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Influence of Release Timing on Survival and Movements of Translocated Mule Deer (*Odocoileus hemionus*) in Utah

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ABSTRACT

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Translocated Mule Deer (*Odocoileus hemionus*) in Utah

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Translocation of wildlife has become common practice for wildlife managers charged with management of animals on increasingly modified landscapes. Translocation can be used to reduce population density in the source area, supplement existing populations, reestablish extirpated populations, and establish new populations. Mule deer (*Odocoileus hemionus*) are a species of great interest to the public in western North America. Although translocations have been used to manage mule deer, very little has been done to document the outcomes of this management practice. The purpose of this research was to evaluate movement, site fidelity, space use, and survival of translocated mule deer in relation to the timing of release (early versus late winter) and to provide managers with information useful in judging the relative value of translocation as a management strategy for this species. We captured 102 mule deer in January and March 2013 and translocated them from winter range near Parowan, UT, to winter range along the Pahvant Mountain Range near Holden, UT (approximately 144 km north of the capture location). Each deer was fitted with a radio transmitter (21 GPS collars, 81 VHF collars) prior to release to document outcomes. In January 2013 and 2014 we also captured and marked a total of 70 resident deer (non-translocated deer; 9 GPS collars, 61 VHF collars) to serve as a reference group within our study area. Following release, we monitored deer weekly through March 2015. We found that translocated deer had lower annual survival rates than resident deer during the first year following release, but similar annual survival rates to resident deer during the second year following release. Additionally, we found that age strongly influenced the survival of translocated deer; young deer (e.g., 2.5 year olds) were more than twice as likely to survive the initial year following translocation than old deer (e.g., 7.5 year olds). We also found that translocated deer had larger home ranges compared to resident deer during the first and second years following release. However, the average size of translocated deer home ranges decreased from year 1 to year 2 following release. Despite these large home ranges and extended movements during the summer months, most surviving deer (96 %) returned (within < 30 km) to winter range where they were released. We found no difference in movement, site fidelity, or survival for transplanted deer released in January and March. Based on our findings, wildlife managers that elect to translocate mule deer should not expect a difference in survival between early and late winter releases, but will likely see high site fidelity, higher survival rates during the second year following translocation (compared to the first year), and higher survival rates for younger deer compared to older deer.

Keywords: mule deer, *Odocoileus hemionus,* translocation, transplant, fidelity, ungulate management

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CHAPTER 1

Translocated Mule Deer: Does Release Timing Influence Survival?

ABSTRACT

Translocation of wildlife has become common practice for wildlife managers charged with management of animals on increasingly modified landscapes. Goals of translocation projects include reducing population density in the source area, supplementing existing populations, reestablishing extirpated populations, and establishing new populations. Since the 19^{th} century, translocations of ungulates have occurred around the world with varying results. Mule deer (*Odocoileus hemionus*) are a species of great interest to the public in western North America. Although translocations have been used to manage mule deer, very little has been done to document the outcomes of this management practice. Our objectives were to evaluate survival of translocated mule deer in relation to release timing (early versus late winter) and to compare survival of translocated mule deer with that of resident animals (i.e., mule deer that were not translocated). This information will help managers judge the relative value of translocation as a management strategy for this species. In January and March 2013, the Utah Division of Wildlife Resources captured and translocated 102 mule deer from winter range near Parowan, UT, USA to winter range along the Pahvant Mountain Range near Holden, UT, USA (approximately 144 km north of the capture location). We fitted each deer with a radio transmitter (n = 102; 21 GPS collars, 81 VHF collars) prior to release. In January 2013 and 2014 we also captured and marked a total of 70 resident deer (9 GPS collars, 61 VHF collars) to serve as a reference group within our study area. Radio-marked deer were monitored weekly through

March of 2015. We then used a 3-step model selection approach with known-fate models in Program MARK to estimate survival. We used Akaike's Information Criterion corrected for small sample sizes (AIC*c*) to evaluate the influence of release group, individual covariates (age, condition, and pregnancy), deer movement, season, and year on survival. Annual survival was greater for resident deer (0.83; 95% CI = 0.72 – 0.90) than for translocated deer (January release 0.51; 95% CI = 0.40 – 0.63, March release 0.53; 95% CI = 0.40 – 0.66) during the first year after translocation. We found no difference in survival for translocated deer released in January and March and elected to group them during the second year following translocation. Annual survival of translocated animals (0.85; 95% CI = 0.71 – 0.93) was not different from that of resident deer (0.80; 95% CI = 0.69 – 0.88) during the second year after translocation. Additionally, age strongly influenced the survival of translocated deer; young deer (e.g., 2.5 year olds) were more than twice as likely as old deer (e.g., 7.5 year olds) to survive the initial year following translocation. Based on our findings, wildlife managers that elect to translocate mule deer should not expect a difference in survival between early and late winter releases, but will likely see higher survival rates during the second year following translocation (compared to the first year) and higher survival rates for younger deer compared to older deer.

INTRODUCTION

Translocation of animals is an increasingly common strategy for managing wildlife populations. Typical goals of translocation include reducing population density in the source area, supplementing existing populations, reestablishing extirpated populations, introducing new populations, and increasing genetic diversity (Griffith et al. 1989, Baxter et al. 2008). Although there have been successes, translocation efforts do not always produce positive results. In a review of translocations from around the world, it was estimated that more than 25% of those involving mammals ended in failure (Wolf et al. 1996).

Reasons for translocation failure included movement of translocated individuals out of release areas, limited reproduction, and low genetic diversity due to founder effects (Mock et al. 2004, Dickens et al. 2009a). Recent evidence further suggests that translocation can alter stress physiology creating survival challenges for released individuals which can limit effectiveness of this management strategy (Dickens et al. 2009b). For some species, a positive relationship with the number of released individuals and translocation success has been observed (Griffith et al. 1989, Wolf et al. 1996, Singer et al. 2000). For others, the details associated with the release itself (e.g. hard versus soft release, time of year, etc.) are important predictors of success (e.g. Bright and Morris 1994). Likelihood of success of translocation efforts often varies across species, and therefore, there is a need for species-specific information.

Despite decades of intensive management in western North America, there is very little information on outcomes associated with translocation of mule deer (*Odocoileus hemionus*). This lack of data has led to questions and public controversy regarding the efficacy of translocation as a management strategy for this species. Wakeling (2003) provided data on two translocation efforts involving black-tailed deer and mule deer. Low annual survival at 15% (n = 13) for the initial year following translocation was observed in one area, whereas the other documented 42% survival (n = 33) over 450 days following translocation. More recently, 7-month survival rates for mule deer translocated from Texas to Mexico ranged between 57 and 84% depending on the year and type of release (Martinez-Garcia 2009). Both of the previous research efforts, however, were limited by small sample sizes or sporadic monitoring (often only during the first year) leading to confusion and uncertainty regarding the efficacy of translocation as a management strategy for mule deer. Low annual survival for ungulates is common during the first year following translocation, but often higher and more variable in year two following release.

Our objective was to thoroughly document the outcomes associated with translocation of mule deer. More specifically, we evaluated the survival of translocated mule deer in relation to timing of release (early versus late winter) and individual covariates such as body condition and age. Mule deer released in early winter (e.g., January) were expected to be in relatively good condition compared with deer released later in the winter (e.g., March). How these expected differences in condition would influence survival of translocated deer, however, was unclear. Deer released early in the winter would have more time to integrate with resident deer prior to spring migration, but may be more likely to leave release areas and wander when compared to deer released later in the winter that were in relatively poor condition. These competing ideas formed the basis of our investigation and we expected to observe differences survival between early and late winter releases. We further predicted that translocated mule deer would experience lower survival rates than resident deer during the first year following release. During the second year following release, however, we predicted survival rates for translocated deer would be higher than those observed in year one (sensu; Frair et al. 2007, McIntosh et al. 2014).

STUDY AREA

Translocated deer were captured along the Parowan front in southern Utah (12 S, 342233 E, 4191163 N), which is winter range for the Markagaunt Plateau (Fig. 1). The Markagaunt Plateau is approximately 91 km long (north to south) and 34 km wide (at its widest point). Elevations across this mountain range varied from 1762 to 3446 m. Mean maximum air temperatures during summer and winter months over the past century were 29.4° C and 6.6° C respectively, with average annual precipitation of 31.0 cm at 1862 m (Western Regional Climate Center). Mule deer in this area were thought to migrate across this elevation gradient seasonally using high-elevation areas in summer and low-elevation areas during winter. Habitat types at high-elevation areas included areas dominated by aspen (*Populus tremuloides*), bitterbrush (*Purshia tridentata*), curl leaf mountain mahogany (*Cercocarpus ledifolius*), and Gambel's oak (*Quercus gambelli*). The winter range along the Parowan front consisted of juniper (*Juniperus* sp.), pinion (*Pinus edulis*), and sagebrush (*Artemesia* sp.). Over the last decade, population estimates for the Parowan front deer herd have exceeded management objectives and the quality of the winter range was classified as being in poor to fair condition (UDWR 2006-2014;2013).

Translocated deer were released by the Utah Division of Wildlife Resources (UDWR) onto the Pahvant Mountain Range (approximately 144 km north of capture areas) in central Utah (Fig. 1). The Pahvant study area was chosen for release due to the following similarities with the Parowan capture area: both mountain ranges run north to south, migratory deer herds with similar west to east migrations across an elevation gradient, similar climates, and winter ranges bordered by Interstate 15 on the west and high-elevation mountains on the east. The Pahvant Mountain Range is approximately 54 km long (north to south) and 22 km wide (at its widest point). Elevations across this mountain range varied from 1520 – 3117 m. Mean high temperatures during the summer and winter months over the past century were 31.4° C and 5.7° C, respectively, with average annual precipitation of 38.1 cm at 1552 m (Western Regional Climate Center). The winter range along the foothills of the Pahvant Mountain Range was dominated by bitterbrush, cliffrose (*Purshia stansburiana*), Gambel's oak, juniper, curl leaf mountain mahogany, and sagebrush. Higher elevation areas were composed of mixed brush communities, aspen, and a variety of conifers (e.g., genus *Abies, Juniperus,* and *Pinus*). Unlike the Parowan front, the deer population on the Pahvant Range has consistently been below management objectives over the past decade and the release area was considered by UDWR biologists to consist of high-quality winter range (UDWR 2012). Potential predators of mule deer inhabiting both areas included black bears (*Ursus americanus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and mountain lions (*Puma concolor*).

