IMPROVING SUCCESS OF TRANSLOCATING

SOUTHERN IDAHO GROUND SQUIRRELS

(*SPERMOPHILUS ENDEMICUS*)

by

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A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Biology

Boise State University

May 2009

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the thesis submitted by

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Thesis Title: Improving Success of Translocating Southern Idaho Ground Squirrels (*Spermophilus endemicus*)

Date of Final Oral Examination: 07 April 2009

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank my advisory committee Dr. Jim Munger (Boise State University), Dr. Eric Yensen (College of Idaho), and Dr. Al Dufty (Boise State University) for their support and guidance throughout my research and classes. I am also grateful to Justin Barrett for helping me start this project and providing invaluable advice to keep me going. A special thanks to Kristin Ross, Gina Patton, and Ann Moser for helping me trap and translocate squirrels as well as dig the holes for my cages.

This project would not have been possible without the funding from Idaho Fish and Game (Bruce Haak), Bureau of Land Management (Jill Holderman), and U.S. Fish and Wildlife Services (Carmen Thomas and Marilyn Hamper).

To my family and friends, thank you for your support and guidance throughout the last three years. And last but not least, thank you Jeremy for dealing with me and always making me laugh.

ABSTRACT

Populations of the southern Idaho ground squirrel (*Spermophilus endemicus*; SIDGS), a federally listed candidate species, have declined in the last 30 years mainly because of habitat degredation, loss, and fragmentation. As a management tool, translocation is commonly used to augment, establish, or re-establish wildlife populations, although translocation has historically not been the most successful conservation strategy for species that are threatened or endangered animals as a result of habitat loss. I employed various techniques to improve translocation success of southern Idaho ground squirrels. To establish new populations, I relocated SIDGS to areas within their native range not already occupied by other individuals of that species. In 2006, I trapped 104 squirrels from the Van Deussen Ranch near Emmett, ID and 212 from the Scotch Pines Golf Course in Payette, ID and translocated them to Little Willow Flat on the Soulen Ranch, approximately 40 km north of Emmett, ID. In 2007, I trapped 170 squirrels from the Van Deussen Ranch and translocated those individuals to another area on the Soulen Ranch, approximately eight km southeast of Midvale, ID. I examined the influence of age, sex, release type, and habitat quality on translocation success. Of the 486 southern Idaho ground squirrels that I trapped and translocated, 112 were fitted with radio collars and monitored for post-release movement and survival. Adult survival to estivation was 45% in 2006 and 55% in 2007. Only 12% of juveniles (4 of 34) survived to estivation (2007 only). An exact logistic regression model showed that age and the interaction of age by release type were significantly associated with survival ($p < 0.05$) in

2007, because more adults survived than juveniles and more hard-released adults survived than soft-released adults. All squirrels, regardless of where they were released, settled in high-quality habitat. Although some factors and interactions correlated with an increase in survival until estivation, over-winter survival was low, at best, so these translocations failed to establish new populations at or near the release site.

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INTRODUCTION

Over the past few decades, various human activities have continued a trend of degradation, fragmentation, and in many areas, total loss of historic habitats. In turn, this has caused an increase in species extinction rates and an overall reduction of global biodiversity (Griffith et al. 1989, Groom et al. 2006). This trend is apparent around the world as well as throughout the United States, including Idaho.

To help alleviate the resulting reduction of biodiversity, translocation has been used to help augment, establish, or re-establish wildlife populations. Translocation can increase genetic heterogeneity of small populations, establish new populations to reduce the risk of catastrophic species loss, or speed the recovery of a species after its habitats have been restored (Griffith, et al. 1989). Historically, translocation success has been associated with populations that have been reduced as a result of overharvesting. However, translocation is generally less successful in cases where species are threatened or endangered because of habitat loss and degredation (Griffith et al. 1989). Nevertheless, my study sought to investigate whether translocation of southern Idaho ground squirrels (*Spermophilus endemicus)*, a federal candidate species, to unoccupied locations could succeed in an ecosystem with degraded habitats.

The southern Idaho ground squirrel (SIDGS) is an example of an endemic Idaho species whose populations have sharply declined as a result of habitat degredation, fragmentation, and loss. In 2000, the estimated population of SIDGS was roughly 4,000 individuals compared to 40,000 individuals that were estimated to be present in 1984

(Yensen 1985, 2001). In addition, fewer than half of the historically occupied sites were still active in 2000, many consisting of only 2 to 10 burrows each (Yensen 2000, 2001), implying not only a decrease in the number of populations, but a decrease in size as well. Because of these declines, the southern Idaho ground squirrel was listed as a federal candidate species in October 2001 (U. S. Fish and Wildlife Service 2001).

Much of the shrub-steppe ecosystem in which SIDGS and other *Spermophilus* species are naturally found consists of native perennial forbs, bunchgrasses, and shrubs. In habitats where these plants are present, a constant and reliable food source is provided for herbivores (Young et al. 1987). Invasion of fire prone exotic annuals that permanently dominate the landscape following wild fires (Young and Evans 1970, Yensen et al. 1992) has altered many habitats including the shrub-steppe ecosystem. These exotic species, mainly medusahead (*Taeniatherium caput-medusae*) and cheatgrass (*Bromus tectorum*), have reduced nutrient availability and increased fire frequency (Sharp et al. 1957, Young and Evans 1978), consequently having a negative effect on *Spermophilus* populations.

Because most ground squirrels in Idaho are only above ground for 4 to 5 months per year, high amounts of fat storage are necessary for their over-winter survival (Yensen and Sherman 2003). Cheatgrass provides sufficient nutrition to squirrels, unlike medusahead, which is very high (75%) in silica content (Young 1992). Ground squirrels will eat cheatgrass and medusahead, but both species become senescent too early in the season during drought years to offer a stable source of nutrition. Although squirrels can survive on a mixed diet of these annuals and perennial grasses and forbs, areas containing only exotic annuals are unlikely to sustain long-term viable populations of ground squirrels (Van Horne et al. 1998).

In addition to reducing nutrient availability, exotic annuals are highly flammable when dry and shorten and intensify natural burn cycles. Areas that once burned every 75 to 100 years are now burning every 5 to 10 years, preventing the return of native vegetation in many cases (Young and Evans 1978, Whisenant 1990, D'Antonio and Vitousek 1992). Consequently, these burned areas become permanently dominated by exotic annuals.

The aforementioned issue is compounded by the fact that changing climatic conditions have increased the number of drought years. As a result, native areas are becoming converted to monocultures of cheatgrass and medusahead, ultimately leading to an overall reduction of nutrient availability for all animals including SIDGS and other *Spermophilus* species.

Moreover, additional factors are changing the landscape and degrading habitat for these animals. Urban sprawl and agricultural conversion have permanently altered SIDGS native habitat in Idaho. Also, overgrazing can alter an ecosystem by reducing the cover of herbaceous plants, disturbing and compacting soils, reducing water infiltration, and increasing soil erosion (Belsky and Blumenthal 1997, Krannitz 2008). In addition, lack of education pertaining to SIDGS may have led to recreational shooting and poisoning efforts (Yensen 1998). Furthermore, although plague (*Yersinia pestis*) has not yet been detected in southern Idaho ground squirrels (Yensen et al. 1996), such a pathogen could have reduced some of the populations of SIDGS (E. Yensen, personal comm.), as it has in other species such as prairie dogs (*Cynomys* spp.) (Dyer and Huffman 1999).

Decreases in the numbers of ground dwelling rodents such as SIDGS have a number of negative ecological consequences. Ground squirrels are an important food base for snakes, raptors (i.e., prairie falcons (*Falco mexicanus*), northern harriers (*Circus cyaneus*), red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*Buteo regalis*), golden eagles (*Aquila chrysaetos*)) and other mammals (i.e., badgers (*Taxidea taxus*), coyotes (*Canis latrans*), long-tailed weasels (*Mustela frenata*)) (Yensen and Sherman 1997). The ecological importance of ground squirrels is evident in the Snake River Birds of Prey National Conservation Area south of Boise, Idaho, where the Piute ground squirrel (*Spermophilus mollis*), a species closely related to SIDGS, fills a keystone niche (Yensen et al. 1992), helping to create one of the densest concentration of nesting raptors in the world (Steenhof and Kochert 1988). Ground squirrels are also important in the infiltration of water into the soil, mixing soils, and improving soil fertility, all of which significantly improve vegetation productivity (Yensen and Sherman 2003). The decrease of ground squirrels in an area causes a decrease of food for badgers, which are also important in mixing soils and providing homes for other ground-dwelling animals (Eldridge 2004). Because of these factors, ground squirrels have been identified as the keystone species in their ecosystem (Yensen et al. 1992, Vander Haegen et al. 2001).

Study Species

Southern Idaho ground squirrels (*Spermophilus endemicus*) are one of two mammalian species that are endemic to Idaho. SIDGS are a smaller member of the genus *Spermophilus*, with a body length of 209 to 258 mm. SIDGS have dorsally-spotted, lighter-colored bodies that blend in with the granite-colored soils in the areas where they reside (Yensen 1991). Its sister species, the northern Idaho ground squirrel (*S. brunneus*), is slightly smaller and darker. Because of native habitat loss and fragmentation (Gavin et al. 1999), population numbers and sizes have plummeted, and the northern Idaho ground squirrel was federally listed as threatened in April 2000 (U.S. Fish and Wildlife Service 2000).

SIDGS are endemic to west-central Idaho (Figure 1). Historically, SIDGS inhabited sagebrush-steppe habitat in Gem, Payette, Washington, and Adams counties. However, as a result of urbanization and agricultural conversion, small populations may also be found in areas such as irrigated golf courses, cemeteries, residential lawns, and agricultural fields within their native range. In these areas, SIDGS can persist and even thrive because these irrigated areas provide constant and enduring food sources. Although, as a result of their abundance in urban areas and the damaging effects of their burrowing in these areas, SIDGS, along with other ground-dwelling mammals, are generally considered nuisances (Howell 1938, E. Yensen personal comm., Barrett 2005) and have been heavily persecuted.

SIDGS are active for only 4 to 5 months per year (Yensen and Sherman 1997). Similar to other species of *Spermophilus*, adult males generally first become active in late January or early February while reproductive females and juveniles initiate activity later, in early to mid-February. The squirrels become torpid to conserve energy during estivation in xeric habitats because of hot, dry weather and lack of succulent vegetation and also during hibernation throughout lengthy periods of unpredictable food shortages and inclement weather. Males begin estivation by late May while reproductive females and juveniles usually retire to estivation in mid June to early July. Estivation is preceded by rapid increases in body fat, and as estivation continues into hibernation, individuals use that fat over the next 7 to 8 months (Yensen and Sherman 1997, Van Horne et al. 1998).

In previous research on SIDGS, Barrett (2005) studied the demographics of SIDGS by monitoring local populations in a variety of habitats. He predicted a continuing downward trend in population size because the survival rates of SIDGS were not sufficient to maintain the long-term viability of isolated local populations. The survival rate of juvenile females was found to have the greatest influence on the predicted viability of SIDGS populations. Barrett also predicted that populations would be less persistent where there were more invasive grasses and fewer forbs were present. He suggested that enhancing habitat quality by limiting the encroachment by invasive annual grasses should be a high priority in any attempt to reverse the long-term decline in SIDGS populations (Barrett 2005).

In 2004 and 2005, Ross (2007) studied the characteristics of SIDGS habitat. She found that higher densities of squirrels were associated with soils that contained higher percentages of silt, east-facing aspects, higher cover of perennial grasses and forbs (Figure 2), and higher species diversity. Conversely, lower densities of squirrels were associated with soils containing higher percentages of sand, south-facing slopes, higher cover of exotic annuals (Figure 2), and lower species diversity (Ross 2007). I used Ross's habitat data (silty soils, east-facing aspect, and native perennial vegetation) to characterize areas where SIDGS are naturally found in high densities when selecting unoccupied release sites for translocation.

Translocation

Translocation can be used for two purposes. First, translocation is a conservation strategy used to establish, re-establish or augment wild populations of animals. Second, translocation is a non-lethal alternative for managing nuisance animals and those that pose threats to agriculture, public health, and biodiversity (Griffith et al. 1989). Several steps are necessary for a successful ground squirrel translocation to occur: survival to estivation, over-winter survival, reproduction, and long-term survival.

There are difficulties associated with translocation, however. First, for a variety of reasons, animals may be difficult to capture or transport. Animals may be nocturnal, sparsely distributed, or located in unforgiving habitat, all of which make trapping difficult (Griffith et al. 1989). Second, animals relocated to an unfamiliar habitat tend to move extensive distances away from release sites, increasing their susceptibility to predation and lowering their odds of survival (Van Vuren et al. 1997). Finally, homing ability has been observed in individuals that initially survived a translocation and then attempted to return home. Homing success was found to be inversely related to displacement distance (Joslin 1977, Rogers 1988).

Griffith et al. (1989) examined the success of a variety of translocation techniques. Species in low density and with declining populations (i.e. threatened, endangered, or sensitive species) were less likely to be successfully translocated than species with sustainable numbers. Also, animals relocated to the core of their historic range were more likely to establish colonies than those released on the edge or outside of their range. In addition, higher success was seen with wild-caught than with captive-reared animals. Furthermore, higher habitat quality was also correlated with higher translocation success. Without high-quality habitat, successes of translocations are generally low, even if high numbers of animals are released. They concluded that releasing larger numbers of animals in an area yields more success than smaller numbers, up to a certain threshold. If a large number of animals are released in the area, and the translocation fails, then one must look at other potential contributing factors.

The way animals are released can affect translocation success. For example, Bright and Morris (1994) examined the effect of soft release, that is, shelter and food were provided, and hard release, that is, an abrupt release with no artificial burrows, shelter, or food, using dormice (*Muscardinus avellanarius*). The researchers found that soft-released dormice tended to stay closer and return to their release nest box while hard-released dormice rarely returned and most moved away from the release site. Three hypotheses were given for the differences between the behavior of soft and hard-released dormice: (1) food availability; (2) disorientation; and (3) territorial pressure. Hard-released individuals received no food supplements, and they may have had to travel farther to obtain sufficient food. In addition, hard-released individuals may have been disoriented by translocation and as a result, traveled farther because they felt no attachment to, or failed to return to, the release area. Finally, extensive movements by hard-released individuals may have resulted from exclusion by territorial adult male dormice located at the release site.

