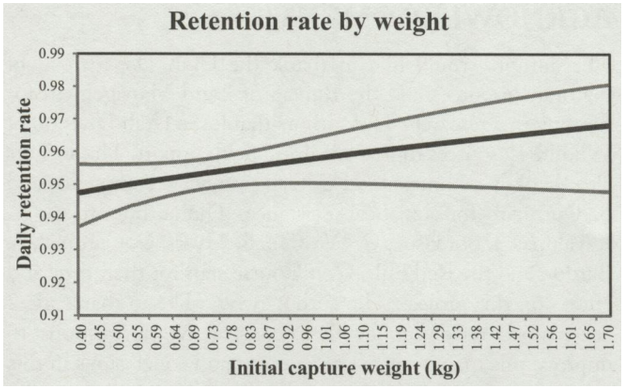

Figure 1. Estimated daily retention rate (probability of remaining in the relocation study area) and 95% confidence intervals for initial capture weight (kg) for Utah prairie dogs relocated in the summers of 2010 and 2011, Garfield County, Utah. We estimated rates based on a recapture assessment period beginning approximately 8 weeks post-release.

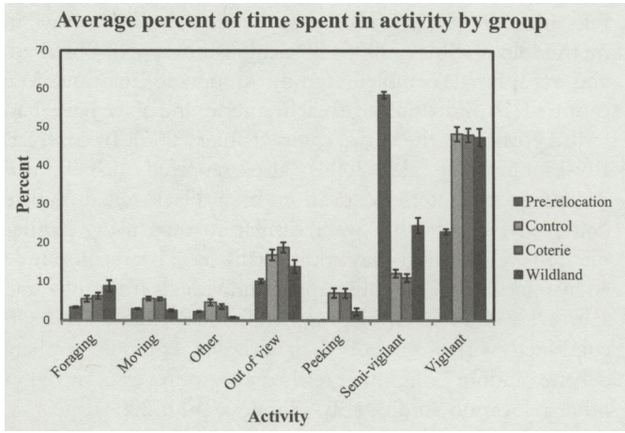

Figure 3. Average time spent in activity (% ±SE) for Utah prairie dogs for pre-relocation ($n = 1{,}357$), relocated control ($n = 374$), relocated coterie ($n = 418$), and wildland ($n = 228$) prairie dog groups. We collected observations in 2010 and 2011 in Iron and Garfield Counties, Utah.

concern for the overwinter survival of relocated animals, particularly because female body mass is already reduced because of lactation (Hoogland 2003).

Previous relocations of Utah prairie dogs conducted in August have had higher success, possibly because juveniles were larger and because the timing allowed reproductive females to regain weight prior to relocation (U.S. Fish and Wildlife Service 2012). We relocated animals primarily in July, which may have caused lower survival and retention than if we had relocated in August. In 2010, we relocated Utah prairie dogs as small as 400 g. In 2011, we set the minimum threshold to 550 g. Our study suggests that even this threshold may be too low. We suggest that only adult prairie dogs be relocated or that a new minimum weight threshold be set. We chose not to determine a new threshold with the data collected for this study because we collected weights in 50-g increments, which is too imprecise for analysis.

We also found that recapture rate decreased as weight increased. Juveniles that tend to have low body weights compared to adults were easy to recapture and were trapped repeatedly, whereas large animals (mostly adults) had low recapture probability, which indicates that experience may influence recapture probability. Additionally, because males begin hibernating in August and September, some males had possibly already begun hibernating during the recapture period and were not trapped. Juveniles remain aboveground longer that adults (U.S. Fish and Wildlife Service 2012) and more individuals may have been available for recapture.