METHODS

Capture, translocation, and monitoring

In January and March 2013, UDWR contracted with a private helicopter company to capture female mule deer via helicopter net-gunning (Krausman et al. 1985) along the Parowan front in southern Utah (Fig. 1). Given the lack of information on rates of capture myopathy associated with translocation of mule deer, UDWR biologists used 0.3 cc azaperone (ZooPharm®, 50mg/mL) and 0.6 cc midazolam (ZooPharm®, 50mg/mL) per individual at point of capture for the first 30 (of 51) deer captured in January. The remaining 21 deer captured in January were not given either of these drugs at point of capture or anytime during processing. Rates of capture myopathy were low and not different (*Z*-test of proportions; *Z* statistic = -0.26; $P = 0.80$) for deer that received azaperone and midazolam (3.33%) compared to deer that did not (4.76%). In addition, deer that received drugs in a nearby area on an unrelated project were reported to have challenges immediately following release (e.g., caught in fences, stuck in a mudhole, roadkill, etc.; Freeman et al., unpublished data). Consequently, UDWR biologists did not administer azaperone or midazolam to deer captured in March for release in late winter.

During handling, we weighed, estimated age (via tooth wear and eruption pattern; Severinghaus 1949, Robinette et al. 1957), measured body size (chest, hind foot length, neck girth), evaluated body condition (body condition score method; Cook et al. 2007), and determined pregnancy (via blood and transabdominal ultrasound; E.I. Medical Imaging portable ultrasound; Smith and Lindzey 1982). Biologists administered 3 cc banimine and 1.5 cc ivermectin to each individual deer and fitted them with a radio-collar (VHF or GPS) and unique ear tag. Each deer also had a rectal biopsy to test for chronic wasting disease (Thomsen et al. 2012). Following the handling process, UDWR biologists used stock trailers to transport deer to the Pahvant range (Fig. 1) where the majority of individuals were immediately released (hard release; average of 6.9 hours between capture and release; range 1.5 to 17.9 hours).

To serve as a reference group, resident deer in the Pahvant study area were also captured, radio-marked (VHF or GPS), and released at the site of capture prior to the translocation. Resident deer were fitted with a radio collar by the capture company and released immediately at point of capture. Prior to each capture and release, United States Department of Agriculture (USDA) Wildlife Services removed coyotes in and around release areas via helicopter and fixed-wing aircraft as part of ongoing efforts to increase mule deer populations in our study area.

Following release, we used radio telemetry from the ground (weekly) and fixed-wing aircraft (approximately monthly, n =19 different flights over 2 years) to locate and assess the status (alive or dead) of each radio-marked deer on the Pahvant Range. When a mortality signal was detected (triggered after 8 hours of inactivity), we located the carcass as soon as possible to determine cause of death by postmortem examination and sign (cached carcass, feces, puncture wounds, tracks, etc.) from the surrounding area (Rominger et al. 2004, Kilgo et al. 2012). When we found a carcass that showed no signs of predation or vehicle impact, we submitted the carcass to the Utah State University, Veterinary Diagnostics Laboratory for necropsy. We classified mortalities as predation, unknown, capture-related (capture myopathy and capture-related injuries), roadkill, poached, or other, which included diseases, such as cancer, not directly associated with capture.

Data Analysis

We used model selection and known-fate models within Program MARK (White and Burnham 1999) to estimate seasonal and annual survival for each group of mule deer (resident, January release, and March release) and evaluate support for covariates that included age, body mass, body condition, movement rate, and pregnancy. We formatted our encounter history by month and year beginning 1 January and ending 31 December for both 2013 and 2014. We used months as opposed to weeks because it simplified our modeling process, but still allowed us to incorporate seasonal variation into survival rates. Structuring our encounter history by year (i.e., year as a group) allowed us to graduate deer (in age) and obtain unique estimates of annual survival for resident and translocated deer in year 1 and year 2 following release. We evaluated relative model support using Akaike's Information Criterion (Akaike 1973) adjusted for small sample sizes (AIC_c) and then used model averaging to produce estimates of annual survival (Burnham and Anderson 2002). To evaluate differences across groups (e.g., resident versus translocated deer), we looked for overlap in confidence intervals associated with estimates of annual survival. To assess the influence of individual covariates, we examined confidence intervals surrounding β estimates.

We used a 3-stage, hierarchical approach to model selection. First, we identified the best model of time (seasonal and annual structure) while keeping survival for all groups equal. Our time models were based on month, season, year, and migration dates as well as time trends (linear and quadratic) following release. Our seasonal structure included 2, 3, and 4 season models based on spring, summer, fall, and winter as well as average migration dates. We defined spring as March–May, summer as June–August, fall as September–November, and winter as December–February. We determined migration dates based on when deer left either winter or summer range and did not return (sensu; Northrup et al. 2014). In the second stage of our modeling process, we added the grouping structure to supported models (i.e., ≥ 0.05 AIC_c weight) of time from step 1. Our groups included the following: resident (2013), January translocated deer (2013), March translocated deer (2013), resident deer (2014), and surviving January and March translocated deer from 2013 that were combined for 2014 to maintain adequate precision around estimates of survival. In our final step, we evaluated the influence of individual covariates (age, age^2, percent body fat, body mass, and pregnancy) to models with ≥ 0.05 AIC_c weight from step 2. Inclusion of age^2 allowed us to represent a potential asymptotic relationship with age. In step 3, we also evaluated the influence of movement patterns (from a sample of deer with GPS collars) on survival rates. We used Home Range Tools (Rodgers 2005) and ArcGIS® software (Environmental Systems Research Institute, Redlands, CA, USA) to estimate average monthly movement distances for this sample and evaluate any correlation between movement rates and survival. We evaluated the final list of supported models for evidence of uninformative parameters and used model averaging to avoid any potential bias (Arnold 2010).

RESULTS

In January and March 2013, UDWR biologists translocated 102 female mule deer (51 in January; 51 in March) from winter range near Parowan, Utah to winter range near Holden, Utah on the Pahvant Mountain Range (Fig. 1). Of those 102 deer, we marked 81 deer with VHF radio collars (41 in January, 40 in March) and 21 deer with GPS collars (10 in January, 11 in March). Estimated age of captured deer ranged from 1 to 9 ($\bar{x}$ = 3.9 years for January and 4.1 years for March, SE = 0.03 for both January and March). Percent body fat ranged from 3.9 – 16.3% and was higher in January 2013 compared to March 2013 as expected (Fig. 2). Of the 102 females captured for translocation, 91% (*n* = 93) were pregnant and none tested positive for chronic wasting disease. Fifty resident deer were captured and radio-marked in the Pahvant study area (41 VHF, 9 GPS) prior to the translocation in January 2013. An additional 20 resident deer (20 VHF) were captured during January 2014 in the Pahvant study area to bolster sample sizes for this reference group.

USDA removed 62 coyotes prior to the January 2013 translocation and 35 prior to the March 2013 release. Coyotes were also removed throughout the year on winter range, especially around livestock calving areas. A total of 221 coyotes were removed by wildlife services from the Pahvant winter range during 2013. Cougars and bears were managed under a statewide management plan. Sixteen cougars were harvested on the Pahvant during the 2013 season and 8 cougars were harvested during the 2014 season. Two bear permits were offered each year (2013 and 2014), but no bears were harvested during either year.

Our first stage of model selection resulted in 5 supported models of time with at least 0.05 AIC_c weight that were advanced to step 2. These models divided the year into 2, 3, and 4 seasons and accounted for 88% of the total AIC_c weight (Table 1). In stage 2, we added group (resident deer, January, and March releases) structure to supported models of time and identified 6 models with at least 5% AIC_c weight (Table 1). These models included three 2-season models (based on season, year, and group), two 4-season models, and one 3-season model. The two 4-

season models were defined by year and migration dates (winter, spring migration, summer, and fall migration). The 3-season model was also defined by year and migration dates with survival rates equal during winter and summer, but differing during the spring and summer migrations. Four of the 6 models included a 3-group structure (residents [2013 and 2014 combined], 2013 transplants combined for January and March releases, and transplants in year 2 [2014]). The other 2 models each had 4 groups (residents [2013 and 2014 combined], 2013 January transplants, 2013 March transplants, and transplants in year 2 [2014] or 2013 residents, 2013 transplants, 2014 residents, and 2014 transplants).

In our final stage, we added individual covariates to our best models from stage 2. This stage resulted in 6 models (2, 3, and 4 seasons) with an AIC_c weight ≥ 5% that accounted for 73% of the total AIC_c weight. The top model was a 2-season model that combined spring with summer and fall with winter periods. This model had 4 separate groups (residents [2013 and 2014 combined], 2013 January transplants, 2013 March transplants, and surviving transplants in 2014) and included age and age^2 as individual covariates (Table 2). Age or age^2 occurred in all models with $w_i > 0.05$ (Table 2). We found little support for the influence of body condition, pregnancy, or body mass on survival as models with these covariates received < 2% of AIC_c weight. Similarly, we found little to no support for movement rates influencing survival because the most supported model with this variable received < 0.01% of AIC_c weight.

Translocated deer mortalities were assigned to causes including capture-related, other, poaching, predation, roadkill, and unknown. We experienced relatively low rates of capture myopathy and capture-related deaths. Four of 102 (3.9%) deer captured and translocated during 2013 died of capture-related causes. All of these deer died within 3 days of release and 2 of the 4 deaths were attributed to injuries (e.g., broken bones) sustained during capture. Two of 70

(2.9%) resident deer died of capture-related causes. Predation accounted for the majority of mortalities (*n* = 54) for translocated deer (50%) followed by unknown (28%), other (8%), poached (8%), and roadkill (6%). Predation was also the highest cause of mortality (*n* = 21 deaths) for resident deer (63%) followed by unknown (32%) and other (5%).

Survival rates were similar between resident deer and translocated deer during the winter months. The majority of mortalities occurred during summer months, peaking during May and June (Fig. 4). Overall annual survival of resident deer during 2013 was estimated at 0.83 (95% CI = 0.72 – 0.90). Annual survival of deer transplanted during January 2013 (0.51; 95% CI = 0.40 – 0.63) was significantly lower than resident deer and was not different from March 2013 translocated deer (0.53; 95% CI = 0.40 – 0.66) for March transplants. During their second year following release, survival of translocated deer was higher (0.85; 95% CI = 0.71 – 0.93) than during the first year and not different from that of resident deer in 2014 (0.80; 95% CI = 0.69 – 0.88; Fig. 3).