Another successful translocation involved soft-release of family groups of black-tailed prairie dogs (*Cynomys ludovicianus*). Shier (2006) trapped family groups, and translocated them to one set of areas. The researcher also trapped individuals not associated with a family group and translocated them to a different set of areas.

Translocation involved a soft release using cages at each site. Survival was higher by a factor of five in family groups than in nonfamily members, and females associated with family groups showed a higher reproductive success one year after release than did nonfamily females. Behavioral differences between the two groups were also apparent. Family members stayed significantly closer to the release site cages and were more vocal than nonfamily members. The social interactions of family groups were thought to have allowed them to more easily escape predation because of communication via alarm calls (Shier 2006).

Van Vuren et al. (1997) used a hard-release technique to translocate nuisance California ground squirrels (*Spermophilus beecheyi*). Although mortality was seen shortly after release, most squirrels survived the translocation, and almost half of the squirrels established new home ranges. Even though most of the squirrels did not settle near the release site, many survived the winter and reproduced.

In 1997 and 1998, two small NIDGS populations in central Idaho were augmented using soft release (Gavin et al. 1998). One population initially showed a small increase in size, but later disappeared altogether. The other population demonstrated a slow start but ultimately survived and had grown to 45 individuals as of 2004.

In 2001 and 2002, the first SIDGS translocation was attempted using a total of 147 squirrels from Rolling Hills Golf Course. In 2001, 59 squirrels were captured and soft-released to an unoccupied site on a private ranch. The squirrels moved to a nearby area shortly after being released, probably as a result of an influx of cattle in the area. In 2002, a few new burrows were observed, and subsequently 88 more squirrels were released in that area. A few squirrels and burrows were seen in the area in 2003, however, after extensive searching in 2004, no signs of SIDGS remained near the release area (Yensen 2003).

In her thesis research, Panek (2005) also attempted various methods in translocating SIDGS and found some success. She used captive-bred juveniles to augment naturally existing populations and found that these individuals did not move away from the release sites. Panek found that pregnant females that were harbored in cages before being released did not move away from release sites. She also placed urine-soaked paper towels at the release site in an attempt to cause juveniles to think that they were in an area occupied by other squirrels. Those juveniles, however, moved away from the release site, with a mean movement distance of 300-400 m. Panek's most important conclusion was that releasing squirrels in already occupied areas yields more success than a release to areas where no squirrels occurred previously. More specifically, squirrels released in occupied areas did not move significant distances away from the release site. Squirrels released to unoccupied areas typically moved to areas where other conspecific squirrels were already established (Panek 2005).

As a final point, a translocation is a success if the result is a self-sustaining population (Griffith et al. 1989). Success is generally measured by high post-release survival and shorter movement distances away from the release site. To understand post-translocation movement behavior, we must understand factors that affect a squirrel's natural propensity to disperse.

Dispersal

Dispersal is defined as "the movement an animal makes from its point of origin to the place where it reproduces or would have reproduced if it had survived and found a mate" (Howard 1960:152). There are two types of dispersal: natal and breeding. Natal dispersal is defined as the permanent movement away from birthplace, while breeding dispersal is described as movement between breeding sites (Greenwood 1980).

Dispersal occurs sometime in the life cycle of nearly all organisms (Holekamp and Sherman 1989) and has important effects on the size, composition, genetic structure, longevity and social organization of their populations (Greenwood 1980). Ultimately, an animal disperses to increase its fitness, although the benefits must outweigh the costs of leaving the natal area for this to occur (Haplin and Chepko-Sade 1987). In addition, there are several immediate, or proximate, reasons for an animal to disperse including body mass, food and shelter shortages, presence of parasitic infestations, hormone fluctuations, competition for mates, and reduction of inbreeding (Holekamp 1986, Holekamp and Sherman 1989).

Ground-dwelling squirrels exhibit both types of dispersal (Holekamp 1984, 1986). Studies have shown that juvenile males are most likely to exhibit natal dispersal while adult males are most likely to exhibit breeding dispersal (Holekamp and Sherman 1989, Dobson 1982). And, in those *Spermophilus* species in which both sexes disperse, males generally travel farther (Holekamp 1984).

Dispersal involves three steps: (1) the decision to leave the area; (2) a transitional phase; and (3) the selection of a new area (Clobert et al. 2001). Dispersers settle when they come across suitable unused habitat or burrow systems (Hackett 1987), or if they encounter an impassible geographic barrier.

In 2006 and 2007, I used translocation as a means of forced dispersal by removing SIDGS from their urbanized and agricultural environments and relocating them to their natural habitat. Previous studies have quantified post-release movement by setting a threshold distance to determine whether the squirrel left the area or stayed (Panek 2005). In the present study, I was more interested in observing whether there was a difference in the post-release movement distances among different individuals; I measured movement as a continuous variable and compared it across treatments.

Research Questions and Overview of Methodology

Translocations of threatened, endangered, and sensitive species have historically shown less successful results (Griffith et al. 1989). How can the success of translocating a sensitive species, like SIDGS, to unoccupied areas be increased? To answer this question, I assessed several factors associated with translocation success to determine whether a squirrel's likelihood to survive and move away from the release site is dependent upon acclimation to the release site, quality of the release site, or individual traits such as age and sex.

1. Is acclimation necessary for a successful translocation?

Hypothesis: Acclimation facilitates survival because animals familiar with the area will be more likely to move shorter distances and settle near the release site.

Forcing an animal to stay in the release area for a certain period of time may reduce stress caused by trapping and traveling, protect the animal from predators, and familiarize the animal with the new area. The need to find food, disorientation, and territorial pressures are three potential reasons for a hard-released animal to move away from the release site and have a lower chance of survival (Bright and Morris 1994). By familiarizing the animal with an area using a soft-release technique, the animal may be: (1) less likely to move long distances; (2) more likely to stay near the release site where the researcher intends for them to stay, in other words, near food, other animals, and shelter; and (3) more likely to survive.

To test this hypothesis, I harbored squirrels in cages with artificial burrows for seven days at the translocation site before soft releasing them. Hard-released squirrels were not caged and were released immediately into their new environment, without artificial shelter. I planned to examine the differences in translocation success of soft- and hard-release individuals, but because this species is sensitive and previous research indicates that hard releasing small mammals is not usually a successful translocation technique (Bright and Morris 1994, Van Vuren 1997, Gavin et al. 1998, Panek 2005), I provided all squirrels with hay, apples, carrots and bird seed. Therefore, I did not perform a true hard-release because squirrels not released in cages were given food as well, but I will refer to it as "hard release" hereafter.

By providing food and releasing animals near high-quality habitat, I eliminated low food availability as one potential cause of post-release movement. Also, the release areas were devoid of resident squirrels, so the effects of territorial pressure, another potential cause of post-translocation movement (Bright and Morris 1994), were likely non-existent. However, disorientation and presence of predators may still have played a role in the survival and movement of hard-released squirrels. Because hard-released individuals were not familiar with, and had no attachment to, the release area, they may have traveled farther from the release site than soft-released individuals. These disoriented and unprotected animals are very susceptible to mortality by predators (Van Vuren et al. 1997).

Prediction: Soft-released SIDGS will have higher survival than hard-released SIDGS.

2. Does age play an important role in the success of translocations?

Hypothesis: Older age and subsequently a larger body size increases the survival of translocated animals, because adults are less likely to move away from the release site and more likely to survive the cold nights in a new area.

Juvenile ground squirrels are more likely than adults to disperse naturally. (Holekamp and Sherman 1989). It is thought that, before birth, an ontogenetic switch is set up by the secretion of androgens in male ground squirrels. When proper fat storage accumulates, the switch turns on, and many juvenile males begin to explore their surroundings (Holekamp and Sherman 1989). If post-translocation movements simulate natural dispersal movements, then juveniles may move farther from the release sites than adults, and thus have a lower chance of survival.

Post-translocation survival may be decreased in radio-collared juveniles because of their smaller body size (Brander and Cochran 1971). Adults typically weigh more than juveniles, so the effects of carrying the extra weight of a radio-collar are not as apparent in adults as they are in juveniles.

To test this hypothesis, I radio-collared and released an equal number of juveniles and adults in 2007. Age classes consisted of juveniles (i.e. young-of-year) and adults. I did not distinguish between adults and yearling individuals. The goal was to determine which age class has higher post-translocation survival.

Prediction: Adult SIDGS will exhibit a higher post-translocation survival rate than juvenile SIDGS.

3. Does sex play an important role in the success of translocations?

Hypothesis: The sex of an animal affects post-translocation survival because males are more likely to disperse than females.

Holekamp (1984) found that sex and body mass together were the most consistent predictors of dispersal status of Belding's ground squirrels (*S. beldingi*). The mechanism, or ontogenetic switch, that initiates male dispersal is the secretion of androgens by the gonads in male squirrels. When proper fat storage accumulates, the switch turns on, and juvenile males begin to explore their environment (Holekamp and Sherman 1989). Conversely, females are more likely to exhibit site fidelity, even when they reach adulthood, and especially when they are caring for their litter (Holekamp and Sherman 1989, Panek 2005). To test this hypothesis, I released and radio-collared equal numbers of males and females to determine which group would have a higher survival rate after translocation.

Prediction: Female SIDGS will stay closer to the release site and survive better than male SIDGS.

4. Is it necessary to release SIDGS in high quality habitat for a successful translocation to occur?

Hypothesis: Availability of high-quality habitat facilitates the survival of translocated animals because there is more food and cover accessible.

SIDGS are naturally found in higher abundance in areas with large quantities of native vegetation, silty soils and on north and east-facing slopes (Ross 2007). If the squirrels are released in this optimal habitat, where cover from predators and food is readily available, they may be more likely to stay in the area, move shorter distances, and may be more likely to survive. Dispersing juvenile Piute ground squirrels (*Spermophilus mollis*) tended to settle in the same habitat they started in (Olson and Van Horne 1998 as *S. townsendii*), suggesting that releasing squirrels in high-quality habitat may be important for their survival.

I released squirrels in two different qualities of habitat (i.e., high and low) and compared post-release survival rates and movement distances. I also compared the vegetation in areas that squirrels occupied with available habitat (i.e., areas where squirrels did not occur and release sites). By assessing vegetation at each site, I sought to determine whether squirrels are selecting for a specific type of habitat, so as to understand whether habitat is an important factor in determining the success of squirrel translocation.

Prediction: SIDGS released in higher quality habitat will stay closer to the release sites and thus have a higher survival rate.

METHODS

2006 Site Selection Criteria

My goal in 2006 was to select ten comparable release sites, all comprising suitable habitat, although matching sites proved to be difficult. Suitable habitat was based on abundance of native vegetation and soil type (i.e. well drained and silty). I chose sites that had high native grass and forb cover as well as a shrub component. Other characteristics of release sites included a south-southwest facing hillside and a gentle slope of 5-10%, because gently-sloped areas generally have well-drained soils that are important for ground squirrel burrowing tendencies (Yensen and Sherman 1997). I also considered convenience when I selected sites, because many areas would have been very difficult to access. The sites were at least 0.5 km apart to ensure that released ground squirrels could not see conspecifics living at other sites (E. Yensen, personal comm.). I also hiked around the release areas for several days before releasing squirrels to ensure that SIDGS or other types of ground squirrels were not present in the area.

Of the ten sites, six were soft-release sites (SR1-SR6) and four were hard-release sites (HR1-HR4) (Figure 3). The sites were located on Little Willow Flat on the Soulen Ranch property, approximately 40 km north of Emmett (11T 539118m E, 4897621m N) (Figure 4).

2007 Site Selection Criteria

My goal in 2007 was to compare survival of squirrels that were released in different qualities of habitat. In March 2007, after searching the area, I chose four sites based on native and exotic vegetation abundance and soil type, using soil maps (Rasmussen 2001) (Figure 3). Two high-quality sites (A and B) comprised mostly native vegetation (native perennial grasses, forbs, and shrubs) and two low-quality sites (C and D) comprised mostly exotic vegetation (exotic annual grasses with little to no shrub cover). However, high-quality vegetation was located within 100 meters of the low-quality release sites. Again I chose well-drained soils and a gentle slope and matched these qualities among the sites as much as possible. However, I used east-facing slopes for the release sites, instead of south-southwest facing slopes, unlike the year before (Ross 2007). Once more, I searched the study area to make certain that SIDGS or other types of ground squirrels were not present in the area. The study area was located approximately 8 km southeast of Midvale (11T 526737m E, 4916842m N) (Figure 4).

2006 Trapping

I captured SIDGS for translocation using two different methods. Initially, I used baited-line transects using single-door Tomahawk live traps (12.7 x 12.7 x 40.6 cm, Tomahawk, WI) baited with apples, and set along a fence line. I pre-baited the traps for three days before setting the traps. This method demonstrated little success compared to focal-point trapping. Focal-point trapping makes use of both burrow-entrance traps (7.6 x 7.6 x 40.6 cm) and Tomahawk live traps to capture squirrels. Every time I saw a squirrel, I followed it until it entered a burrow, at which time I would place one of the two types of traps on or near the burrow (Sherman and Runge 2002, Yensen and Sherman 2003). I used empty, plastic bottles to block all suspected connecting burrow entrances. After trapping, I transferred squirrels to a small cotton bag and processed them as described below. Trapping efforts occurred during late March, early April, and early May (Tables 1 and 2).

2007 Trapping

I used only focal-point trapping, as in 2006, for the present experiment. Trapping occurred at the Van Deussen Ranch on 19 and 20 April and 1 and 3 May (Table 3).