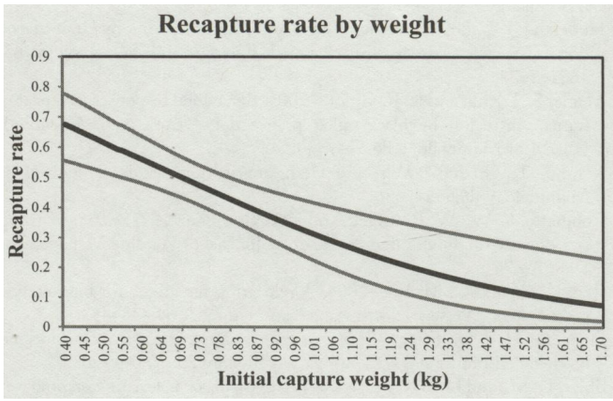

Figure 2. Estimated recapture rate and 95% confidence intervals for initial capture weight (kg) for Utah prairie dogs relocated in the summers of 2010 and 2011, Garfield County, Utah. We estimated rates based on a recapture assessment period beginning approximately 8 weeks post-release.

Recapture probability also did not account for emigration from the site. We observed dispersal from our sites and previous relocation efforts reported a 25–50% decrease in population within the first 2 days following release (U.S. Fish and Wildlife Service 1991). During follow up visits to our study sites, the relocated animals used natural burrows over artificial ones when they were available. No natural burrows occurred at the sites prior to the first release of prairie dogs, but animals quickly excavated burrows, which were then available for future prairie dogs to use. The availability of refuge burrows may have allowed higher dispersal away from the release sites. Dispersal suggests that actual survival is not as low as the retention rate calculated using the recapture data. Post-relocation dispersal was also observed in black-tailed prairie dog relocation (Bly-Honness et al. 2004) and previous Utah prairie dog research (Ackers 1992, U.S. Fish and Wildlife Service 2012). Also, many animals that remained in the relocation site were not included in the recapture figures. For example, 1 juvenile male relocated in Lime Kiln in July of 2010 was not recaptured during the fall trapping period that year. However, in August of 2011, we found him caught in the wire mesh of a predator-deterrent cage. He appeared stressed but uninjured when we released him. This animal was also not recaptured during the fall trapping period in 2011.

Our results were different than those reported by Shier (2006) who found increased survival when prairie dogs were

relocated by coterie. This may be due to differences in methodology. Shier (2006) meticulously trapped, observed, and recaptured complete family groups to relocate. We captured 10 individuals of each coterie and may have had only a portion of the entire coterie (Shier 2006). In contrast, Bly-Honness et al. (2004) also reported no survival advantage to coterie relocation in a black-tailed prairie dog study, results that were similar to ours using similar methods. Our results may additionally have been confounded by relocating randomly trapped individuals from the same source location. Control group individuals may have been combined with some of their original coterie members despite random assignment to the new groups, as occurred in other relocation studies (Bly-Honness et al. 2004).

Behavior

We observed no evidence of a behavioral difference between treatments of relocated prairie dogs. Regardless of treatment, relocated animals showed significantly different behavior than pre-relocation and wildland prairie dogs for many activities. With the exception of time spent underground, peeking from burrows, and exploring, relocated prairie dogs tended to act more like wildland prairie dogs than they did prior to relocation. Particularly, newly relocated and previously established animals spent a similar percentage of their time engaged in vigilant and foraging behavior.

Utah prairie dogs at the golf course commonly approached members of other coteries with friendly displays that often turned into fights. Fighting also occurred in the previously established wildland prairie dog colonies but was rarely observed in the relocated animals. This may be because the released prairie dogs did not have established territories, which eliminated territorial disputes. Our findings were consistent with a previous Utah prairie dog relocation study. Ackers (1992) found that released prairie dogs behaved independently of social constraints and social units did not form in the initial months following relocation. Behaviors such as exploring, vigilance, and burrow construction overrode the tendency to divide into social groups (Ackers 1992).

MANAGEMENT IMPLICATIONS

Our study found no advantage to relocating Utah prairie dogs in groups of coterie members, particularly when considering the additional effort required to trap coteries. Instead, we found that initial weight of Utah prairie dogs at trapping was most important to release-site retention. Heavier individuals had higher retention rates than lighter ones, such as juveniles. We recommend that adult animals be used for relocation or at least that juveniles be relocated later in the trapping season when they are heavier. Additional data on weight collected to 5-g precision may provide a more accurate minimum weight threshold for Utah prairie dog relocation. Although this study addressed the influence of coterie and individual characteristics on site retention, our field observations suggest that future research should focus on developing additional release methods to reduce dispersal and increase site retention.

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