Age of deer influenced survival of translocated animals and age or age^2 occurred in all of the top models (Table 2). The β estimate for age was negative in the top model (β = -0.73), although the 95% CI around this estimate slightly overlapped zero (-1.61-0.14). The β estimate for age^2 in the top model was positive with the 95% CI also slightly overlapping zero (β = 0.06, 95% CI = -0.03-0.14). Estimates of annual survival for 2-year old transplants during year 1 following release were approximately double (0.71; 95% CI = 0.52 – 0.84) those of 7-year olds (0.35; 95% CI = 0.17 – 0.58) (Fig. 5).

DISCUSSION

We had very few capture-related deaths and documented low mortality rates immediately following release. Our observed 3.9% rate of mortalities associated with capture was similar to that observed with resident deer released at point of capture (2.9%) as well as rates common in traditional capture, radio-marking, and release projects that do not involve translocation (general range 3-5%; Quinn et al. 2012, Lendrum et al. 2014). This low rate was observed despite UDWR electing not to dose the majority of deer with azaperone (ZooPharm®, 50mg/mL) or midazolam (ZooPharm®, 50mg/mL). The majority of mortalities we observed for translocated deer occurred during summer (May-September) and were similar to causes reported in other areas for mule deer (Beringer et al. 2002, Rominger et al. 2004, Frair et al. 2007, McIntosh et al. 2014).

Survival rates for translocated mule deer, during the first year post release, were lower than rates commonly observed for animals not translocated. Data from Colorado, Idaho, and Montana provided a mean annual survival estimate of 0.85 (SE = 0.01) for adult female mule deer (Unsworth et al. 1999) which is higher than our observed rates of 0.51 and 0.53 for January and March transplants, respectively. Similarly, survival rates for translocated mule deer in year one (0.51 and 0.53) were lower than those of resident deer (0.83). These lower rates during the initial year following release, however, were similar to those reported for black-tailed and mule deer translocated in other areas (O'Bryan and McCullough 1985, Martinez-Garcia 2009). During the second year, survival rates for translocated mule deer were higher and not different from resident deer (Fig. 3) suggesting that survival challenges related to translocation were transitory and dissipated by the end of the initial year. This finding supports our prediction that translocated deer would experience lower survival rates than resident deer during the first year after release, but higher rates of survival (when compared to year 1) during the second year. While low survival of ungulates is a common observance following translocation (Beringer et al. 2002, Frair et al. 2007), there are relatively few translocation studies that have documented survival for multiple years following release. Most studies that have documented survival for multiple years show an increase in survival of transplants after the first year following release (Haydon et al. 2008, McIntosh et al. 2014). Documenting survival of translocated animals over multiple years is critical when considering the success of relocations.

We found no difference in annual survival rates for deer translocated in early versus late winter. Deer released in early winter (January) were in better condition at time of release than deer released later in winter, but these differences did not influence survival rates. Moreover, we did not detect a relationship between survival and body condition. These results did not support our hypothesis of differences in survival between early and late winter as survival rates were not different for deer released at either time. This finding suggests that managers could transplant mule deer throughout the winter as survival rates were not related to the timing of release (early or late winter). Nonetheless, we note that winter conditions during our study years were relatively mild as temperatures were above the long-term mean and precipitation below the long-term average (Western Regional Climate Center). Transplanting mule deer during a severe winter may yield different results and perhaps more of a difference between animals released early and late in the winter.

We found strong support for age as a predictor of survival, with younger animals more likely to survive the initial year following translocation than older animals (Fig. 5). Two year old deer, for example, were approximately 2 times more likely to survive the initial year post release than 7 year old deer. Jones and Witham (1990) found that translocated white-tailed deer fawns had point estimates of annual survival that were slightly higher, although not significantly so, than translocated adults while Hawkins and Montgomery (1969) and Parker et al. (2008) found no difference in survival based on age of translocated white-tailed deer. Thus, our results are unique in this respect with much higher survival for younger animals. Younger animals may have more plasticity in their behavior and may have responded to novel environments better than older animals in our study. The specific mechanisms explaining this result, however, are unclear.

MANAGEMENT IMPLICATIONS

Our results suggest that translocation is a strategy that could be used to address management objectives for mule deer populations. We experienced low rates of capture myopathy, even without the use of sedative drugs for the majority of captured animals. We observed survival rates for translocated mule deer that were lower for transplants compared with resident deer during the first year following translocation. During the second year after translocation, however, translocated mule deer had much higher survival rates that were not different from resident deer suggesting challenges to survival were transitory and short-lived. Moreover, we found a strong relationship with age where young deer survived the initial year following translocation much better than older deer. Given the difference we observed between survival in year one compared to year two, we recommend that translocated animals be monitored for at least 2 years following release. Results from multiple years provide managers with critical data when considering the relative value of translocation as a management strategy for mule deer. In our study, there was no difference in survival rates for deer translocated in January or March. Although winters during our study period were relatively mild, this result suggests managers can use translocation throughout the winter months to address management objectives.

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Table 1-1. Akaike's Information Criterion selected models of survival (s) for resident and translocated mule deer (Odocoileus hemionus) on the Pahvant Range in central, Utah, USA, during 2013 and 2014. We report AIC_c, change in AIC_c (ΔAIC_c), AIC_c weight (w_i), number of parameters (K), and deviance (Dev, defined as -2 x log likelihood) for all time models (stage 1, top half of table) and time plus grouping (residents, January and March releases) structure (stage 2, bottom half of table) with $w_i \geq 0.05$.

Model	AIC_c	ΔAIC_c	w_i	K	Dev
Time models					
{S(2 seasons [spring/summer vs fall/winter])}	620.78	0.00	0.57	2	616.77
{S(3 seasons [spring/summer migration + year])}	624.33	3.55	0.10	3	618.32
{S(4 seasons [winter, spring, summer, fall])}	624.58	3.80	0.09	4	616.56
{S(4 seasons [winter, spring migration, summer, fall migration])}	625.34	4.57	0.06	4	617.32
{S(2 seasons [spring/summer/fall vs winter])}	625.37	4.60	0.06	2	621.36
Time models with groups					
{S(2 seasons [spring/summer vs fall/winter] + 3 groups[a])}	603.60	0.00	0.19	6	591.57
{S(2 seasons [spring/summer vs fall/winter] + 4 groups[b])}	603.63	0.03	0.19	8	587.57
{S(4 seasons [winter/spring, spring migration, summer, fall migration] + 4 groups[c])}	604.03	0.43	0.15	16	571.80
{S(4 seasons [winter/spring, spring migration, summer, fall migration]+ 3 groups[a])}	604.19	0.58	0.14	12	580.06
{S(2 seasons [spring/summer/fall vs winter] + 3 groups[a])}	606.04	2.44	0.06	6	594.01
{S(3 seasons [winter/spring/summer/fall, spring migration, fall migration]+ 3 groups[a])}	606.11	2.50	0.05	9	588.03

a) Grouping structure: 1) 2013 and 2014 resident deer, 2) 2013 translocated deer, and 3) all surviving translocated deer (from 2013 transplant) in 2014

b) Grouping structure: 1) 2013 and 2014 resident deer, 2) 2013 January translocated deer, 3) 2013 March translocated deer, 4) all surviving translocated deer (from 2013 transplant) in 2014

c) Grouping structure: 1) 2013 resident deer, 2) 2014 resident deer, 3) 2013 translocated deer, 4) all surviving translocated deer (from 2013 transplant) in 2014

Table 1-2. Akaike's Information Criterion selected models of survival (s) for resident and translocated mule deer (Odocoileus hemionus) on the Pahvant Range in central, Utah, USA, during 2013 and 2014. We report AIC_c, change in AIC_c (ΔAIC_c), AIC_c weight (w_i), number of parameters (K), and deviance (Dev, defined as -2 x log likelihood) for all stage 3 models with $w_i \geq 0.05$.

Model	AIC_c	ΔAIC_c	w_i	K	Dev
{S(2seasons [spring/summer vs fall/winter] + group[a] + age + age^2)}	592.34	0.00	0.17	12	568.21
{S(2seasons [spring/summer vs fall/winter] + group[b] + age + age^2)}	592.40	0.05	0.16	10	572.30
{S(4seasons [winter/spring, spring migration, summer, fall migration] + group[c] + age + age^2)}	592.72	0.38	0.14	20	552.37
{S(4seasons [winter/spring, spring migration, summer, fall migration] + group[b] + age + age^2)}	592.85	0.51	0.13	16	560.62
{S(2seasons [spring/summer/fall vs winter] + group[b] + age + age^2)}	594.35	2.01	0.06	10	574.26
{S(3seasons [winter,spring,summer,fall, spring migration, fall migration] + group[b] + age + age^2)}	594.51	2.16	0.06	13	568.36

a) Grouping structure: 1) 2013 and 2014 resident deer, 2) 2013 January translocated deer, 3) 2013 March translocated deer, 4) all surviving translocated deer (from 2013 transplant) in 2014

b) Grouping structure: 1) 2013 and 2014 resident deer, 2) 2013 translocated deer, and 3) all surviving translocated deer (from 2013 transplant) in 2014

c) Grouping structure: 1) 2013 resident deer, 2) 2014 resident deer, 3) 2013 translocated deer, 4) all surviving translocated deer (from 2013 transplant) in 2014