2006 Processing

After transferring each squirrel to a small cotton bag, I weighed each individual to the nearest gram using a 300 g spring scale (Avinet Inc., Dryden, NY). I marked squirrels by attaching matching numbered Monel metal ear tags to each ear (National Band and Tag Co., Newport, KY). I examined each squirrel to determine sex. I selected 38 adult squirrels, sedated them with isofluorane (1 ml), and fitted them with six-gram radio-collars around their necks (Merlin Systems, Boise, ID), each tuned to a unique frequency. Then I transported the squirrels on the same day as captured to their appropriate release sites.

2007 Processing

I used the same processing techniques as in 2006. Because I collared juveniles as well as adults during the 2007 season, unlike in 2006 when I only collared adults, I had to set a minimum weight for the safety of the squirrels. Only juvenile squirrels weighing at least 80 g were collared, so that the collar was no more than 7.5% of the total body weight. This target weight of 80 g was used in previous research (Panek 2005). However, it should be noted that the standard guideline for the weight of a collar is only 5% of the individual's body weight (Brander and Cochran 1971), a guideline that was established for the use of radio collars on birds. I assumed that a ground-dwelling mammal could bear more weight. Obviously the juvenile squirrels would grow to a larger size, so my goal was to search for squirrels at this site in 2008, re-trap the juveniles, and remove the collars.

2006 Translocation

I established four hard-release sites (HR1-HR4) where squirrels were simply released in an area that contained no shelter or burrow systems (Figure 5). Food (hay, dog food, apples and carrots) was provided at the time of release and supplemented, if eaten, for seven days after release.

I also established six soft-release sites (SR1-SR6). Two sites contained two large cages, two had one large cage, and two sites contained six small cages. The large cages were 2.4 m x 2.4 m x 1.2 m (Figure 6). The small cages were 0.6 m x 0.6 m x 1.2 m (Figure 7). Both cage sizes were constructed with 1.3 x 1.3 cm [0.5 x 0.5 inch] mesh wire. I placed the cages 46 cm into the ground. There was no bottom, making it possible for the squirrels to dig out. I made artificial burrows out of 10 cm diameter corrugated plastic tubing, providing 60 cm length per squirrel. I placed the burrows inside the cages and buried them under the soil with one end exposed at the surface. I placed one squirrel per small cage and six squirrels per large cage. I supplemented the sites with additional squirrels to bring the number of squirrels at each site to approximately 25. Again, I placed food inside of the cages on the day of release and supplemented, if eaten, for seven days.

The first squirrels dug out of their cages after seven days. Consequently, I cut holes in all the cages at this time. This allowed the squirrels to move in and out of the cage, thus retention time was the same throughout the sites, and therefore time of release was not a variable.

During two rounds of trapping in the spring of 2006, I captured 316 squirrels and translocated them to the study area. During the first round of trapping, which lasted 9 days from 20 March to 10 April, I trapped and translocated 104 SIDGS from the Van Duessen Ranch and hard-released to the study area (Figure 4). I released 50 adults and 2 juveniles at each of 2 hard-release sites established here, HR1 and HR2. Of these, I radio-collared 16 adult squirrels, 8 at each site, and monitored them for survival and movement. These squirrels were used as a pilot study to test out equipment and to learn more about SIDGS and what to expect.

I had planned to trap all of the squirrels necessary for the study in a single round of trapping. However, because of an unusually wet season, the ground was too frozen and then too saturated to dig holes for the cages in early spring. Once the cages were completed later in the season, an additional round of trapping was completed to obtain the squirrels for this experiment.

The second round of trapping occurred at the Scotch Pines Golf Course in Payette, ID on 2, 3, and 4 May. I trapped and translocated 212 squirrels. I relocated 162 of these squirrels to sites SR1-SR6 (Figure 4). Here, I soft-released individuals into previously built cages. Because I soft released only 6 or 12 individuals into cages at each site, I also hard-released squirrels near the cages at sites SR1-SR6. This was done to distribute the same number of squirrels, about 25, to each site. At the same time and in the same area, I hard released 25 squirrels to each of the sites HR3 and HR4. During this second round of trapping, I radio-collared 22 adult squirrels and monitored them for post-translocation survival and movement. I soft released 16 and hard released 6 of these collared squirrels

2007 Translocation

I translocated squirrels to four different sites at an area approximately eight km southeast of Midvale, ID. Sites A and B were considered high-quality habitat sites, and sites C and D were low-quality sites. I translocated 43 SIDGS to each of sites A, C, and D and 41 to site B for a total of 170 individuals (Table 3). I radio-collared 74 total squirrels. At each site I released an even ratio of males to females and adults to juveniles. I also soft and hard released an equal number of squirrels to each site.

I used individual cages, 0.6 x 0.6 x 0.46 m (1.3 x 2.5 cm [0.5 x 0.75 inch] mesh), with a bottom, that lay on top of the ground (purchased from Bass Equipment, Monett, MO), for soft release (Figure 8). I constructed artificial burrows out of 10 cm corrugated plastic tubing partially filled with straw or hay. Sixty cm (2 ft) of artificial burrow was available to each soft released individual. I released the caged squirrels after four days. I released non-caged squirrels (hard release) at a central release area, near the cages, and did not provide any artificial burrows; however, I provided food and hay to all squirrels (Figure 5), as in 2006. Translocations occurred the same day as capture.

Monitoring

After releasing the squirrels, I tracked the collared squirrels using a Telonics receiver, a five-prong Yaggi antenna for long range, and a handheld antenna for close range. The range averaged 300 to 500 meters, and up to 1 kilometer for line of sight squirrels with new collars. I attempted to monitor survival and movements of collared squirrels. After I found a signal with a handheld antenna, I recorded the UTM's (NAD

83) using a Garmin GPS unit. I continued to monitor squirrels until I found them dead or estivating or until the signal was no longer detectable, usually after 3 to 4 weeks. Loss of signal was a result of everyday wear and tear or squirrels chewing the antennae off. I used the same monitoring methods in 2006 and 2007.

Occupancy vs. Availability

In 2007, I released squirrels in areas containing mainly high-quality (i.e., native grasses, forbs, and shrubs) or low-quality (i.e., annual grasses with little to no shrub cover) vegetation, although all study areas contained patches of both. One of my objectives was to determine whether high-quality habitat is necessary for translocation success. To answer this question, I analyzed vegetation at each occupied site, near the burrow or area where a squirrel was last observed, and also at a matching unoccupied site, for each squirrel that survived. Vegetation analysis at occupied sites provided information about what habitat the squirrel was using, and vegetation analysis at unoccupied sites offered information on what kind of habitat is available to, but not necessarily used by each squirrel.

I chose matching unoccupied sites by drawing a circle on a map, using ArcMap (version 9.2), around the release sites (A, B, C, and D), which are the centers of the circles. The squirrels that occupied an area farthest away from each release site determined the size of the circle around the site; the outside of the circle would touch the outermost occupied site. I drew a radius from the release site through each occupied site to the outside of the circle, and I randomly chose one matched unoccupied point along each radius (Figure 9).

Vegetation Analysis

In 2007, I performed a vegetation analysis at each occupied and matching site. At each site I set up a circular plot with a ten-meter radius, with a burrow, if present, as the central point. Next to the burrow, I hammered a four-foot piece of rebar into the ground. From the center rebar, I laid out eight ten-meter transects, one in each direction (N, NW, W, etc.), with a measuring tape. On each transect I started using five Daubenmire plots frames, places two meters apart, but I determined that equivalent results could be obtained by sampling with three Daubenmire plot frames placed four meters apart. Adequacy of sampling was tested by running of means method. I randomly chose the starting point, at either one or two meters, by flipping a coin. I determined plant cover by using the Daubenmire method of vegetation analysis (Daubenmire 1959) (Figure 10).

I analyzed and assessed 64 total vegetation plots (32 occupied sites, 32 matched unoccupied sites). I calculated absolute and relative cover provided by all plants in each plot and designated five plant functional groups: exotic annual grasses, native annual grasses, native perennial forbs, exotic perennial forbs, and shrubs (Appendix A). In addition to comparing cover, I calculated importance values for each species. Importance values are an index of relative dominance of a species (Whittaker 1972), which can be calculated in various ways. I used the following formula: Importance value = (% Freq + % Cover)/2.

Over-winter Survival Analysis

In the spring of 2007 and 2008, I further explored the translocation sites to assess over-wintering survival. I hiked around the release sites one to two times per week in search of squirrels and concentrated on areas with burrows where I thought squirrels had estivated during the previous season. I also looked for fresh burrows and droppings to further assess any sign of survival.

2006 Statistical Analysis

All data were analyzed using SAS 9.1 statistical software (SAS Institute, Inc., Cary, North Carolina). I was unable to determine the post-release movement distances and survival status of some squirrels; therefore, I excluded them from the analyses. I cannot completely exclude the possibility that some SIDGS were lost because they moved long distances (> 1.5 km) very rapidly. Therefore, post-release movement estimates may be underestimated. Movement distance means include standard error of the mean. Squirrels that died in cages, or immediately after release, were excluded from analysis.

To determine whether survival was based on sex and release type in 2006 (i.e., soft or hard release) I used a Fisher's exact test. Although collar batteries were intended to last for six weeks, most signals were lost or very weak after three to four weeks. I examined survival after the first week after release because this period is a critical in determining the fate of a translocated animal. I also examined survival after three weeks. To assess whether the post-translocation movements of squirrels from the second round of trapping differed between sex and release type, I used an analysis of variance (ANOVA).

2007 Statistical Analysis

The same statistical software was used in 2007 as was in 2006. I used logistic regression to determine whether age, sex, release type, and habitat quality were significant predictors of survival. I also assessed interactions. Because of empty cells and a small sample size, I used an exact logistic test (Cody and Smith 2006). I chose the best model fit, as shown by the lowest AIC_c[1] value of 66.907, which included all variables and interactions except for Habitat*Sex. Odds ratio estimates were unstable because of the presence of quasi-complete separation in the model; therefore, I do not report them. However, whether the odds ratio is greater than one or less than one is an indication of the direction of any effect that was detected. The recommendation (L. Bond, personal comm.) is to make inferences from the p-values and illustrate with bar graphs. Also, with exact logistic regression, the computational procedures do not use a standard error; therefore, I do not report them (Figure 9).

I used an analysis of variance (ANOVA) to compare the post-release movements among treatments (age, habitat quality, sex, and release type). I also assessed interactions. To find the best-fit ANOVA model, I used a selection of two-way models and compared AIC_c values. The best-fit model included habitat quality, sex, release type and the three two-way interactions ($AIC_c = 237.3$). Age was not included in the analysis because so few juveniles survived (Table 6).

I used logistic regression to determine whether any plant functional groups (Appendix A) were significant predictors of occupancy. I performed analyses on both absolute and relative covers. I compared the calculated importance values of occupied and available sites using Wilcoxon signed-rank tests, because the data were not normally distributed.

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[1] Akaike's information criterion adjusted for small sample size. This value is a measure of the goodness of fit of an estimated statistical model.

RESULTS

2006 Results

Two rounds of trapping and translocation occurred in the spring of 2006. The first trapping and translocation session occurred at the Van Deussen Ranch in late March and early April. I used these squirrels in a pilot study, and I statistically analyzed the results from this round separately from the results of the second round for three reasons:

1. I released about 50 squirrels at each of the sites, HR1 and HR2, compared to sites SR1-SR6 and HR3 and HR4, where I released about 25 squirrels each.
2. I released these squirrels earlier in the season: in late March or early April vs. early May.
3. I trapped these squirrels from the Van Deussen ranch as opposed to Scotch Pines golf course.

During this pilot study, I trapped and translocated 104 squirrels to HR1 and HR2 (Table 1). I radio collared and monitored post-release survival and movement for 16 adult squirrels (8 at each site). Of these collared squirrels, seven squirrels were preyed upon by various predators. The signals of two squirrels were lost within two days after being released. The remaining seven squirrels survived and they were monitored for 3 to 4 weeks. In total, 7 of 16 SIDGS (44%) survived until monitoring ended. Mean movement distance was 229 ± 84 m (n = 15). The longest distance traveled by a male was 1035 m and by a female was 90 m.

Survival

During the second round of trapping at Scotch Pines Golf Course during May 2-4, I trapped and translocated 212 squirrels to SR1-6 and HR3-4 (Table 2). I radio-collared 22 adults and monitored them for post-release survival and movement. Of these collared 22 squirrels, I soft-released 16 and hard-released 6. I determined that 10 of the 22 collared squirrels estivated in the area, and I observed 5 squirrels that survived at least 3 weeks until their signals were too weak to detect, resulting in a 45% survival rate. Survival was not significantly associated with release type after one week (Fisher's exact test, $n = 22$, $P > 0.999$) or after three weeks ($n = 22$, $P = 0.533$). In addition, survival was not based on sex after one week (Fisher's exact test, $n = 22$, $P > 0.999$) or three weeks ($n = 22$, $P > 0.999$).

Post-translocation Movement

Mean distance traveled was 118 ± 20 m ($n = 20$). Soft and hard-released squirrels movements did not differ significantly (ANOVA, soft-release 117 ± 24 m, hard-release 120 ± 37 m) (Table 4) (Figure 11). Males did not move a greater distance than females (ANOVA, males 90 ± 12 m, females 140 ± 34 m) (Table 4) (Figure 12). The maximum distance moved was 340 m, by a soft-released female.

Over-winter Survival

A wildfire burned part of the 2006 release site and a large area near the study area in the fall of 2006. I searched the study area (5 km^2) one to two times per week in April, May, and June of 2007, but I did not detect the presence of squirrels, squirrel burrows, or squirrel droppings within a 1 km^2 radius of the release sites.

2007 Results

Survival

Of the collared squirrels, 35% survived (55% of adult and 12% of juveniles) until the signals from their collars were no longer detectable, usually 3 to 4 weeks after being released. Logistic regression showed that age was a significant predictor of survival (Table 5), as adults showed a higher survival rate than juveniles (odds ratio > 1) (Figure 13). Sex and release type alone were not significantly associated with survival (Table 5). However, there was a significant interaction between age and release type, caused by the fact that no juvenile soft-release squirrels survived (Figure 14). But more soft-released adults survived than hard-released adults.