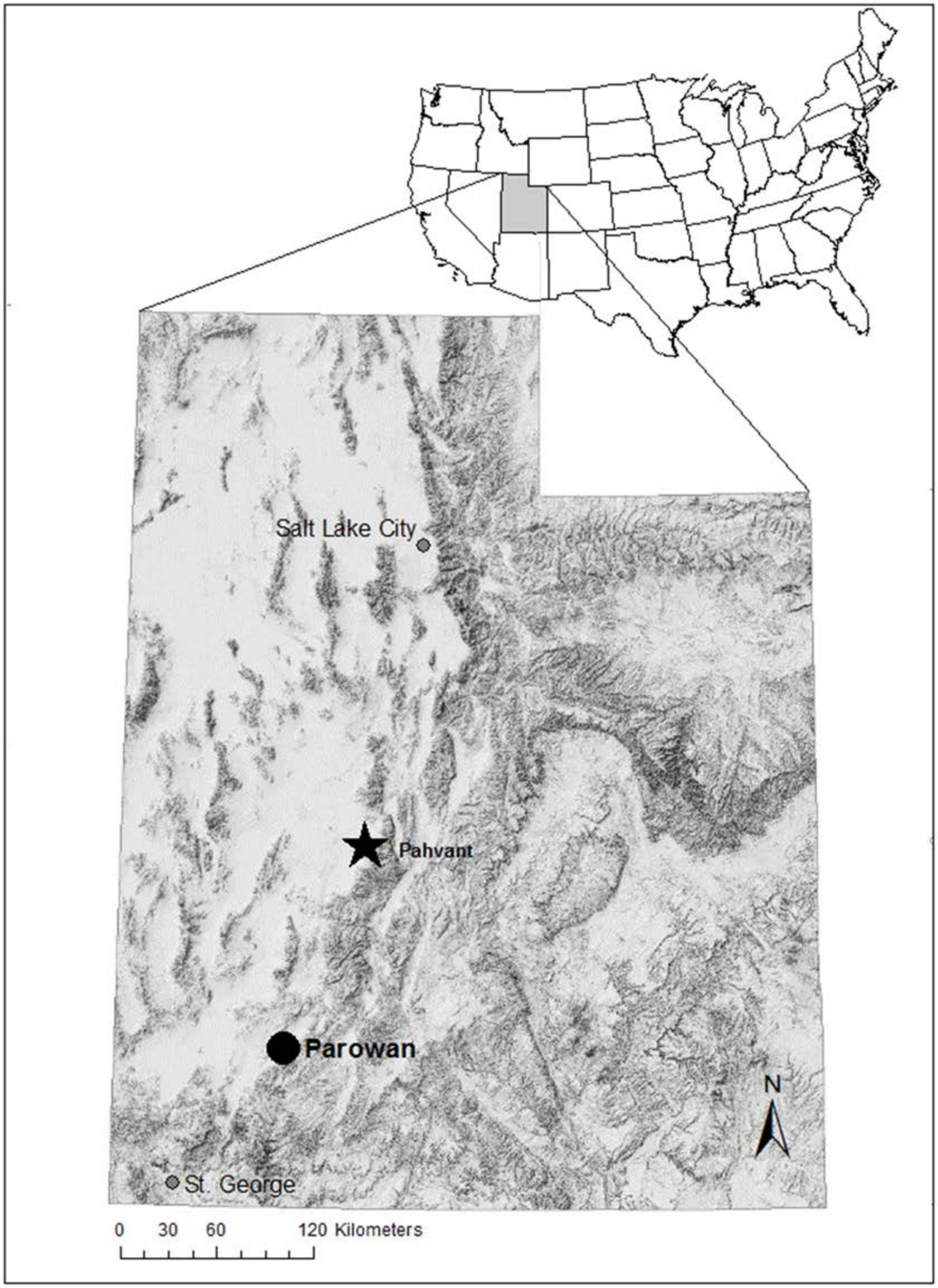

Figure 1-1. Map of Utah, USA showing our study area where the Utah Division of Wildlife Resources (UDWR) captured (circle) and released (star) mule deer (Odocoileus hemionus) in January and March of 2013.

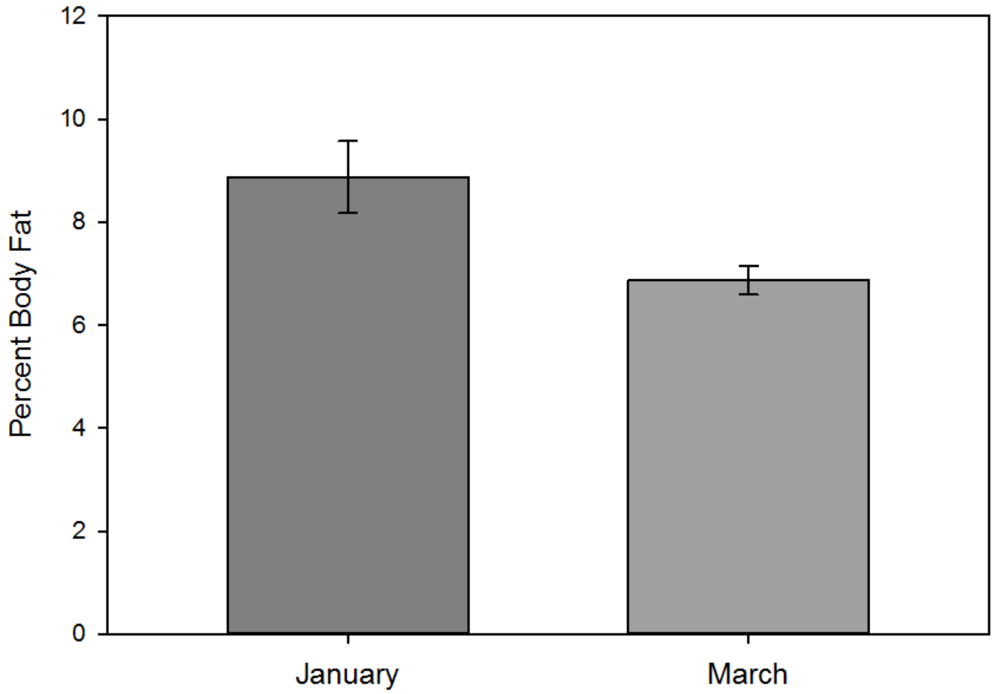

Figure 1-2. Percent body fat (± 95% CI) of translocated mule deer (Odocoileus hemionus) that were captured in southern Utah, USA during January and March of 2013 prior to translocation. Percent body fat was calculated using the body condition score method (Cook et al. 2007).

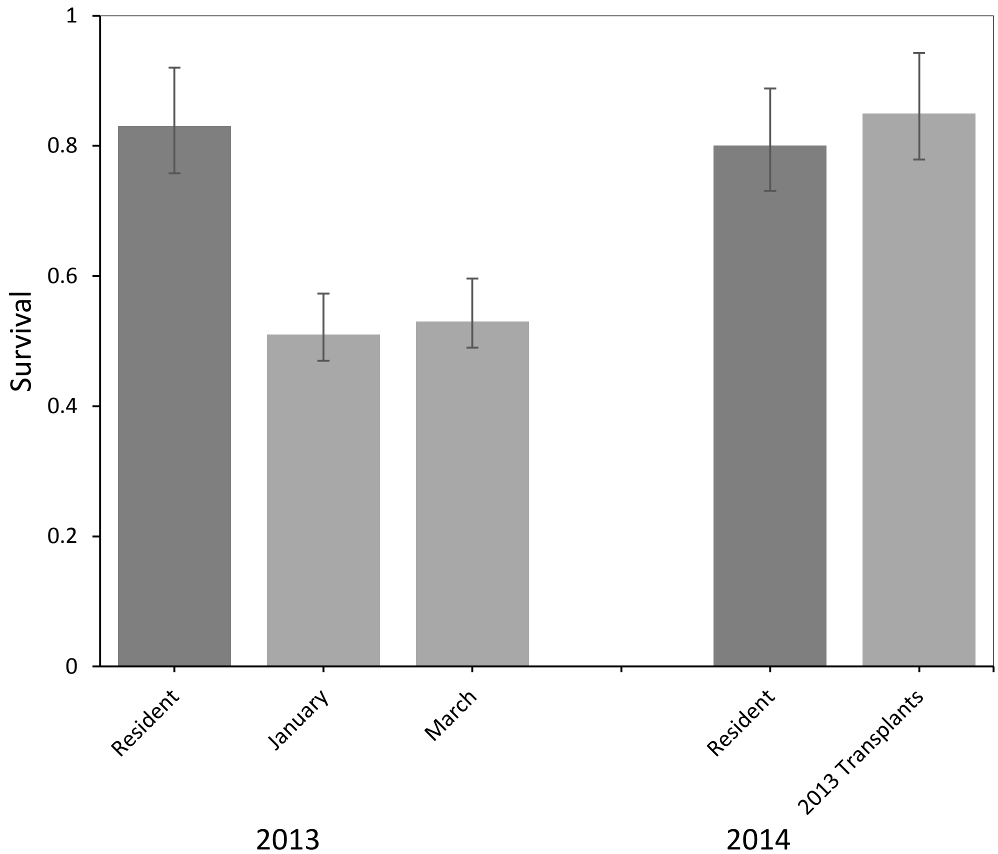

Figure 1-3. Annual survival rates (± 95% CI) of resident (reference group) and translocated mule deer (Odocoileus hemionus), released in January of 2013 and March of 2013, on the Pahvant Range in southern Utah, USA during the initial year following release (2013) and year two after release (2014). Note that the 2013 transplant bar includes deer from both January and March given we found no support for a difference in survival between early and late releases.

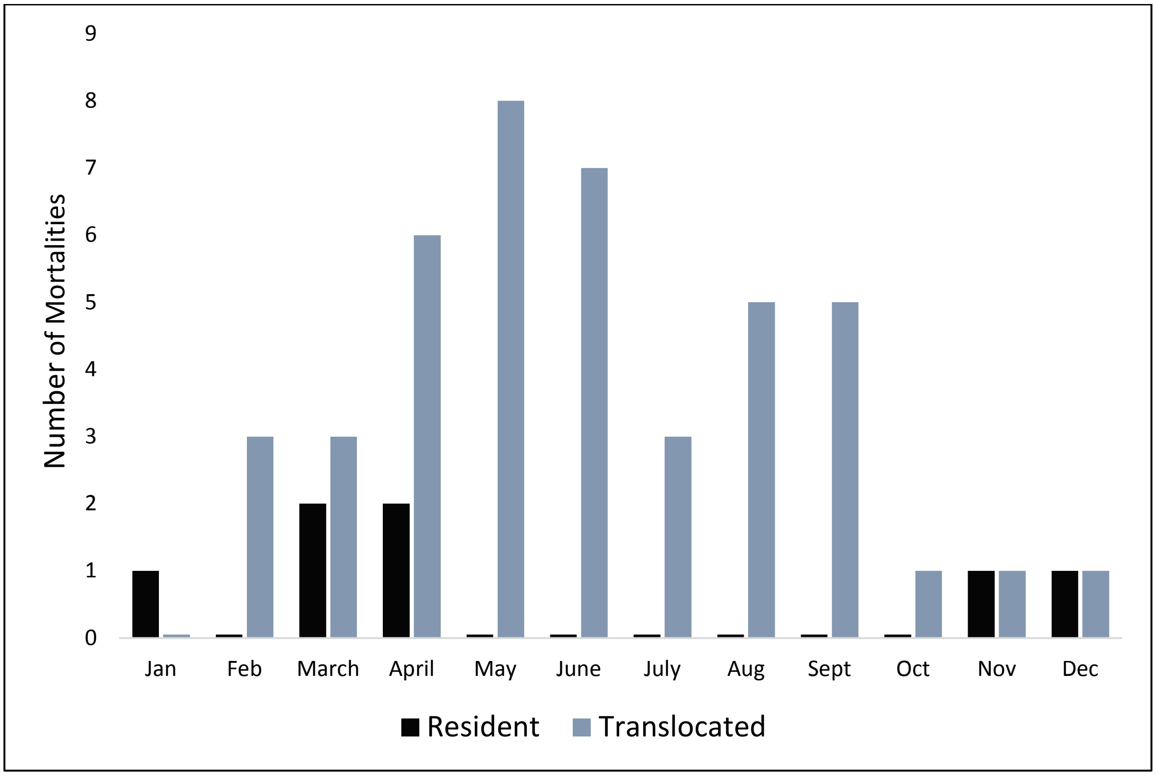

Figure 1-4. Number of mortalities by month for resident and translocated mule deer during the first year (2013) following release in January or March on the Pahvant Range in central Utah, USA.

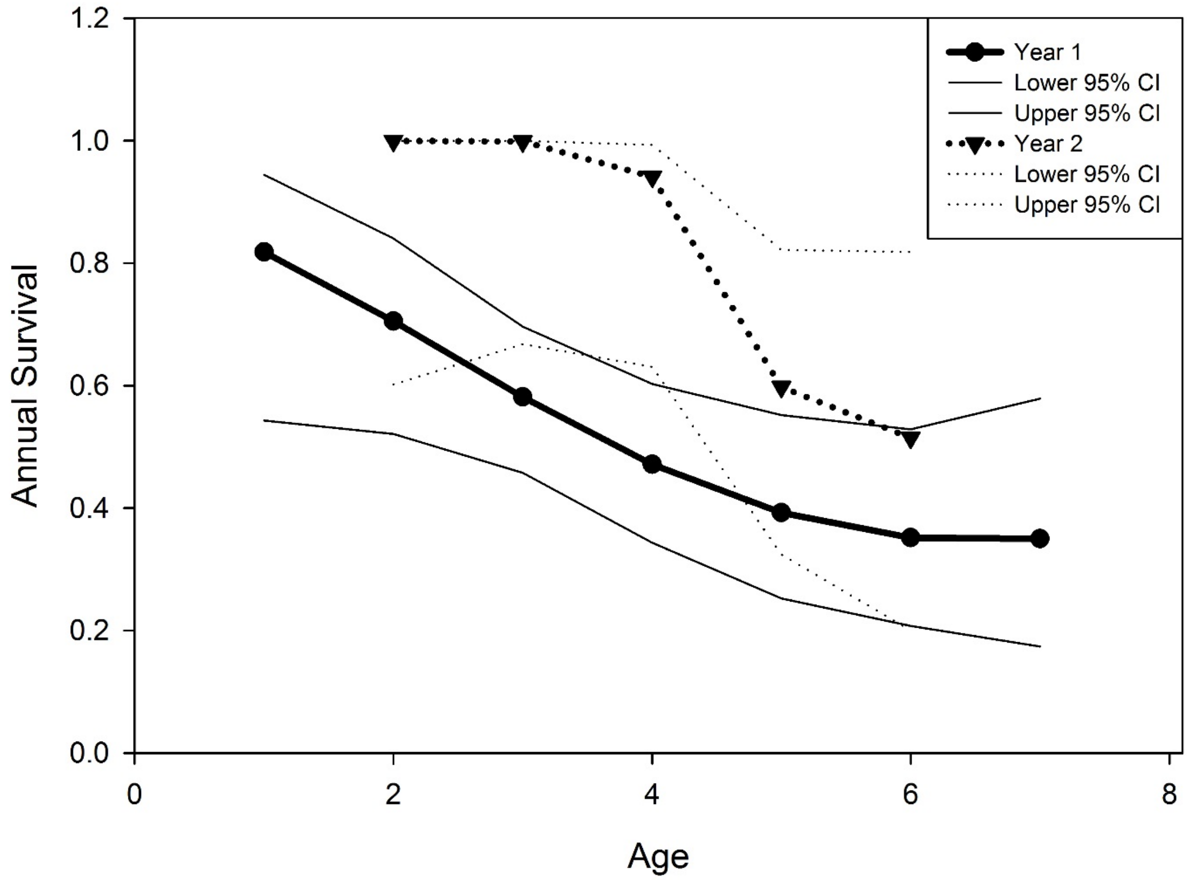

Figure 1-5. Annual survival of translocated mule deer (Odocoileus hemionus) in relation to estimated age (tooth eruption and tooth wear; Severinghaus 1949, Robinette et al. 1957) during the first two years (2013, year 1; 2014, year 2) following release on the Pahvant Range in central Utah, USA.

CHAPTER 2

Movements and Space Use of Translocated Mule Deer

ABSTRACT

Translocation of wildlife has become common practice for wildlife managers charged with management of animals on increasingly modified landscapes. Since the 19th century, translocations of ungulates have occurred around the world with varying results. Mule deer (*Odocoileus hemionus*) are a species of great interest to the public in western North America and have been translocated several times. Nonetheless, very little has been done to document the outcome of those translocations. Our objectives were to 1) evaluate the movement, site fidelity, and space use of translocated mule deer in comparison with resident deer and 2) determine the influence of early versus late winter translocation on these life history attributes. We assisted the Utah Division of Wildlife Resources in the capture and translocation of 102 mule deer from winter range near Parowan, UT, to winter range near Holden, UT, (approximately 144 kilometers north of the capture location) during 2013. We fitted each deer with a radio transmitter (n = 102; 21 GPS collars, 81 VHF collars) prior to release and monitored them weekly throughout 2013 and 2014. As a reference group, we also captured and marked 70 resident deer (9 GPS collars, 61 VHF collars) near Holden, UT. We used Home Range Tools with ArcGIS to estimate movement distances and an ad hoc approach within HoRAE to select the smoothing parameter (h) associated with kernel density estimates for seasonal and annual home ranges. Mean distance moved for translocated deer ($\bar{x}$ = 655.7 km; range 389.3 – 844.2 km) was higher than resident deer ($\bar{x}$ = 484.6 km; range 308.6 -698.8 km) during 2013 ($P < 0.01$). However, mean distance moved for translocated deer ($\bar{x}$ = 333.2 km; range 216.2 – 540.3 km) was not different from that

of resident deer ($\bar{x}$ = 331.8 km; range 246.8 – 481.8 km) during 2014 (P = 0.98). Mean size of annual home range (95% kernel density estimate) for translocated deer during 2013 ($\bar{x}$ = 572.2 km^2; range 182.9 – 980.1 km^2) was larger (P < 0.01) than that of resident deer ($\bar{x}$ = 115.0 km^2; range 22.9 – 484.3 km^2). In 2014, size of annual home ranges for translocated deer decreased ($\bar{x}$ = 318.2 km^2; range 78.3 – 762.1 km^2), but was not different from year one (P = 0.06). Mean size of annual home range for translocated deer during their second year (2014) following release was larger, but not different, than that of resident deer ($\bar{x}$ = 134.1 km^2; range 18.7 – 545.8 km^2) during 2014 (P = 0.07). Translocated deer demonstrated high site fidelity to their release areas. Seventy-five percent of surviving deer returned during the fall migration to within 7 km of release sites. Our results suggest that initial home ranges and movements made by translocated deer can be expected to decrease over time. Furthermore, the high site fidelity we observed suggests that translocation is a strategy managers could use to establish or augment populations of mule deer on winter range.

INTRODUCTION

Location data from marked animals can be used to infer ecological processes, test hypotheses about movement and space-use patterns, and identify critical habitats for conservation. A sudden and sustained drop in movement rates, for example, was indicative of parturition in ungulates such as woodland caribou (*Rangifer tarandus*) and moose (*Alces alces*) (Poole et al. 2007, DeMars et al. 2013). Similarly, movement patterns associated with carnivores identified the timing and location of predation events (Frohlich et al. 2012, Davidson et al. 2013, Svoboda et al. 2013). Recently, spatial and temporal information from marked animals related to timing of movement and habitat use during migration has helped identify important areas for conservation (Sawyer et al. 2005, Berger et al. 2006, Lendrum et al. 2013, Tape and Gustine 2014).

The timing and distances moved by animals during migration and dispersal can be influenced by environmental conditions, individual variability, and anthropogenic disturbance (Monteith et al. 2011, Debeffe et al. 2012, Lendrum et al. 2013, Sawyer et al. 2013). Movement potential, for example, is often related to nutritional status (often measured as body condition), which generally varies between individuals and across populations. Animals in relatively good body condition often show differences in movement (direction, distance, and timing) when compared to animals in relatively poor condition (Garrott et al. 1987, Lowe et al. 2006, Monteith et al. 2011, Lendrum et al. 2013, Walter et al. 2014). Body condition is also associated with the timing of migration for some species. Female mule deer (*Odocoileus hemionus*) in better nutritional condition, for example, arrived on winter range later and departed winter range earlier than females in relatively poor condition (Monteith et al. 2011, Lendrum et al. 2013). Similarly spring migration was delayed following a severe winter, giving deer more time to consume forage prior to migrating (Garrott et al. 1987). For birds, there is an optimal migration hypothesis which suggests that animal migration is a function of fuel loads (body reserves), optimal timing of migration, optimal use of winds, and potential distance moved (Hedenstrom 2003). This hypothesis predicts that animals in better condition migrate or disperse earlier and travel farther than animals in relatively poor condition. Knowledge of the underlying ecological processes associated with movement dynamics including the role of nutritional status could be used to inform wildlife management and conservation activities.

Erratic or extreme movement of translocated animals, for example, has been identified as one of the reasons nearly 25% of all translocations involving mammals ended in failure (Wolf et al. 1996). Generally, as dispersal and movement distances increase, mortality risk also increases (Debeffe et al. 2012). This relationship between movement and mortality risk can be particularly strong for animals translocated into novel and unfamiliar habitats. Reintroduced elk (*Cervus canadensis*), for example, dispersed 2 to 142 km away from release areas and experienced higher mortality rates the further they moved from the release site (Haydon et al. 2008, Yott et al. 2011). Furthermore, success of translocation or reintroduction efforts often hinges on fidelity of released animals to release areas (Rogers 1988, Ryckman et al. 2010, Yott et al. 2011). Consequently, the degree that animals disperse away from the release is one of the best predictors of successful translocations (Yott et al. 2011).