Habitat quality was probably not significant although more squirrels released in lower quality survived than those released in high-quality habitat (Exact logistic regression, $P < 0.05$, odds ratio < 1) (Table 5) (Figure 13). This is because five squirrels released in low-quality habitat used old vole tunnels as burrows. Vole tunnels provided shelter, or at least the start of a shelter, for the squirrels. If these five squirrels are excluded from the exact logistic analysis, then low-quality habitat would be only a marginally significant predictor of survival ($P = 0.062$).

Post-translocation Movement

Mean movement distance for all squirrels was 178.2 ± 32.0 m ($n = 31$). I did not find any significant differences in the movement distances across all treatments, including interactions (ANOVA, $P = 0.497$, $F_{6,24} = 0.93$) (Table 6) (Figure 15).

Habitat

I released squirrels in two habitat types, high quality and low quality, to determine effects of habitat on post-translocation survival and movement of squirrels. I also wanted to more closely examine the areas where squirrels settled or occupied (i.e., last spot seen or estivation burrow), so that I could compare these occupied areas to other available areas.

Although more squirrels that were released in low-quality habitat survived, as a result of the presence of vole tunnels, than those released in high-quality habitat, a logistic regression analysis found no significant predictors of occupancy among the five plant functional groups ($P > 0.05$) (Table 7). Wilcoxon signed-rank test found no significant differences in the relative dominance of plant groups between occupied and available sites ($P > 0.05$, $n = 32$). Essentially, all of the squirrels used areas of equal quality, in terms of vegetation cover.

Originally, I did not intend to compare the vegetation of the release sites to the occupied sites; therefore, I did not perform vegetation analysis plots on the release sites. However, I observed individuals that I released in lower quality areas selected higher quality areas to occupy (Figure 16). The low-quality release sites had little to no shrub cover and consisted mostly ($\geq$ 80%) of annual grasses. Compared to the average cover of occupied sites (Table 7), the low-quality release sites were clearly different, although no data were taken to reinforce this observation.

Over-winter Survival

In spite of searching the study area one-to-two times per week in April, May, and June of 2008, I did not detect any over-winter survival at or near either study site. I searched a 5 km^2 area around the 2006 area, and searched a 6 km^2 area around the 2007 release area as well. Again, I found no signs of squirrels, fresh burrows, or droppings.

On 5 June 2008, however, researcher Eric Yensen observed two adult squirrels in an area where he had never seen squirrels before. The area is northeast of Cherry Gulch, which is within 4 km of the 2006 release site. On 17 June, Yensen observed 1 individual SIDGS and found 14 clusters of burrows, mostly to the south and east of where he had searched on 5 June. The majority of the burrows were located in a clump of lupine (*Lupinus* sp.). A number of burrows had harvested lupine (stems and leaves with flowers and seeds) at the entrances, which is very typical of ground squirrels, and Yensen also found harvested lupine not associated with burrows (Yensen 2008).

DISCUSSION

I performed these translocation experiments to answer one question: How can the success of translocating SIDGS to unoccupied areas be increased? I examined four factors, release type, age, sex, and habitat quality, to determine their effects on post-release movement and survival. Although some factors and interactions were associated with an increase in survival to estivation, the over-winter survival of all squirrels was very low, suggesting that the translocation of SIDGS to unoccupied areas was unsuccessful.

Release type

In 2006, contrary to my prediction, there was no significant difference in movement distance between soft- and hard-released squirrels, nor was there a difference in survival rates, although sample sizes were small. In 2007, the results were more complex. Release type had an effect on survival, but the effect of release type depended on age. There are two parts to this interaction. First, more soft-released adults survived than hard-released adults. This result is consistent with previous translocation studies. Panek (2005) soft-released pregnant adult females and almost all survived the translocation. One of the soft-released adults in that study was a pregnant female that bore her litter in the release cage. That event may have increased her likelihood of remaining near the release site, because she had to stay there to rear her pups. Gavin et al. (1998) found some success with soft-release of northern Idaho ground squirrels, although no squirrels were hard released in that study. In another study, researchers found that soft-released dormice tended to stay closer and return to their release nest box while hard-released dormice rarely returned and most moved away from the release area (Bright and Morris 1994).

Second, juvenile survival was very poor. Zero soft-released juveniles and only four hard-released juveniles survived. Most soft-released juveniles died in their cages, shortly after translocation, while the remaining soft- and hard-released juveniles died after being released. I speculate that the exposure to the cold environment and stress of being trapped, translocated, and radio-collared was too much to handle for a young-of-year squirrel.

Two possible reasons for why more soft-released adults than hard-released adults survived are acclimation and protection. Soft-released squirrels were harbored in cages with burrows that protected the individuals from weather and predators, and they had time to become familiar with their new environment (Bright and Morris 1994). Although post-release movements between soft- and hard-released individuals were not significantly different, hard-released squirrels were unprotected and thrown into a new environment.

No significant difference in survival between soft- and hard-released squirrels was observed in 2006, although more soft-released adults survived than hard-released adults in 2007. Although soft-release generally requires more time, energy, and money, I suggest using this method for translocating adults, especially if pre-built cages are available.

Age

Translocating adult squirrels was more successful than translocating juveniles. I predicted that more adults would survive than juveniles, first because of a juvenile's natural propensity to disperse. If translocation simulates natural dispersal, then I assumed that juveniles would move further away from the safe release area than adults. And second, I thought that the more robust body size of adults (Holekamp and Sherman 1989, Dobson 1982) may facilitate survival because of resistance to cold weather and stress from trapping and translocation.

Most of the mortality of juveniles occurred shortly after translocation, which is consistent with other translocation studies (Griffith et al.1989, Van Vuren et al. 1997). In 2007, ten juveniles died in cages before being released, and in both years, many hard- and soft-released juveniles were found dead near the release sites, possibly as a result of exposure to cold temperatures. Although a few juveniles survived for several days after being released, no juveniles moved long distances away from the release site. During the first two weeks of May, when I trapped and translocated juveniles, is the time when juveniles are most likely to disperse (Panek 2005). At this time, juveniles have gained an appropriate amount of body fat to successfully disperse or move away from the release site. However, I speculate that most juvenile mortality likely occurred because of a response to the cold weather and an inability to handle stressful situations, likely as a result of smaller body size, as opposed to their propensity to move away from the release site.

The outcome of the present study may have been different if I had distinguished between adults and yearlings or waited longer for the juveniles to gain more weight.

However, waiting until later in the season to trap, I would have been trapping in very high and dense vegetation. Generally, it is much harder to efficiently trap ground squirrels when the vegetation is thick and high, because it is more difficult to see where the squirrels disappear.

I recommend not attempting to translocate or radio-collar young-of-year squirrels. Instead, I suggest relocating only adults.

Sex

I did not detect any differences between males and females in the success of translocation, contrary to my prediction that males, because of hormonal influences (Holekamp and Sherman 1989), would move farther away from the release site and therefore have a lower survival rate than females. There were no differences in post-release distances, and in fact, the average distances traveled away from the release sites were relatively low, compared to a similar study (Panek 2005) in which males moved farther (Figure 17). Females in my study moved similar distances to female squirrels in Panek’s (2005) study. Why is there a difference in the male movement distances? Perhaps because Panek (2005) released squirrels in areas where SIDGS were already established, and all long-distance travelers finished moving in occupied areas. In the present study, no resident squirrels were present near the release sites. Therefore there was no territorial pressure from the resident squirrels to leave the release areas and no other colonies present into which males could move.

Habitat Quality

I predicted that SIDGS released in high-quality habitat would move shorter distances and have a higher survival rate than ones released in low-quality habitat.

Although I did not detect any differences in post-release movements between squirrels released in high- and low-quality sites, all squirrels settled in, or occupied, areas with high shrub and native plant cover and low exotic annual cover. Squirrels selected areas with high-quality vegetation, which is not surprising and is consistent with previous studies. Barrett (2005) concluded that forbs, unlike exotic grasses, provide beneficial qualities and allowed squirrels to gain the necessary fat storage for over-winter and long-term survival. Steenhof et al. (2006) found that shrub habitats provide a more favorable and stable environment for squirrels than grass habitats; Piute ground squirrel (*S. mollis idahoensis*) abundance was higher in sagebrush than in areas dominated by grass.

SIDGS were found in higher abundance in areas where more native grasses and forbs were present, and in lower abundance in areas consisting mostly of annual grasses (Ross 2007). I compared the 2007 vegetation data from the present study with results from Ross (2007) (Figure 18). This comparison shows that the vegetation cover at sites of the present study were of higher quality than Ross's high density SIDGS sites. However, compared to Ross's (2007) study, an in-depth soil quality assessment was not completed before I released squirrels to the study areas. Low-quality soil is a possible cause for the low over-winter survival seen in both years of the present study.

I suspect that the reason for the high survival rate to estivation in the lower quality vegetation was the presence of vole tunnels, which made for easier burrow digging. Once these squirrels were removed from the analysis, habitat was no longer an initial predictor of survival, reinforcing the importance of vole tunnels in a release area. In the present study, habitat quality measurements were only dependent upon vegetation. However, other habitat factors may play a key role in survival. In one study, dispersing juvenile Piute ground squirrels tended to end up in the same habitat type that they started in. That study also found similar dispersal rates of squirrels located in different habitat types, indicating that the process of dispersal, and consequently survival, may not be influenced by habitat (Olson and Van Horne 1998).

Results from my study, however, show that high-quality vegetation is necessary for at least part of successful translocation. Without high-quality habitat, translocations are generally unsuccessful (Griffith et al. 1989). I suggest focusing efforts towards high soil quality (i.e., silty, loamy and dry) and determining the presence of voles or other burrow diggers in an area before releasing squirrels there. I also suggest releasing squirrels in an area with a high nutrient availability via native grasses and forbs, along with a shrub component, for cover.

Over-winter Survival

The lack of success of the present SIDGS translocation was ultimately determined by what I did not find after estivation and hibernation. The goal of the present study was to establish a self-sustaining population of squirrels. The only evidence of over-winter survival was seen by researcher Eric Yensen in June 2008 (Yensen 2008).

Although the fire that burned a hard release site at the 2006 study area is a possible cause for the low observed over-winter survival in that area, no other over-winter survival was seen at any other release sites in at either study area. Because no over-winter survival was observed near the release sites, I speculate that the translocations failed as a result of other reasons not associated with this fire.

Because of the small number of entrances and the fact that burrows appeared to be in former vole tunnels, Yensen suspects that the population he observed has lived in the area for only a short time. Other reasons for suspecting that these squirrels represent survivors from the present study include the absence of physical barriers to dispersal in this valley, the suitableness of the intervening area as a dispersal route, and the four km distance, which is within the known dispersal capabilities of SIDGS (Panek 2005).

I can say with some certainty, however, that the squirrels did not establish a colony at the release sites. They may have, in fact, settled elsewhere, as possibly observed by Eric Yensen, and started colonies in other areas, as was found by Van Vuren (1997). In Van Vuren's study, 85% of the squirrels that survived but did not return home established a new home range, but most settled away from the release site (Van Vuren 1997). Overall, however, the results of this study are consistent with others (Griffith et al 1989). Translocation is a management tool of last resort for sensitive or threatened species.

CONCLUSION

The southern Idaho ground squirrel has undergone severe declines in the past 30 years. The main culprits of these declines include habitat loss and degredation as a result of introduced exotic plant species and conversion of native sagebrush steppe to agricultural land. Federal agencies have made efforts to restore native vegetation and also to continue monitoring population numbers. Reintroductions have been attempted with this species and others, but with little success.

I translocated 489 SIDGS to the study areas and monitored 112 for post-release movements and survival. Much like previous translocation experiments (Griffith et al. 1989, Van Vuren et al. 1997, Gavin, et al. 1998, Panek 2005), I observed low survival rates to estivation of 45% and 35% in 2006 and 2007, respectively.

Preliminary results showed that adults are more likely to survive a stressful event, such as translocation, than juveniles. In addition to age playing a potential role in translocation success, evidence also points to habitat quality as a key factor. High-quality vegetation was chosen by all squirrels, regardless of the habitat type into which they were released. The presence of vole tunnels also appeared to aid in the survival of several squirrels to estivation. These observations reinforce the fact that high-quality habitat is likely necessary for a successful translocation to occur. Depending on age, release type also played a role in survival, because more soft-released adults survived than hard-released adults.

There was no over-winter survival seen at or near the release sites. However, over-wintering survival was observed four km away from the 2006 release site. I have no concrete evidence that these squirrels were from the present study, but it is likely. I am unable determine whether the majority of the squirrels did not survive or were undetected during surveys. Regardless, no colonies were established at the release sites, indicating that the translocations were, in fact, unsuccessful.

If current patterns of habitat loss and degredation persist, natural communities may become restricted to small, fragmented populations (Griffith et al. 1989). Therefore translocations may be even more of a requirement to maintain community structure for declining species. However, once habitat degredation and loss becomes too severe, there will be no place to translocate animals. In certain situations, translocation may be the only conservation or management option available, however it must be considered long before it becomes a last resort for sensitive and endangered species, such as the southern Idaho ground squirrel.

LITERATURE CITED

Barrett, J.S. 2005. Population viability of the southern Idaho ground squirrel (*Spermophilus brunneus endemicus*): effects of an altered landscape. M.S. Thesis, Boise State University, Boise, ID.

Belsky, A.J. and D.M. Blumenthal 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the interior west. Conservation Biology 11:315-327.

Brander, R.B. and W.W. Cochran. 1971. Radio location telemetry. Pp. 95-103, in R.H. Giles, ed. Wildlife management techniques. The Wildlife Society, Washington, D.C.

Bright, P.W. and P.A. Morris. 1994. Animal translocation for conservation: performance of dormice in relation to release methods, origin and season. Journal of Applied Ecology 31:699-708.

Clobert, J., E. Danchin, A.A. Dhont, and J. Nichols (eds). 2001. Dispersal – Causes, Consequences and Mechanisms of Dispersal at the Individual, Population and Community Level. Oxford University Press, Oxford, United Kingdom.

Cody, P.R. and J.K. Smith. 2006. Applied Statistics and the SAS Programming Language. Pearson Prentice Hall, NJ.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-87.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-62.

Dobson, F.S. 1982. Competition for mates and predominant juvenile male dispersal in mammals. Animal Behaviour 30:1183-1192.

Dyer, N.W., and L.E. Huffman. 1999. Plague in free-ranging mammals in western North Dakota. Journal of Wildlife Diseases 35:600-602.

Eldridge, D.J. 2004. Mounds of the American badger (*Taxidea taxus*): significant features of the North American shrub-steppes ecosystems. Journal of Mammalogy 85:1060-1067.

Gavin, T.A., P.W. Sherman, and E. Yensen. 1998. Translocation and inventory of northern Idaho ground squirrels (*Spermophilus brunneus brunneus*) in 1998. Unpublished report for USFWS, Snake River Basin Office.

Gavin, T.A., P.W. Sherman, E. Yensen, and B. May. 1999. Population genetic structure of the northern Idaho ground squirrel (*Spermophilus brunneus brunneus*). Journal of Mammalogy 80:156-168.

Greenwood, P.J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behaviour 28:1140-1162.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Groom, M.J., G.K. Meffe, and C.R. Carroll, 2006. Principles of Conservation Biology, Third Edition. Sinauer Associates Inc., Sunderland, MA.

Hackett, D. 1987. Dispersal of yearling Columbian ground squirrels. Ph.D. Dissertation, University of Alberta, Edmonton, Canada.

Halpin, Z.T. and B.D. Chepko-Sade. 1987. Mammalian Dispersal Patterns: The effects of social structure on population genetics. University of Chicago Press, Chicago, IL.

Holekamp, K.E. 1984. Natal dispersal in Belding's ground squirrels (*Spermophilus beldingi*). Behavioral Ecology and Sociobiology 16: 21-30.

Holekamp, K.E. 1986. Proximal causes of natal dispersal in Belding's ground squirrels (*Spermophilus beldingi*). Ecological Monographs 56:365-391.

Holekamp, K.E. and P.W. Sherman. 1989. Why male ground squirrels disperse. American Scientist 77:232-239.

Howard, W.E. 1960. Innate and environmental dispersal of individual vertebrates. American Midland Naturalist 63:152-161.

Howell, A.H. 1938. Revision of the North American ground squirrels with a classification of the North American Sciuridae. North American Fauna 56:1-256.

Joslin, J.K. 1977. Rodent long distance orientation ("homing"). Advances in Ecological Research 10:63-89.

Krannitz, P.G. 2008. Response of antelope bitterbrush shrubsteppe to variation in livestock grazing. Western North American Naturalist 68:138-152.

Olson, G.S. and B. Van Horne. 1998. Dispersal patterns of juvenile Townsend's ground squirrels in southwestern Idaho. Canadian Journal of Zoology 76:2084-2089.

Panek, K.C. 2005. Dispersal, translocation, and population connectivity in fragmented populations of southern Idaho ground squirrels. M.S. Thesis. Boise State University, Boise, ID.

Rasmussen, L. 2001. Soil Survey of Adams-Washington area, Idaho, parts of Adams and Washington counties. Natural Resources Conservation Service, United States.

Ross, K.L. 2007. Influence of topography, soils, and vegetation on densities and body condition of southern Idaho ground squirrels. M.S. Thesis. Boise State University, Boise, ID.

Rogers, L.L. 1988. Homing tendencies of large mammals: a review. Pages 76-91 *in* L. Nielson and R.D. Brown, eds. Translocation of wild animals. Wisconsin Humane Society, Milwaukee, WI.

Sharp, L.A., M. Hironaka, and E.W. Tisdale. 1957. Viability of medusa-head (*Elymus caput-medusae* L.) seed collected in Idaho. Journal of Range Management 10:123-126.

Sherman, P.W., and M.C. Runge. 2002. Demography of a population collapse: the northern Idaho ground squirrel (*Spermophilus brunneus brunneus*). Ecology 83:2816-2831.

Shier, D. M. 2006. Effect of family support on the success of translocated black-tailed prairie dogs. Conservation Biology 20:1780-1790.

Steenhof, K., and M.N. Kochert. 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. Journal of Animal Ecology 57:37-48.

Steenhof, K., E. Yensen, M.N. Kochert, and K.L. Gage. 2006. Populations and habitat relationships of Piute ground squirrels in southwestern Idaho. Western North American Naturalist 66:482-491.

U.S. Fish and Wildlife Service. 2000. Federal Register 65:17779 (5 May).

U.S. Fish and Wildlife Service. 2001. Federal Register 66:54808-54832 (30 October).

Vander Haegen, W.M., S.M. McCorquodale, C.R. Peterson, G.A. Green, and E. Yensen. 2001. Wildlife communities of eastside shrubland and grassland habitats. Pages 349-377, *in* D.H. Johnson and T.A. O'Neil (editors). Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR, 736 pp.

Van Horne, B., R.L. Schooley, and P.B. Sharpe. 1998. Influence of habitat, sex, age, and drought on the diet of Townsend's ground squirrels. Journal of Mammalogy 79:521-537.

Van Vuren D., A.J. Kuenzi, I. Loredo, A.L. Leider, and M.L. Morrison. 1997. Translocation as a nonlethal alternative for managing California ground squirrels. Journal of Wildlife Management 61:351-359.

Whisenant, S.G. 1990. Changing fire frequencies on Idaho's Snake River plains: ecological and management implications. Paper from the Symposium on Cheatgrass Invasion, Shrub Die-Off, and Other Aspects of Shrub Biology and Management. Las Vegas, NV. April 5-7.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21:213-251.

Yensen, E. 1985. Taxonomy, distribution, and population status of the Idaho ground squirrel, *Spermophilus brunneus*. Final Report prepared for Non-game Species Program, Idaho Dept. of Fish and Game and Office of Endangered Species, U.S. Fish and Wildlife Service: 1-41.

Yensen, E. 1991. Taxonomy and distribution of the Idaho ground squirrel, *Spermophilus brunneus.* Journal of Mammalogy 72:583-600.

Yensen, E. 1998. Known localities of *Spermophilus endemicus*. A report submitted to the U.S. Fish and Wildlife Service, Snake River Basin Office.

Yensen, E. 2000. Additional surveys for southern Idaho ground squirrels, *Spermophilus brunneus endemicus*. A report submitted to the U.S. Fish and Wildlife Service, Snake River Basin Office.

Yensen, E. 2001. Population estimate for the southern Idaho ground squirrel (*Spermophilus brunneus endemicus*). Unpublished report for U.S. Fish and Wildlife Service.

Yensen, E. 2003. Survey for southern Idaho ground squirrels on Soulen Livestock Company lands. Unpublished report for USFWS, Snake River Basin Office.

Yensen, E. 2008. Southern Idaho ground squirrel surveys on Soulen Livestock Company Lands: 2008 Annual Report and Final Report. Unpublished report, US Fish and Wildlife Service, Snake River Field Office, Boise, ID.

Yensen, E., C.R. Baird, and P.W. Sherman. 1996. Larger ectoparasites of the Idaho ground squirrel (*Spermophilus brunneus*). Great Basin Naturalist 56:237-46.

Yensen, E., D.L. Quinney, K. Johnson, K. Timmerman, and K. Steenhof. 1992. Fire, vegetation changes, and population fluctuations of Townsend's ground squirrels. American Midland Naturalist 128:299-312.

Yensen, E., and P.W. Sherman. 1997. Mammalian species account for *Spermophilus brunneus.* No. 560. American Society of Mammalogists: 1-5.

Yensen, E. and P.W. Sherman. 2003. Ground squirrels. Pages 211-231 *in* G. Feldhammer, B. Thompson, and J. Chapman, editors, Wild mammals of North America. 2nd edition. Johns Hopkins University Press, Baltimore, MD.

Young, J.A. 1992. Ecology and management of medusahead (*Taeniatherum caput medusa* ssp. *asperum* [Simk.] Melderis). Great Basin Naturalist 52:245-252.

Young, J.A. and R.A. Evans. 1970. Invasion of medusahead into the Great Basin. Weed Science 18: 89-97.

Young, J.A. and R.A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management 31:283-289.

Young, J.A., R.A. Evans, R.E. Eckert, Jr. and B.L. Kay. 1987. Cheatgrass. Rangelands 9:266-270.

Table 1. Hard-released squirrels trapped during the pilot study at Van Deussen ranch and translocated to Little Willow Flat study area in 2006. Sixteen adults were radio-collared.

Trans-location Site	**Date**	**# Captured**	**# Adults**	**# Juveniles**
HR1	20 March	3	3	0
	21 March	6	6	0
	22 March	3	3	0
	30 March	17	15	2
	2 April	7	5	2
	3 April	12	12	0
	6 April	8	8	0
HR2	30 March	7	7	0
	2 April	6	6	0
	6 April	18	18	0
	7 April	12	12	0
	10 April	5	5	0
	TOTALS	**104**	**100**	**4**

Table 2. Squirrels trapped from Scotch Pines Golf Course and translocated to Little Willow Flat study area in 2006. Twenty-two adults were radio-collared.

Trans-location Site	Date	# Captured	# Adults	# Juveniles
SR1	2 May	14	1	13
	3 May	10	2	8
	4 May	4	2	2
SR2	2 May	15	2	13
	3 May	9	0	9
	4 May	3	1	2
SR3	2 May	15	1	14
	3 May	9	1	8
	4 May	2	1	1
SR4	2 May	15	1	14
	3 May	10	2	8
	4 May	3	1	2
SR5	2 May	14	1	13
	3 May	10	1	9
	4 May	2	0	2
SR6	2 May	15	1	14
	3 May	10	1	9
	4 May	2	0	2
HR3	4 May	25	3	22
HR4	4 May	25	3	22
	TOTALS	**212**	**25**	**187**

Table 3. Squirrels trapped at Van Deussen Ranch and translocated to Midvale study area in 2007. A total of 74 adults and juveniles were radio-collared.

Trans-location Site	**Date**	**# Captured**
A	19-Apr	14
	20-Apr	8
	1-May	16
	3-May	5
B	19-Apr	13
	20-Apr	8
	1-May	16
	3-May	4
C	19-Apr	14
	20-Apr	8
	1-May	16
	3-May	5
D	19-Apr	13
	20-Apr	9
	1-May	16
	3-May	5
	TOTAL	**170**

Table 4. ANOVA table showing post-release movements versus sex and release type in 2006. Post-release movement is the dependent variable.

Source	DF	Mean Square	F Value	Pr > F
Sex	1	12614.92	1.53	0.2326
Release	1	0.72	0	0.9927
Error	17	8231.88		

Table 5. P-values from exact logistic regression of survival in 2007.

Parameter	p-value
Habitat	0.0195
Age	0.0119
Sex	0.9788
Release	0.3767
Age*Sex	0.4280
Age*Release	0.0048
Age*Habitat	0.2200
Release*Sex	0.5314
Release*Habitat	0.1566

Table 6. ANOVA table showing post-release movements vs. habitat, sex, release type, and interactions in 2007. Post-release movement is the dependent variable. Age was not included in analysis because so few juveniles survived.

Source	**DF**	**Mean Square**	**F-Value**	**Pr > F**
Habitat	1	53167.02	1.39	0.2545
Sex	1	4608.67	0.12	0.7327
Release	1	22750.47	0.6	0.4511
Habitat*Sex	1	15601.53	0.41	0.5315
Habitat*Release	1	5456.50	0.14	0.7103
Sex*Release	1	28201.16	0.74	0.4024
Error	17	38232.22		

Table 7. Average absolute cover percentages of vegetation classes for occupied and matched unoccupied sites in 2007.