Our goal was to evaluate the movement patterns, site fidelity, and space use of translocated mule deer. Specific objectives included 1) assessing the influence of body condition on movement and space use of translocated mule deer, 2) comparing differences in movement, site fidelity, and space use between resident and translocated mule deer, and 3) determining the influence of early and late winter releases on movement and space use of translocated deer. We predicted that animals in relatively good condition (released earlier in the winter) would travel farther during the months following release compared to animals released later in the winter (relatively poor condition). We further predicted that translocated deer would have relatively large home range sizes during their first year following release due to an exploration and acclimation phase (Beringer et al. 2002, Parker et al. 2008). During their second year, however, we predicted that size of home ranges for translocated deer would be smaller than those observed in year 1 and perhaps not different from resident deer (Jones et al. 1997). Because success of translocations is improved when released animals demonstrate high site fidelity, these data will help managers interested in the conservation of mule deer judge the relative value of translocation as a management strategy for this species.

STUDY AREA

Translocated mule deer were captured on winter range along the Parowan front in southern Utah. The Parowan front is on the west side of the Markagaunt Plateau (Fig. 1). The Markagaunt Plateau is approximately 91 km long (north to south) and 34 km wide (at its widest point). Elevations across this mountain range varied from 1762-3446 m. Mean high air temperatures during the summer and winter months over the past century were 29.4° C and 6.6° C respectively, with average annual precipitation of 31.0 cm at low elevation (1862 m) areas (Western Regional Climate Center). Mule deer in this area migrated across this elevation gradient seasonally using high elevation areas in summer and low elevation areas during winter (J. Nicholes, personal communication). Habitat types varied across higher elevation areas used by mule deer during summer and included areas dominated by aspen (*Populus tremuloides*), bitterbrush (*Purshia tridentata*), curl leaf mountain mahogany (*Cercocarpus ledifolius*), and Gambel's oak (*Quercus gambelli*). The winter range along the Parowan front was dominated by juniper (*Juniperus* sp.), pinion (*Pinus edulis*), and sagebrush (*Artemisia* sp.). Over the last decade, population estimates for the Parowan front deer herd have exceeded management objectives and the quality of the winter range was classified as being in poor to fair condition (UDWR 2006-2014;2013).

Translocated deer were released by the Utah Division of Wildlife Resources (UDWR) onto the Pahvant Mountain Range (approximately 144 km north of capture areas) in central Utah (Fig. 1). The Pahvant study area was chosen for release due to topographic similarities with the

Parowan capture areas, better quality winter range, and a deer herd that was persistently below objective during the years prior to this study (UDWR 2006-2014). Both mountain ranges are oriented north to south, climates are similar, deer herds are migratory, and winter ranges are bordered by Interstate 15 on the west and high elevation mountains on the east. The Pahvant Mountain Range is approximately 54 km long (north to south) and 22 km wide (at its widest point). Elevations across this mountain range varied from 1520 – 3117 m. Mean high temperatures during summer and winter months over the past century were 31.4° C and 5.7° C, respectively, with average annual precipitation of 38.1 cm at low elevation (1552 m) areas (Western Regional Climate Center). The winter range along the foothills of the Pahvant Mountain Range was dominated by bitterbrush, cliffrose (*Purshia stansburiana*), Gambel's oak, juniper, curl leaf mountain mahogany, and sagebrush. Higher elevation areas used by mule deer during summer were composed of mixed brush communities, aspen, and a variety of conifers (e.g., genus *Abies, Juniperus,* and *Pinus*).

METHODS

Capture, translocation, and monitoring

In January and March 2013, the UDWR contracted with a private helicopter company to capture female mule deer via helicopter net-gunning (Krausman et al. 1985) at 3 different staging areas along the Parowan front in southern Utah (Fig. 1). Given the lack of information on rates of capture myopathy associated with translocation of mule deer, UDWR used 0.3 cc azaperone (ZooPharm®, 50mg/mL) and 0.6 cc midazolam (ZooPharm®, 50mg/mL) per individual at point of capture for the first 30 (of 51) deer captured in January. The remaining 21 deer captured in January were not given either of these drugs at point of capture or anytime during processing.

Rates of mortality associated with capture (and transport for translocated animals) were low and not different (*Z*-test of proportions; *Z* statistic = -0.26; $P = 0.80$) for deer that received azaperone and midazolam (3.33%) compared with deer that did not (4.76%). In addition, deer that received drugs in a nearby area were reported to have challenges immediately following release (e.g., caught in fences, stuck in a mudhole, roadkill, etc.) (Freeman et al., unpublished data). Consequently, UDWR did not administer azaperone or midazolam to deer captured in March for release in late winter.

During handling, we weighed, estimated age (via tooth wear and eruption pattern; Severinghaus 1949, Robinette et al. 1957), measured body size (hind foot length, chest and neck girth), evaluated body condition (body condition score method; Cook et al. 2007), and determined pregnancy (via transabdominal ultrasound; E.I. Medical Imaging portable ultrasound; Smith and Lindzey 1982). Biologists administered 3 cc banimine and 1.5 cc ivermectin to each individual deer captured in both January and March and fitted them with a radio-collar (VHF or GPS) and unique ear tag. Each deer also had a rectal biopsy to test for chronic wasting disease (Thomsen et al. 2012) and we collected blood samples to verify pregnancy. Following the handling process, UDWR biologists used stock trailers to transport deer to the release area (Pahvant Range; Fig. 1) where the majority of individuals were immediately released (hard release; average of 6.9 hours between capture and release; range 1.5 hours to 17.9 hours).

To serve as a reference group, resident deer in the Pahvant study area were also captured, radio-marked (VHF or GPS), and released prior to the translocation of mule deer from the Parowan Front. Resident deer were fitted with a radio by the capture company and released immediately at point of capture. Following release, we used radio telemetry from the ground (weekly) and fixed-wing aircraft (n =19 different flights over 2 years) to identify the general location and assess the status (alive or dead) of each radio-marked deer throughout the subsequent year.

To provide additional information on the health and status of translocated mule deer, we recaptured animals one year following release and assessed body condition and subcutaneous fat using the same procedures associated with the initial 2013 captures. We also captured resident deer in the Pahvant study area during January of 2014 and collected the same information. These captures during the second year allowed us to evaluate body condition one year following release and make comparisons from year to year and between resident and translocated deer.

Data Analysis

We programmed GPS collars to acquire a fix every 1, 2, or 7 hours. The frequency of fixed locations was set for 1 hour during the first month following release and for 2 hours during the month of June to capture changes in movement patterns related to parturition. Fixes were attempted every 7 hours for all other months of the study. We used GPS locations to estimate annual and seasonal movements as well as home range sizes. We screened GPS locations for accuracy prior to analysis by visual observation for unrealistic movements and retained all 3D fixes or 2D fixes with a positional dilution of precision (PDOP) <10 (Lendrum et al. 2012, Lendrum et al. 2013, Northrup et al. 2014). Additionally, we randomly selected 3 points per day from the months with fixes set for every 1 or 2 hours. Doing so allowed us to remove possible bias when calculating movement distances and made the number of fixes during those months similar to the number of fixes throughout the study.

For movement analysis, we used GPS data points to calculate straight-line distances between consecutive locations (Long et al. 2013). Using the calculated distances, we then used a mixed-effects ANOVA with a random intercept for each deer to compare annual movement distances across groups (resident, January, and March translocations) and years (2013, initial year following release; 2014, second year post translocation). To estimate home range sizes, we used a 95% kernel density estimator (Worton 1989). Kernel-based methods use a utilization distribution and have the potential to accurately estimate home range sizes of any shape, given that the smoothing parameter is selected properly (Seaman and Powell 1996). To minimize under smoothing or over smoothing of the estimated home ranges, we used an ad hoc (*h_ad hoc*) approach to select the smoothing parameter (Kie et al. 1996, Schuler et al. 2014). We determined migration dates based on when deer left winter or summer range on a trajectory path and did not return (sensu; Garrott et al. 1987, Lendrum et al. 2014, Northrup et al. 2014) and then used these dates to identify summer and winter periods. We then tested for differences in annual home range sizes between groups (resident, early and late translocated) and across years using a mixed-effects ANOVA with random intercept for each deer. We tested for differences in home range sizes of translocated deer between their first and second year following release using a matched pairs t-test. To test for differences in seasonal home range sizes between groups, we used a Mann-Whitney *U* test. We estimated site fidelity as the number of individuals that remained at or returned to the west side of the Pahvant Mountain Range and within 30, 15, and 7 km of release areas 1 year after translocation (sensu; White and Garrott 1990). We set alpha equal to 0.05 for all statistical tests and made the appropriate adjustments where needed to keep the family-wise error rate at this level. We used Program R (R Core Team 2016).

RESULTS

In January and March 2013, UDWR biologists translocated 102 female mule deer (51 in January; 51 in March) from winter range near Parowan, Utah, to winter range near Holden, Utah, on the Pahvant Mountain Range (Fig. 1). We marked 81 deer with VHF radio collars (41 in

January, 40 in March) and 21 deer with GPS collars (10 in January, 11 in March). Estimated age of captured deer ranged from 1 to 9 ($\bar{x}$ = 3.9 years for January and 4.1 years for March, SE = 0.03 for both release groups). Percent body fat ranged from 3.9 – 16.3% and was higher in January of 2013 compared to March of 2013, as anticipated (Fig. 2). Of the 102 females captured for translocation, 91% (n = 93) were pregnant and none tested positive for chronic wasting disease. Prior to capturing deer for translocation, UDWR via a private helicopter capture company radio-marked 50 resident deer in the Pahvant study area (41 VHF, 9 GPS).

Annual distances moved varied between groups (Table 1). Annual distances moved for deer translocated in January 2013 ranged from 517.8 – 844.2 km. Annual distances moved for March 2013 translocated deer ranged from 389.4 – 793.4 km. Timing of release (January or March) did not influence distances moved (P = 0.36). There was, however, a difference in annual distance moved between resident deer ($\bar{x}$ = 484.6 km; range 308.6 – 698.8 km) and translocated deer ($\bar{x}$ = 655.7 km; range 389.3 – 844.2 km; (P < 0.01) during the first year (2013) following release. There was no difference in annual distance moved between resident deer ($\bar{x}$ = 331.8 km; range 246.8 – 481.8 km) and translocated deer ($\bar{x}$ = 374.1 km; range 216.2 – 540.3 km) during the second year (2014) after translocation (P = 0.98). Analysis of average monthly distances showed similarity during the fall and winter months, but differences in movement for translocated mule deer (compared to resident deer) during the spring migration and summer months (Fig. 4).