Vegetation Class	**Occupied**	**Unoccupied**
Annual Grass	19.16	17.55
Perennial Grass	18.61	18.38
Shrub	17.45	17.39
Exotic Perennial Forb	0.60	0.39
Native Perennial Forb	24.90	26.37
TOTAL	80.72	80.07

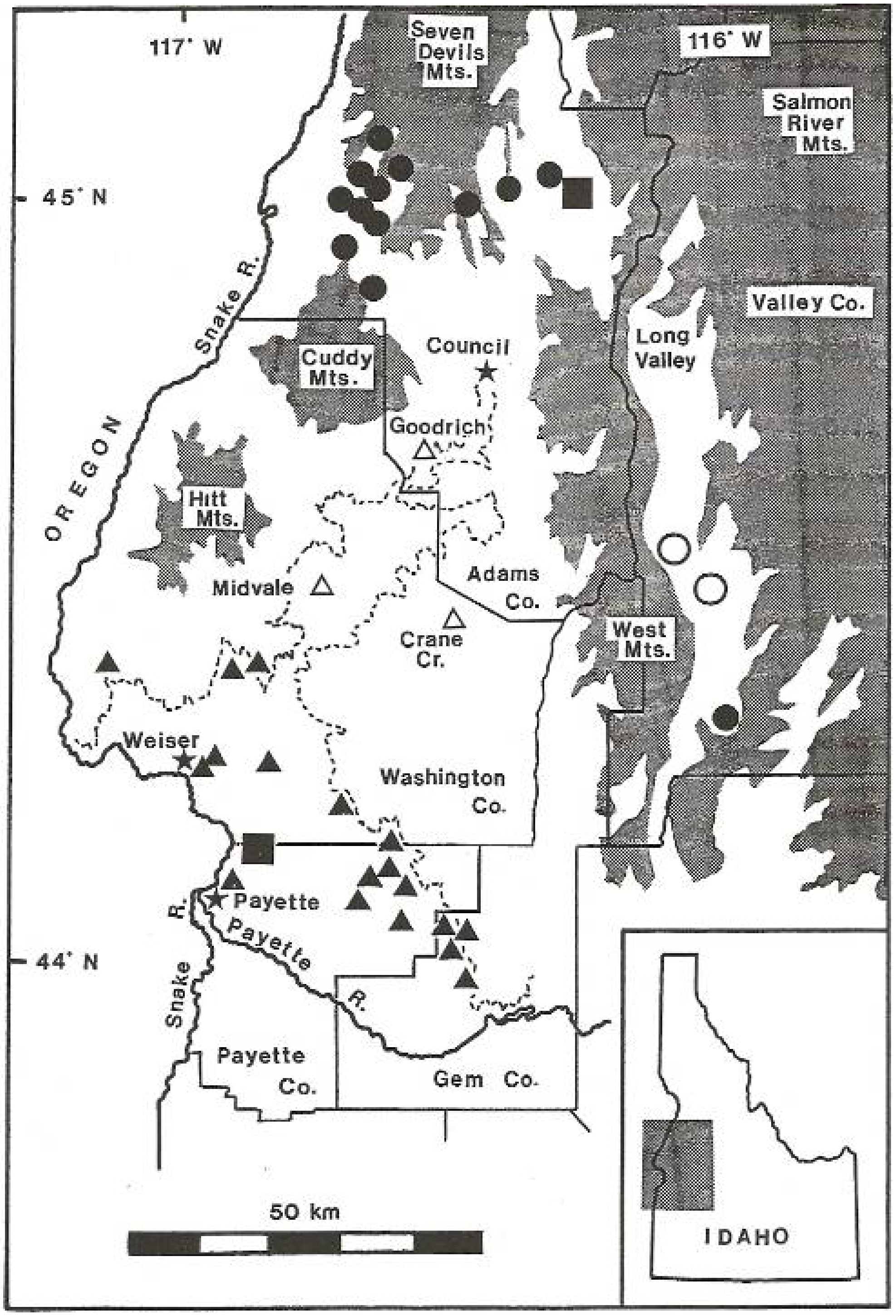

Figure 1. Distribution of the Idaho ground squirrel. Symbols: solid, extant; open, extirpated; circles *S. brunneus*; triangles, *S. endemicus*; squares, type localities. Elevations above the 1,525 m contour interval are shaded; the 915 m contour interval is indicated by a dashed line (Yensen 1991).

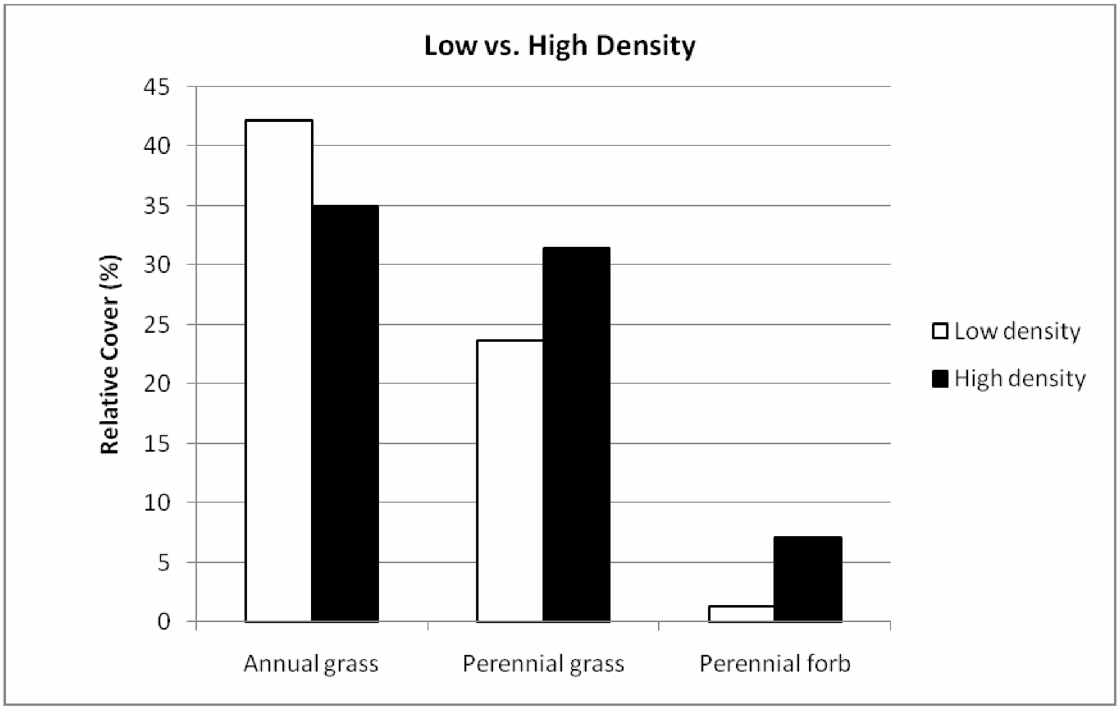

Figure 2. More perennial grasses and forbs and fewer annual grasses were found in high density compared to low density SIDGS plots (modified from Ross 2007).

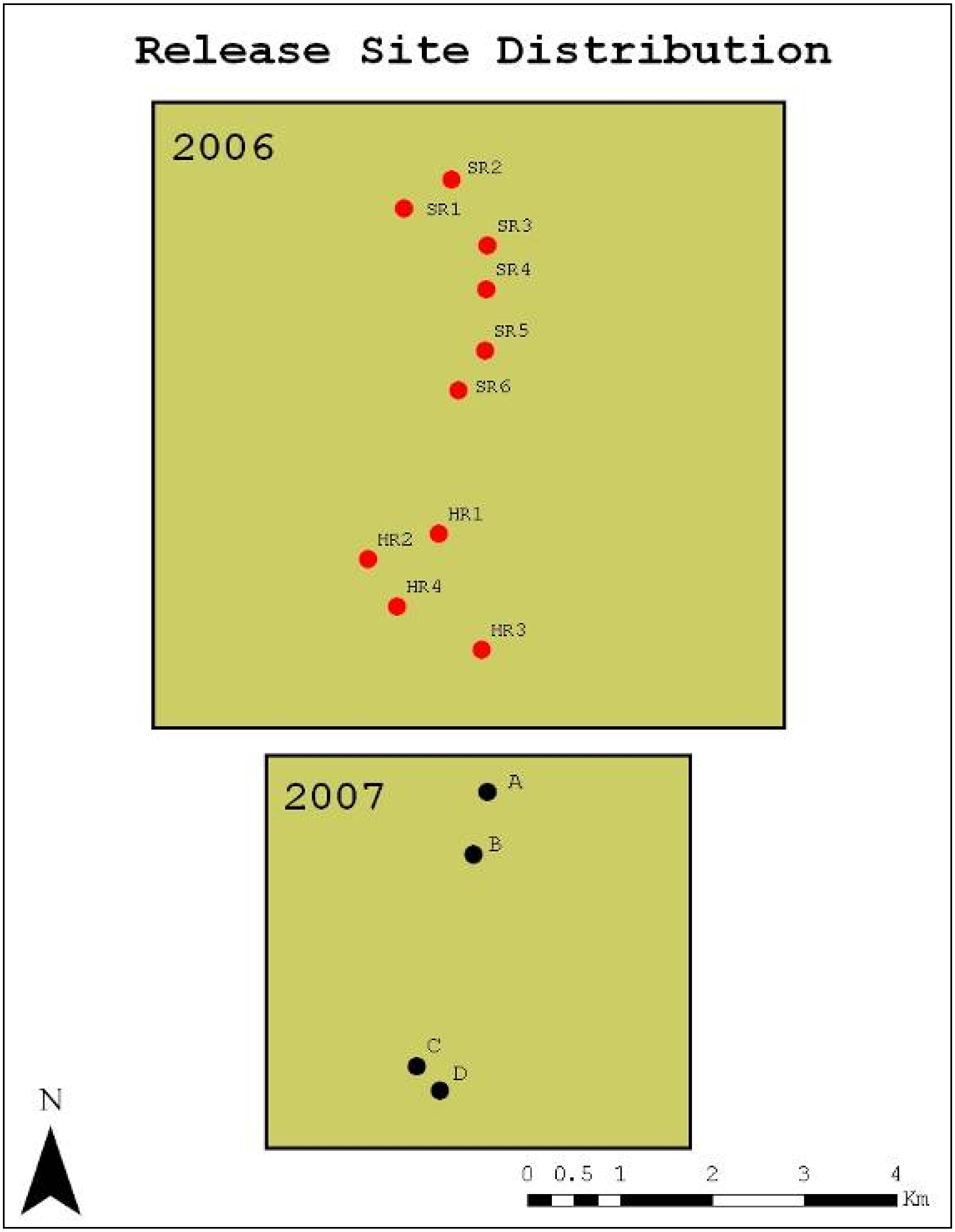

Figure 3. Spatial relationships among release sites used in 2006 and 2007. SR = soft-release sites, HR = hard-release sites, A and B = high-quality habitat sites, C and D = low-quality habitat sites.

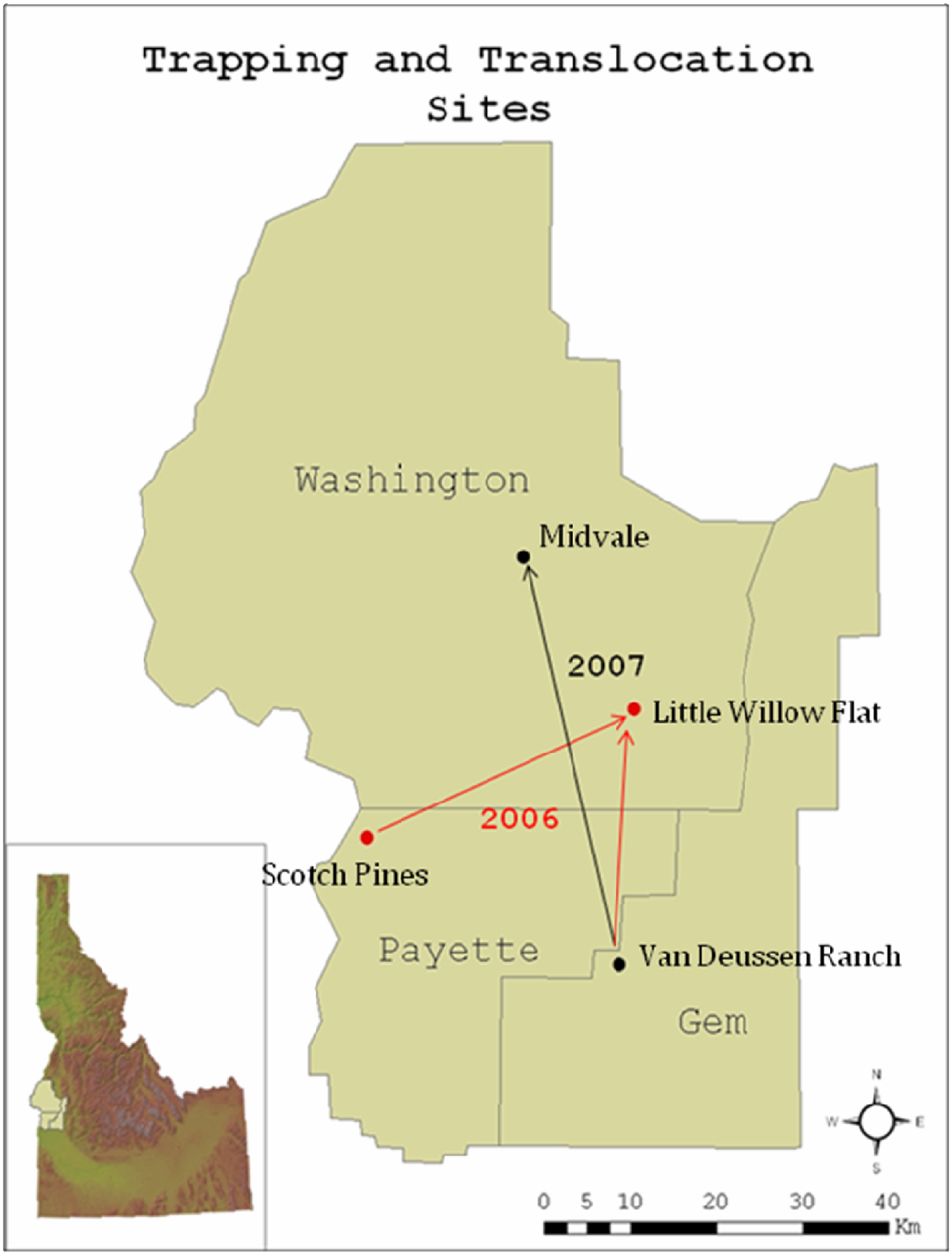

Figure 4. 2006 and 2007 trapping and translocation sites. In 2006, squirrels were trapped from Scotch Pines Golf Course in Payette and Van Deussen Ranch, north of Emmett, and translocated to the study area near Little Willow Flat. In 2007, squirrels were trapped from Van Deussen Ranch, and translocated the study area near Midvale.

Figure 5. Example of a hard-release site. This is the central area where squirrels were released.

Figure 6. Large cage design used in 2006. Dimensions are 2.4 m x 2.4 m x 1.2 m. Each cage held six squirrels.

Figure 7. Small cage design used in 2006. Dimensions were 0.6 m x 0.6 m x 1.2 m. Each cage held one squirrel.

Figure 8. Individual cage used in 2007 soft-release. Dimensions were 0.6 x 0.6 m x 0.46 m (1.27 x 2.54 cm mesh). Cage had a bottom that lay on top of the ground so squirrels could not escape until released. Each cage held one squirrel.