Annual home range sizes of translocated deer were larger (P < 0.01) than annual home range sizes of resident deer (Table 1). The difference in annual home range sizes was largely driven by summer movements of translocated mule deer. These large summer movements resulted in estimates of annual home range that were nearly 5 times larger for translocated deer

($\bar{x}$ = 572.2 km^2 ; range 182.9 – 980.1 km^2) compared to resident deer ($\bar{x}$ = 115.0 km^2; range 22.9 – 484.3 km^2). During the second year following release (2014) annual home range size for translocated deer decreased ($\bar{x}$ = 318.2 km^2; range 78.3 – 762.1 km^2), and was not different (P = 0.07) than that of resident deer ($\bar{x}$ = 134.1 km^2; range 18.7 – 545.8 km^2). There appeared to be a decrease in home range size of translocated deer during 2014 ($\bar{x}$ = 323 km^2; range 78-762km^2) compared to 2013 ($\bar{x}$ = 572.3 km^2; range 182.9 – 980.1 km^2), but this difference was not significant with our sample sizes (P = 0.06).

Likewise, winter home range sizes for translocated deer ($\bar{x}$ = 42 km^2; range 9-128 km^2) during 2013 were larger than those of resident deer ($\bar{x}$ = 24 km^2; range 4-88 km^2; P = 0.03). However, there was no difference in winter home range size between translocated deer ($\bar{x}$ = 12 km^2; range 7-18 km^2) and resident deer ($\bar{x}$ = 22 km^2; range 5-56 km^2) during 2014 (P = 0.45). Summer home ranges during 2013 were also larger (P < 0.01) for translocated deer ($\bar{x}$ = 398 km^2; range 87-1,211 km^2) compared to resident deer ($\bar{x}$ = 4 km^2; range 2-8 km^2), but not during 2014 (P = 0.07).

Translocated deer exhibited high site fidelity to release areas. Ninety-four percent of translocated deer summered and wintered on the Pahvant study area. Of deer that survived the first year with working collars (n = 51), 96% returned to the general (west side of the Pahvant, < 30 km from release) winter range where they were released. Eighty-eight percent of surviving deer were < 15 km from release site and 75% returned to within 7 km of the release site. Site fidelity remained high (> 90%) during the second year. Of 102 translocated deer, only 1 deer returned to the capture area (actually moved further south of the capture location [208 km from release site]). Five other deer moved off of the Pahvant study area and onto the Beaver Mountain Range directly south of the Pahvant. These deer ranged from 74-92 km from the release sites, but all 3 that survived the first year migrated back north to the general winter range where they were released.

One year after the initial release (January 2014), we recaptured 20 translocated deer (10 from January 2013, 10 from March 2013). An additional 20 resident deer (20 VHF) were also captured during January 2014 in the Pahvant study area to bolster sample sizes for this reference group and provide data on condition for comparison. Percent body fat for recaptured deer ranged from 6.28 – 12.19%. Percent body fat for resident deer ranged from 5.90 – 17.17%. There was no difference in mean body condition ($P = 0.09$) between recaptured translocated deer 1 year post release and resident deer captured during the same time period. There was also no difference in body condition ($P = 0.30$) between translocated deer captured in 2013 and recaptured translocated deer 1 year post release (January 2014; Fig. 3).

DISCUSSION

Translocated deer had larger annual home ranges than resident deer in 2013 and 2014. However, while translocated deer home ranges were larger than resident deer during 2014, they were smaller in comparison to 2013 home ranges. Translocated animals may experience an acclimation period initially (Parker et al. 2008), but then reduced size of home ranges over time (Martinez-Garcia 2009). Reintroduced elk, for example, were on the landscape 2-3 years before establishing predictable home ranges (Fryxell et al. 2008). Similarly, translocated white-tailed deer in New York also had larger home ranges than those of resident deer during the first year following release. By the second year following release however, translocated deer had established home ranges similar in size to those of resident deer (Jones et al. 1997). Our results are different from those of translocated black-tailed deer (*O. h. columbianus*) and white-tailed deer (*O. virginianus*) in Illinois. On Angel Island, CA translocated black-tailed deer had similar home range sizes to resident deer during the first year following release (O'Bryan and McCullough 1985). In Illinois, point estimates for size of home ranges of translocated white-tailed deer in Illinois compared to resident deer, although not significant ($P > 0.05$) (Jones and Witham 1990). Jones et al. (1997) suggested that once translocated deer stabilize in an area, they behave similarly to resident animals. Our data support this idea as movement patterns and home range sizes during year 2 (2014) were more similar to those of resident deer than estimates from the initial year following release (2013).

Despite differences in movement and larger home ranges, translocated deer were similar to resident deer in demonstration of high site fidelity to winter range. Eighty-eight percent of surviving deer the first year were within 15 km or less of the release sites one year after translocation. All of these deer were within the same area where resident deer wintered. Interestingly, the 3 surviving deer that left the Pahvant and summered on the Beaver Mountain Range (approximately 70 km south of release areas), were closer to their capture areas than to the release areas, but migrated north back to the general winter range where they were released, providing support for defining site fidelity as the west side of the Pahvant and within 30 km of the release site. High site fidelity has also been seen in other translocation studies (Parker et al. 2008, Martinez-Garcia 2009). Increased habitat suitability has been suggested as being responsible for site fidelity (Parker et al. 2008). This likely contributed to the site fidelity in our study as deer were released in a productive and underutilized winter range that exceeded condition of the winter range where animals were captured (UDWR 2006-2014;2012).

Large movements by translocated animals did not appear to be influenced by body condition. While body condition has been shown to influence movement (Garrott et al. 1987, Lowe et al. 2006, Lendrum et al. 2013, Walter et al. 2014), it did not appear to do so in our study. We found no difference in movement between deer translocated in January (good condition) or March (poor condition). We also found no difference in the overall body condition of January 2013 and March 2013 translocated that were recaptured in January 2014. Despite extensive movements made by translocated deer during summer of 2013, translocated deer migrated onto winter range in relatively good condition. The body condition of translocated deer, at time of recapture, was not different from their body condition at the time of translocation or from resident deer captured at the same time (January 2014). Deer that were translocated in March were excluded from this analysis. Doing so allowed us to compare the body condition of translocated deer captured in January (prior to translocation) with the same deer.

During winter months, translocated deer had similar monthly movements as resident deer. Multiple studies have suggested that translocated animals demonstrate an exploratory phase following release (Beringer et al. 2002, Parker et al. 2008). Haydon et al. (2008) suggested that animals experience a dispersive phase where they rapidly emigrate from the point of origin. Reintroduced elk in Canada demonstrated extensive movements immediately after release (Yott et al. 2011). We found extensive movements were made during the spring migration and summer months rather than in the months immediately following release. It is likely that the location, snow levels, and timing of release contributed to a delayed exploratory phase and may have helped to influence the high site fidelity we observed with translocated mule deer. Exploratory movements during the months following release of translocated deer contributed to larger home ranges than resident deer (Jones et al. 1997).

MANAGEMENT IMPLICATIONS

Our results suggest that translocation is a strategy that could be used to address management objectives for mule deer populations. We experienced low rates of capture myopathy, even without the use of sedative drugs for the majority of captured animals. We observed that translocated deer movements were high during the first year following release but were trending toward resident deer by the second year post release. We expect that with further monitoring there would be another decrease in home range size and movement for translocated deer during the third year. Because of the distances translocated animals moved away from release sites ($\overline{x}$ = 26 km; range 8 – 94), we recommend that deer be translocated at least 100 km from the capture location. We found that translocated deer demonstrated high site fidelity. This observation may have been influenced by the location of release and timing of year. Releasing deer during the winter months and into quality habitat may help reduce immediate exploratory movements and allow deer to acclimate to new winter ranges. Given the high site fidelity, we suggest that translocation may be a suitable way to reestablish deer populations on unused or underutilized winter ranges. In our study, there was no difference in movement rates and space use patterns for deer translocated in January or March. Although winters during our study period were relatively mild, this result suggests managers can use translocation throughout the winter months to address management concerns.

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Table 2-1. Output (fixed effects) from a mixed-effects ANOVA for annual home range and annual distance moved of resident and translocated mule deer on the Pahvant Mountain Range in central Utah, USA during 2013 and 2014.

Effect	Estimate	Std. Error	t value	Pr (>|t|)
Annual Home Range				
Intercept	115.05	67.80	1.697	0.10
Year (2014)	19.09	74.13	0.258	0.80
Group (Transplant)	457.20	93.46	4.892	< 0.01
Year (2014):Group (Transplants)	-273.17	106.33	-2.569	0.02
Annual Distance Moved				
Intercept	484.61	42.22	11.479	< 0.01
Year (2014)	-152.82	26.03	-5.871	< 0.01
Group (Transplant)	171.09	58.19	2.940	< 0.01
Year (2014): Group (Transplants)	-169.66	37.75	-4.494	< 0.01