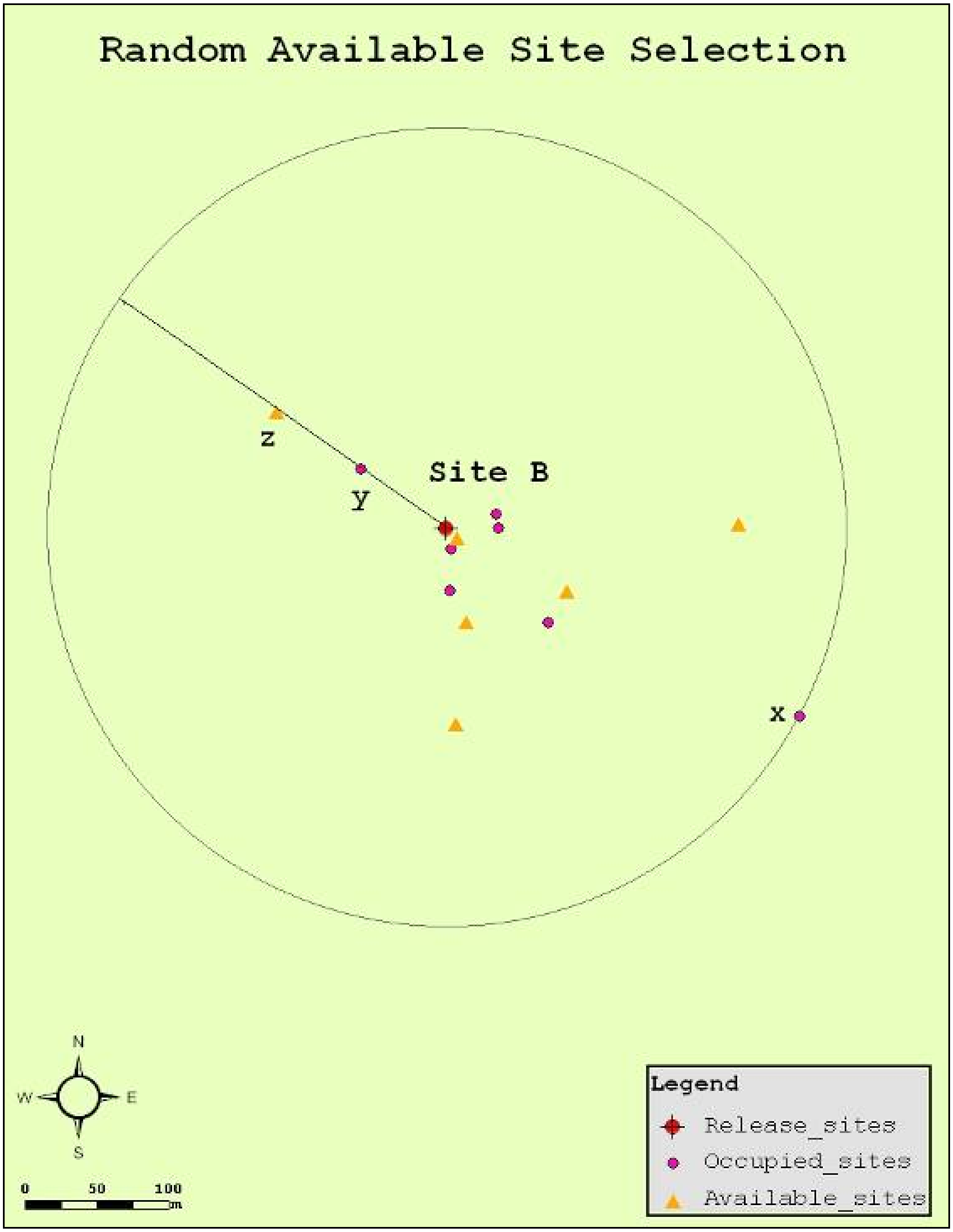

Figure 9. Matched unoccupied or available site selection technique used in 2007 vegetation surveys. x represents an occupied site located farthest from release site B, thus determining the size of the circle around the release site. y represents another occupied site and z represents a matched unoccupied site corresponding with site y.

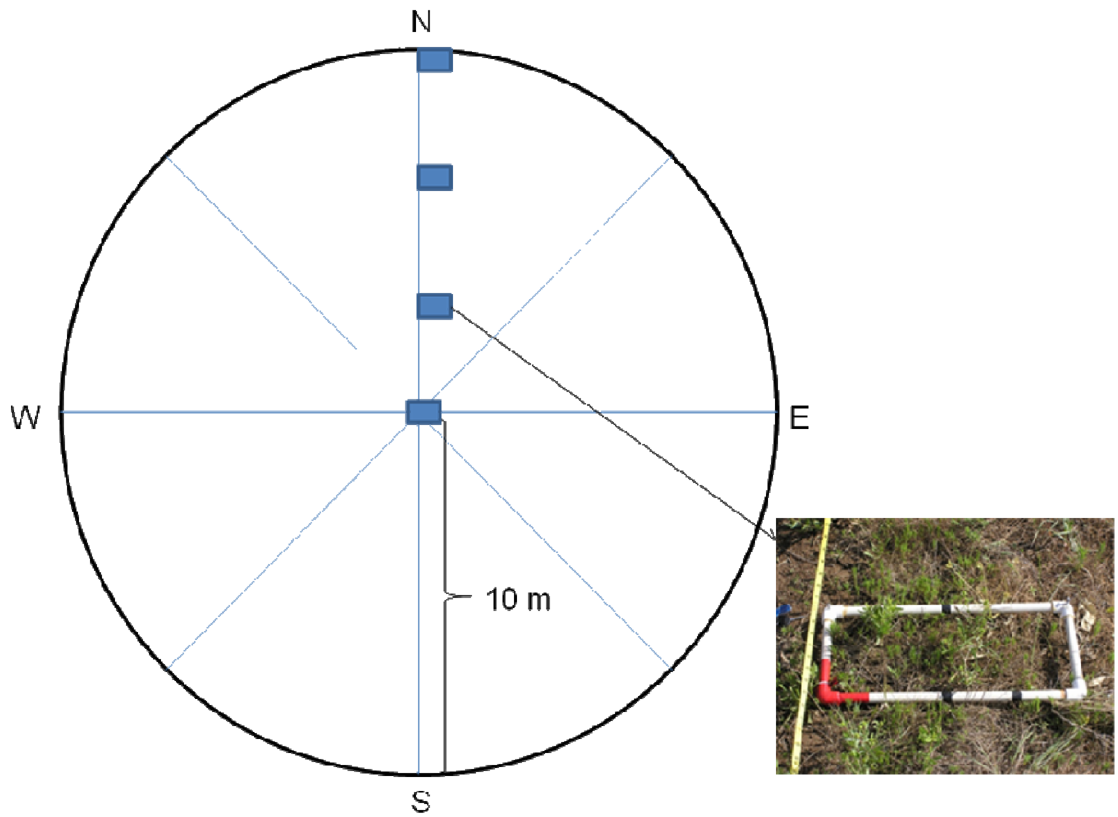

Figure 10. Radial vegetation plot using Daubenmire plot frames. This method was used for the 2007 vegetation surveys.

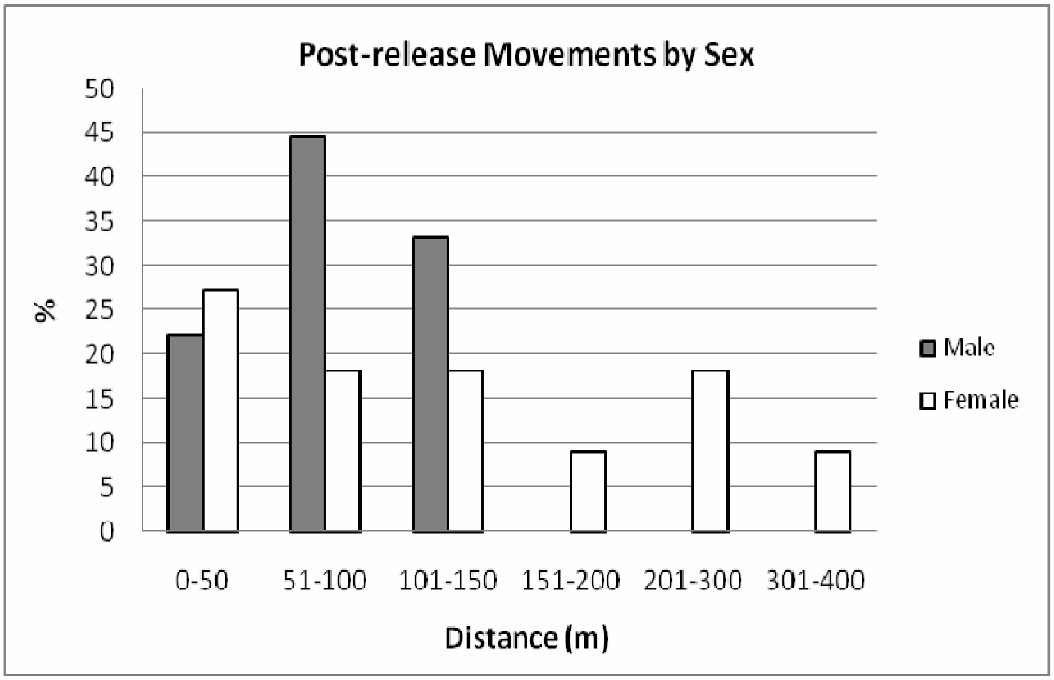

Figure 11. Post-release movements of male and female squirrels away from release site in 2006. No significant differences were found ($p > 0.05$).

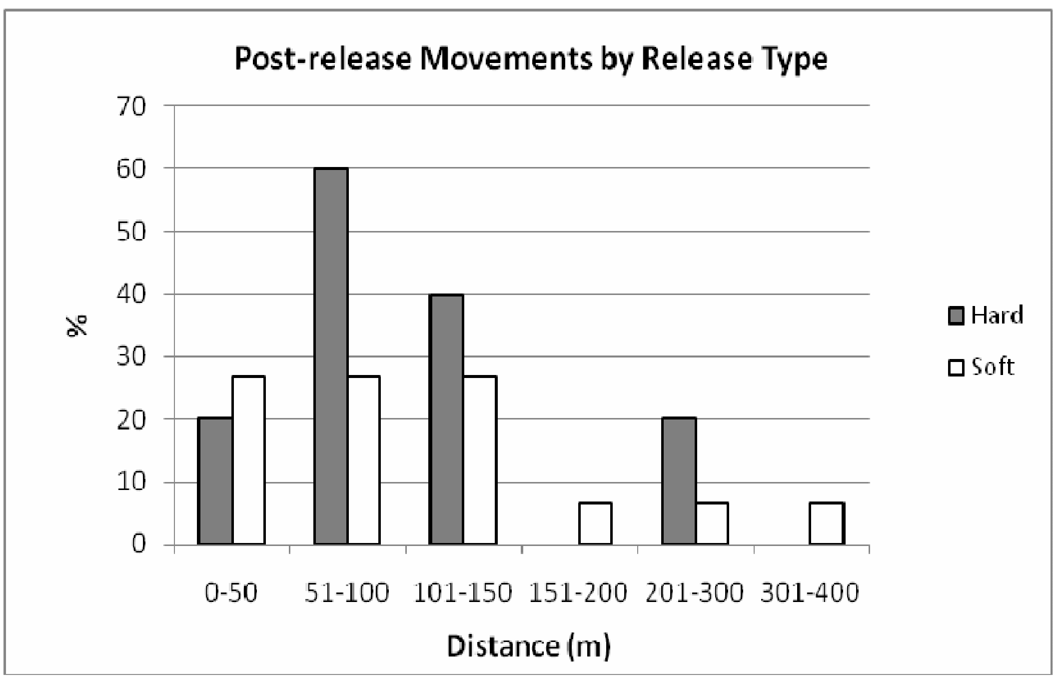

Figure 12. Post-release movements of soft and hard released squirrels away from release site in 2006. No significant differences were found ($p > 0.05$).

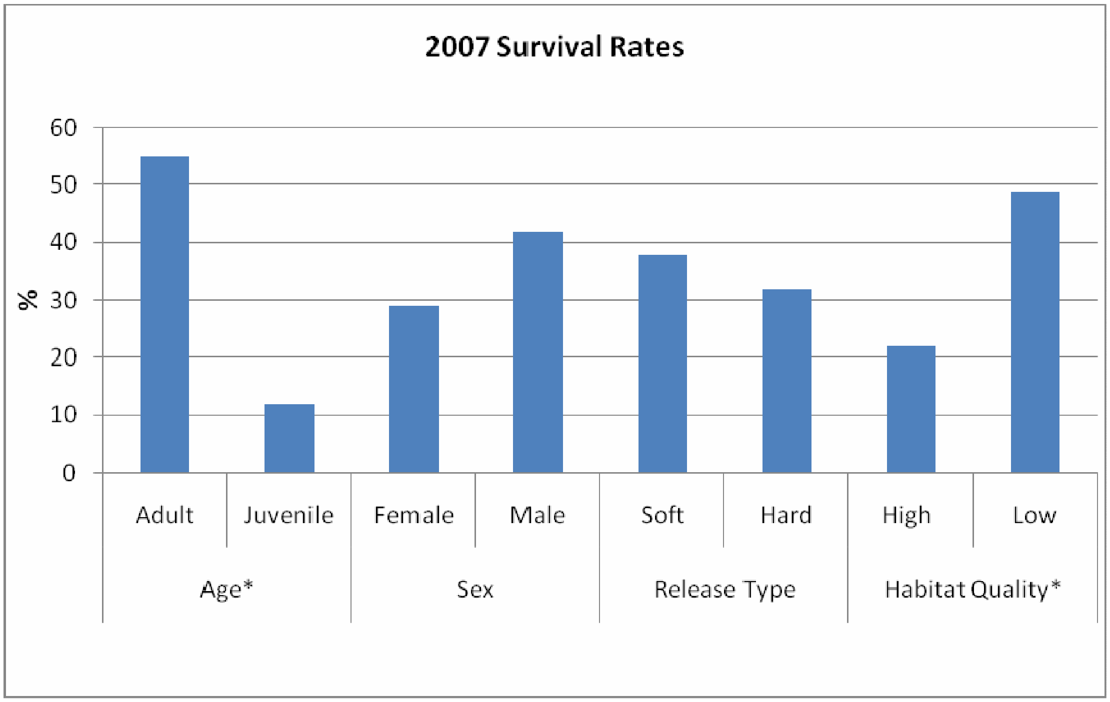

Figure 13. Observed survival percentages in 2007. * indicates a significant difference.

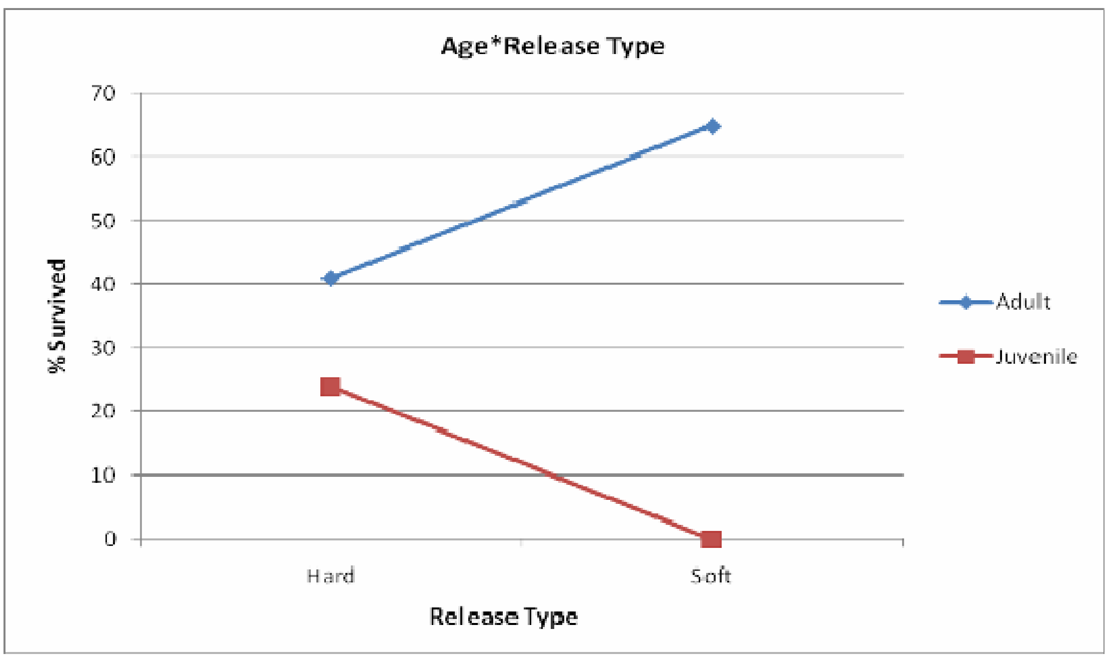

Figure 14. Interaction diagram showing observed survival percentages of release type and age in 2007. Release type had an effect on survival, but it depended the age of the squirrels. Adults survived better with soft release while juveniles survived better if hard released. However, juvenile survival is biased by pre-release cage deaths.

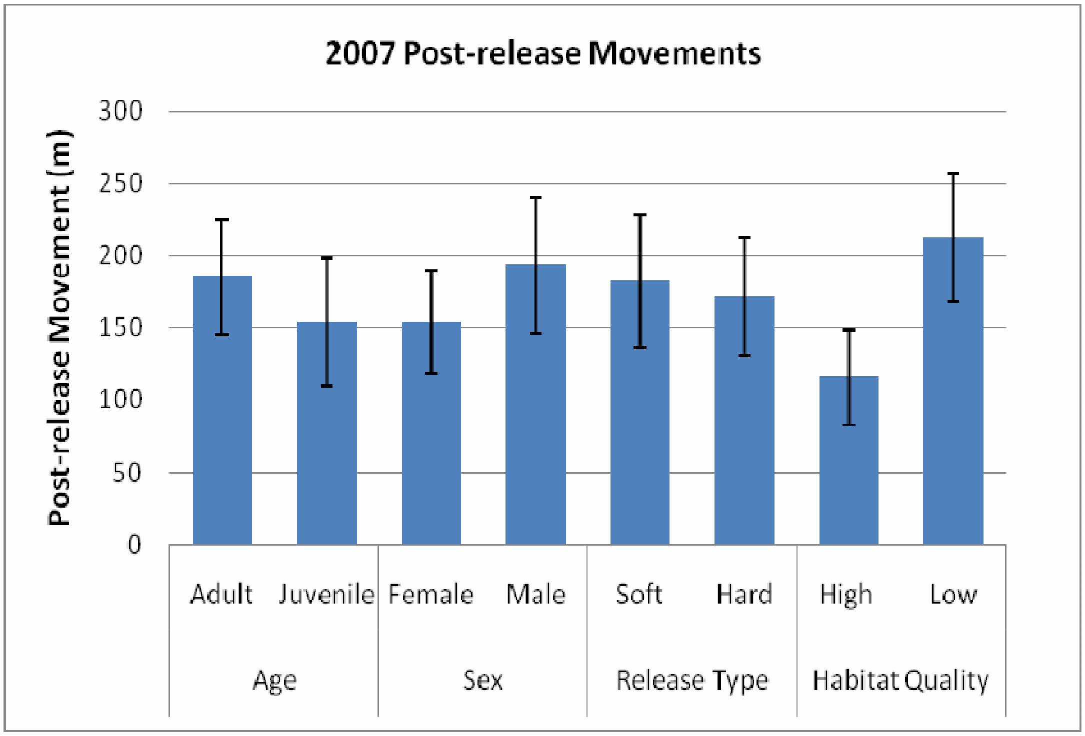

Figure 15. Post-release movements of all squirrels (mean ± SE). No significant statistical differences found across all variables ($p > 0.05$). Age was not included in the ANOVA model because of the low numbers of juveniles that survived.

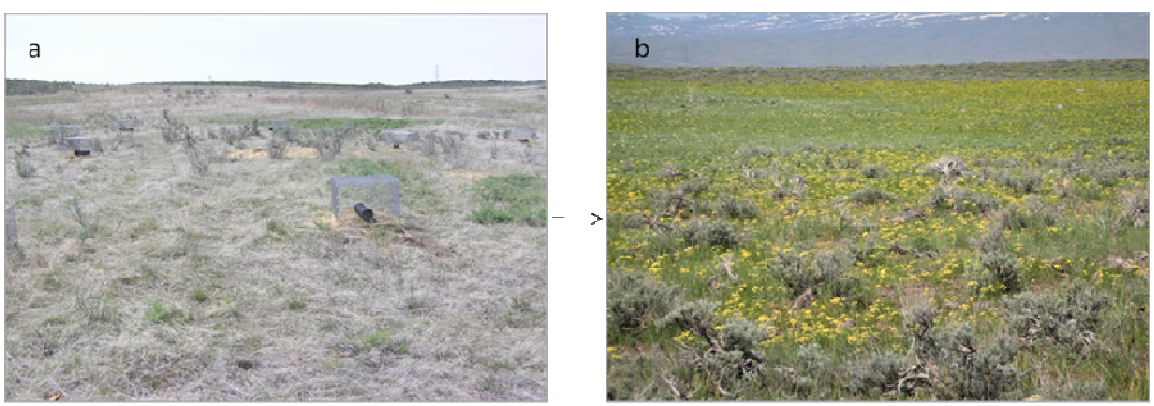

Figure 16. a. Low-quality release site D containing mostly exotic annual grasses and little shrub cover; b. Occupied site where a squirrel, released at site D, was found to be estivating. This site is mostly comprised of shrubs and native forbs.

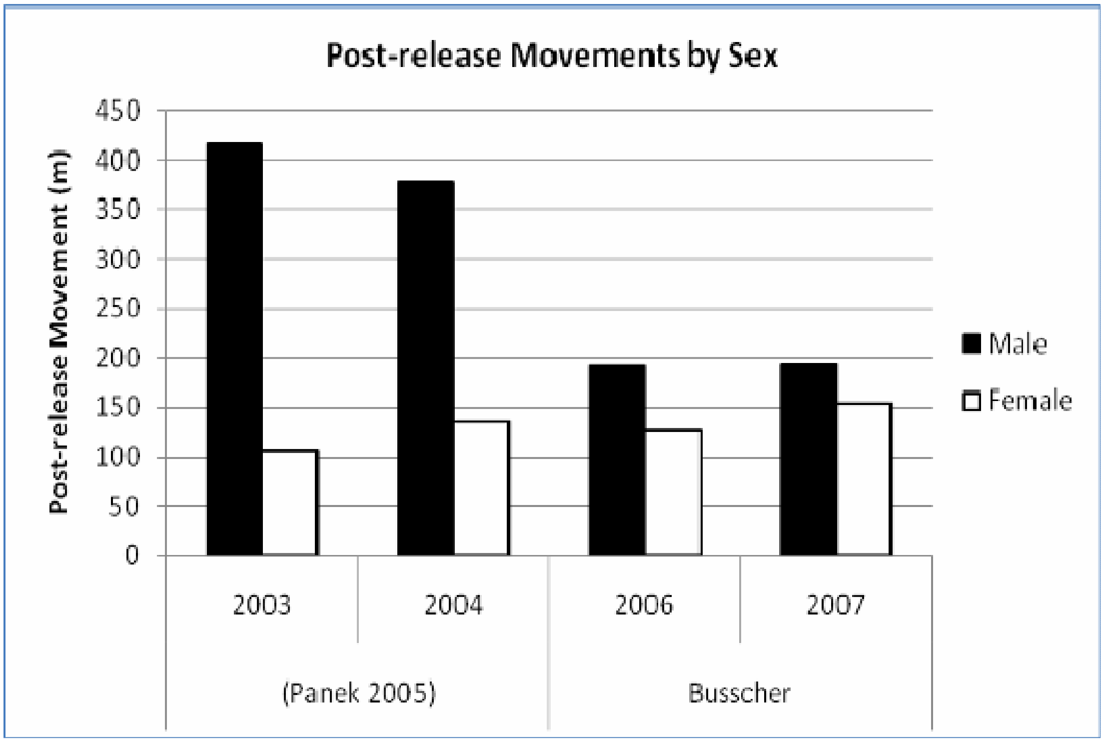

Figure 17. Post-release movements versus sex in two studies of SIDGS (modified from Panek 2005).

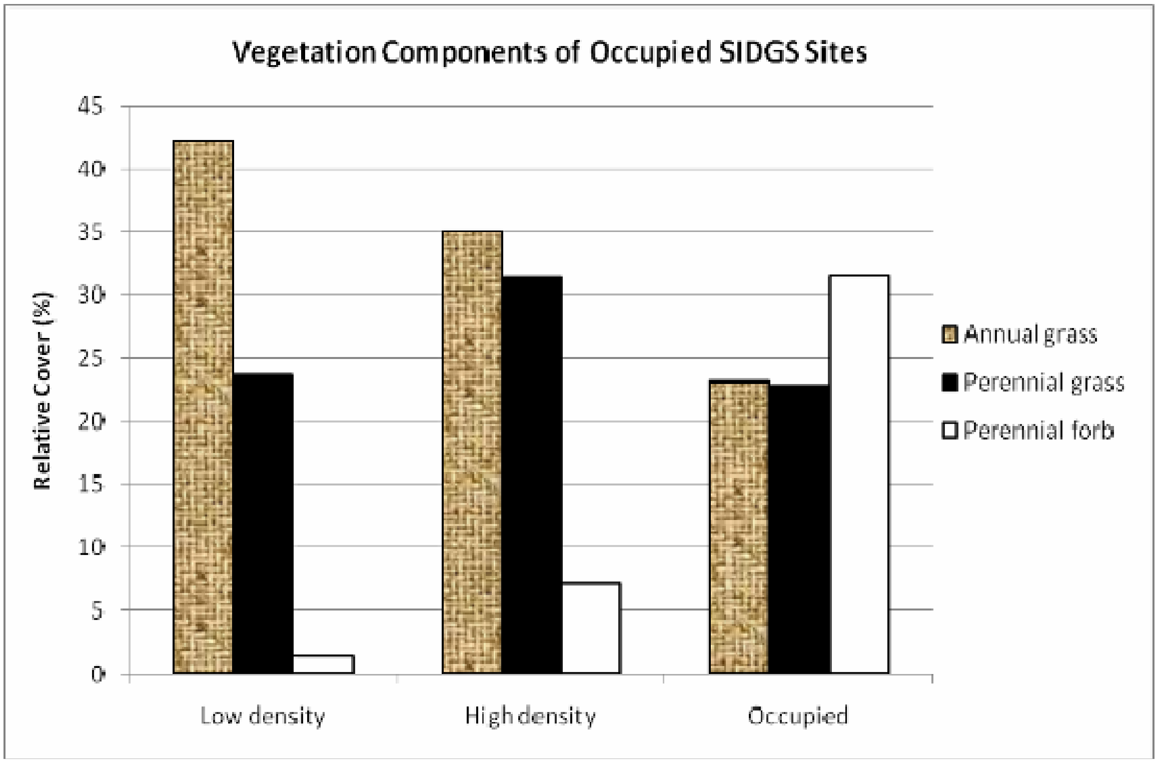

Figure 18. Relative cover of three vegetation cover classes of occupied sites. Modified data from Ross (2007) with data from my study. Low density and high density data is from Ross (2007), and occupied data is from the present study. Note the highly significant differences in perennial forbs.

APPENDIX A

Plant Functional Groups

Annual grasses
Bromus tectorum
Taeniatherum caput-medusae
Agropyron cristatum

Perennial grasses
Elymus elemoides
Poa secunda
Poa bulbosa

Forbs
Achillea millefolium
Agoseris
Allium
Artemisia ludoviciana
Astragalus
Balsamorhiza
Blepharipappus scaber
Convolvulus
Crepis
Epilobium
Gnaphalium
Grindelia
Helianthus annuus
Lactuca
Lomatium
Lupinus
Perideridia
Phlox
Thistle
Tragopogon dubius

Shrubs
Artemisia tridentata
Artemisia cana
Purshia tridentata
Rosa woodsii