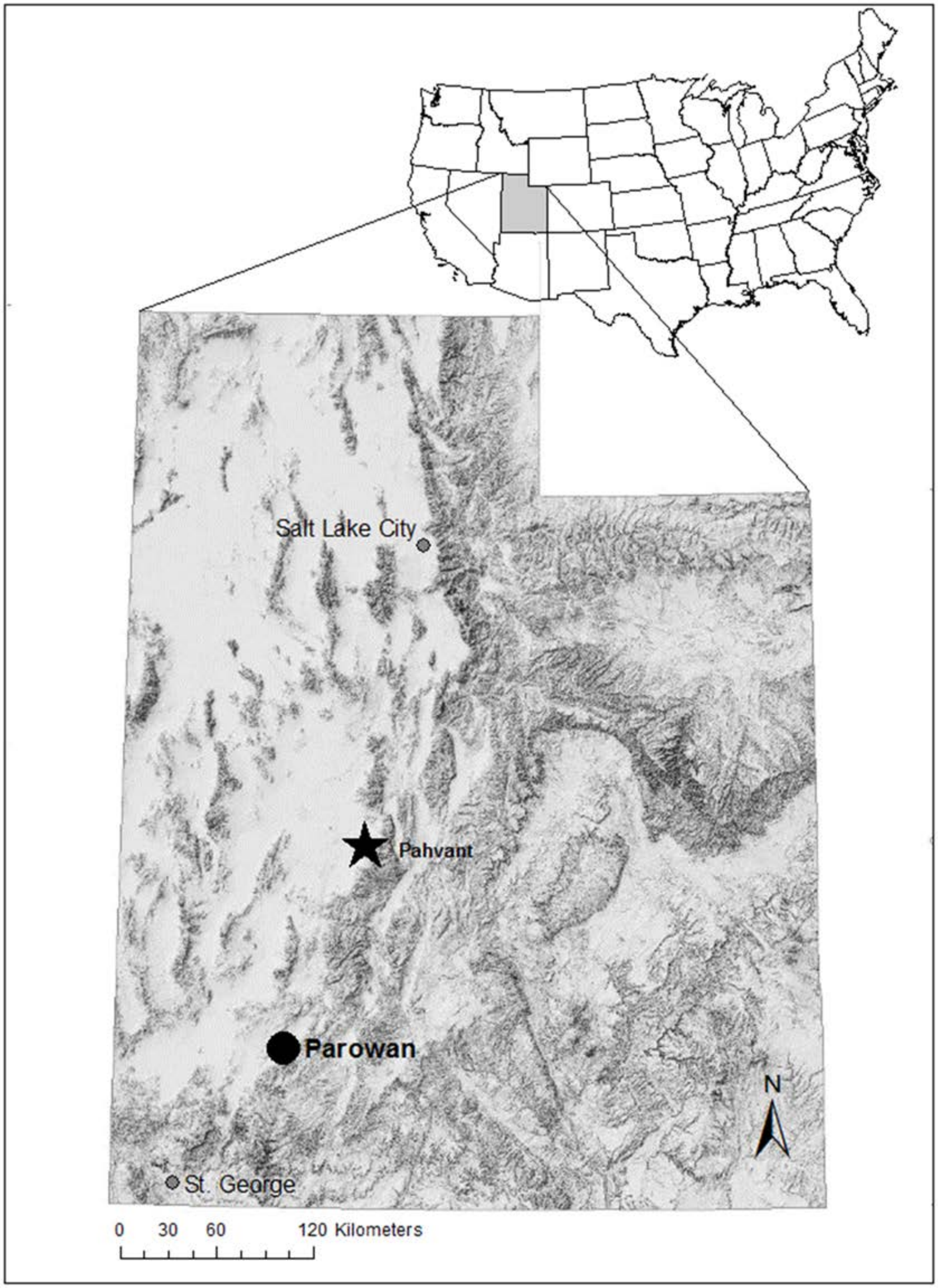

Figure 2-1. Map of Utah, USA showing our study area where the Utah Division of Wildlife Resources (UDWR) captured (circle) and released (star) mule deer (Odocoileus hemionus) in January and March of 2013

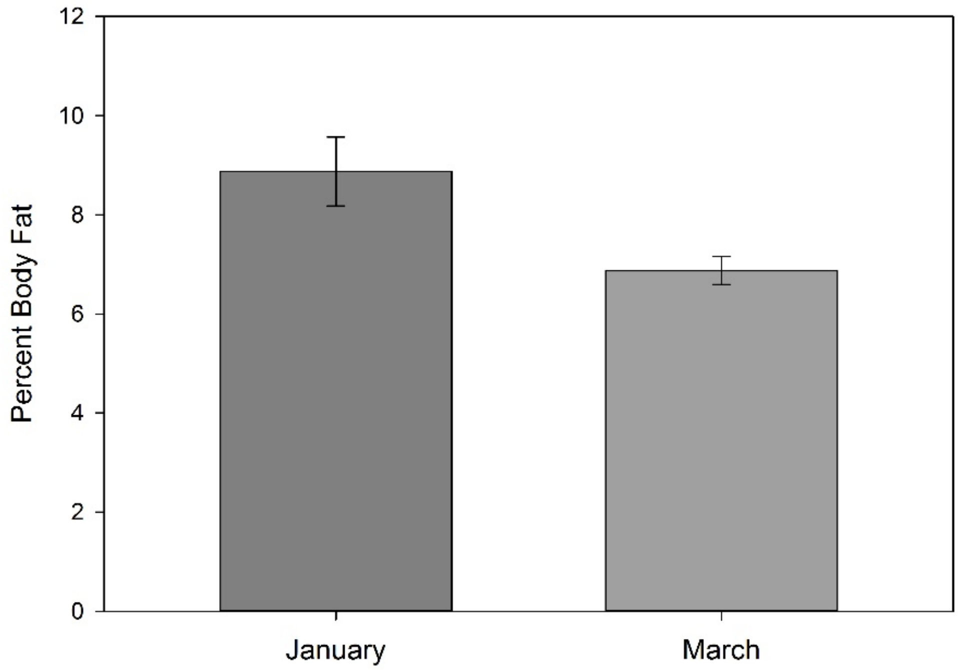

Figure 2-2. Percent body fat (± 95% CI) of translocated mule deer (Odocoileus hemionus) captured in southern Utah, USA during January and March of 2013 prior to translocation to winter range further north. Percent body fat was calculated using the body condition score method (Cook et al. 2007).

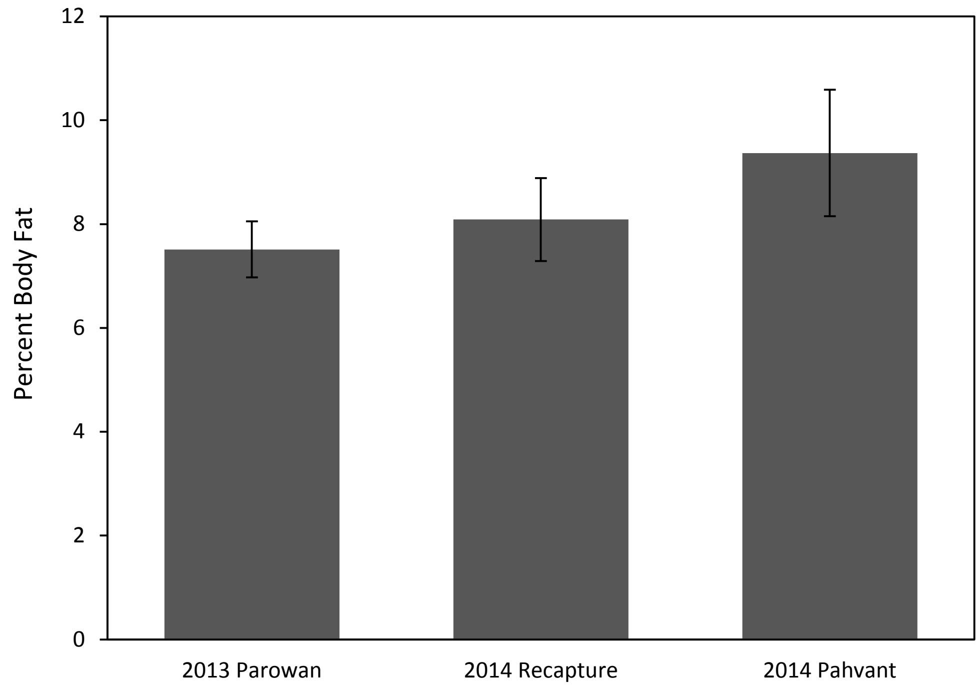

Figure 2-3. Percent body fat (± 95% CI) of translocated mule deer and resident mule deer (Odocoileus hemionus) one year following release. The 2013 Parowan deer were captured in southern Utah, USA during 2013 prior to translocation to winter range further north. Percent body fat was calculated using the body condition score method (Cook et al. 2007).

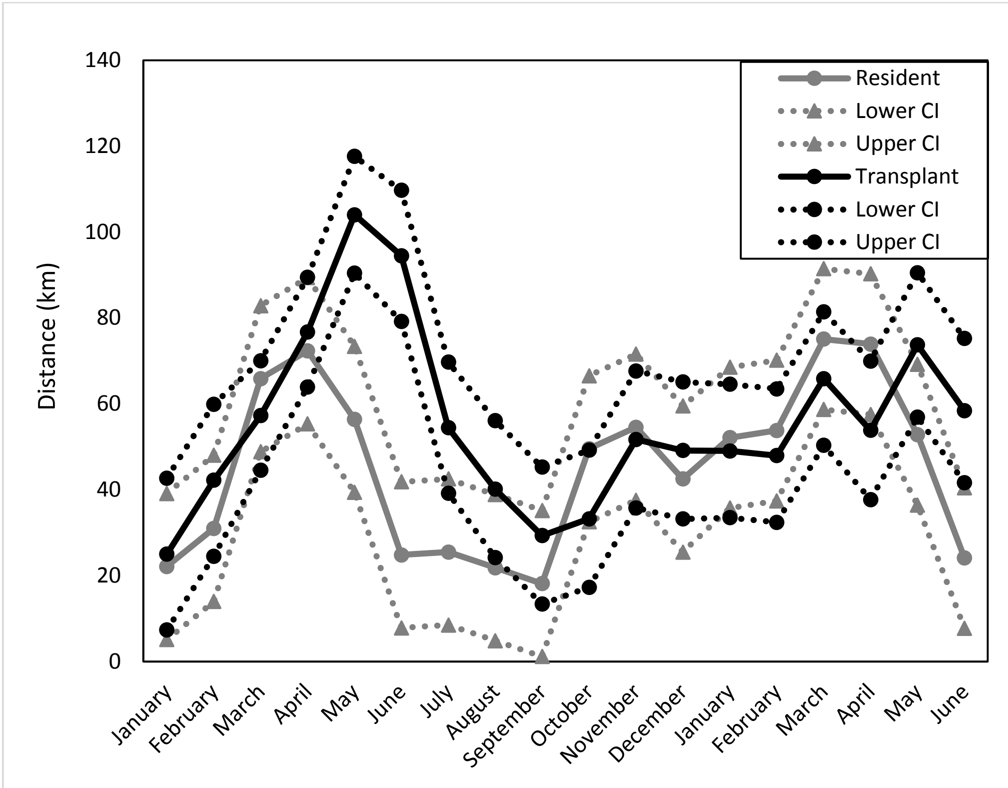

Figure 2-4. Monthly movements (km) of resident and translocated mule deer, January 2013 – June 2014. Movements were similar for both groups of deer during the winter months, but translocated mule deer moved more beginning in April and throughout the summer months.

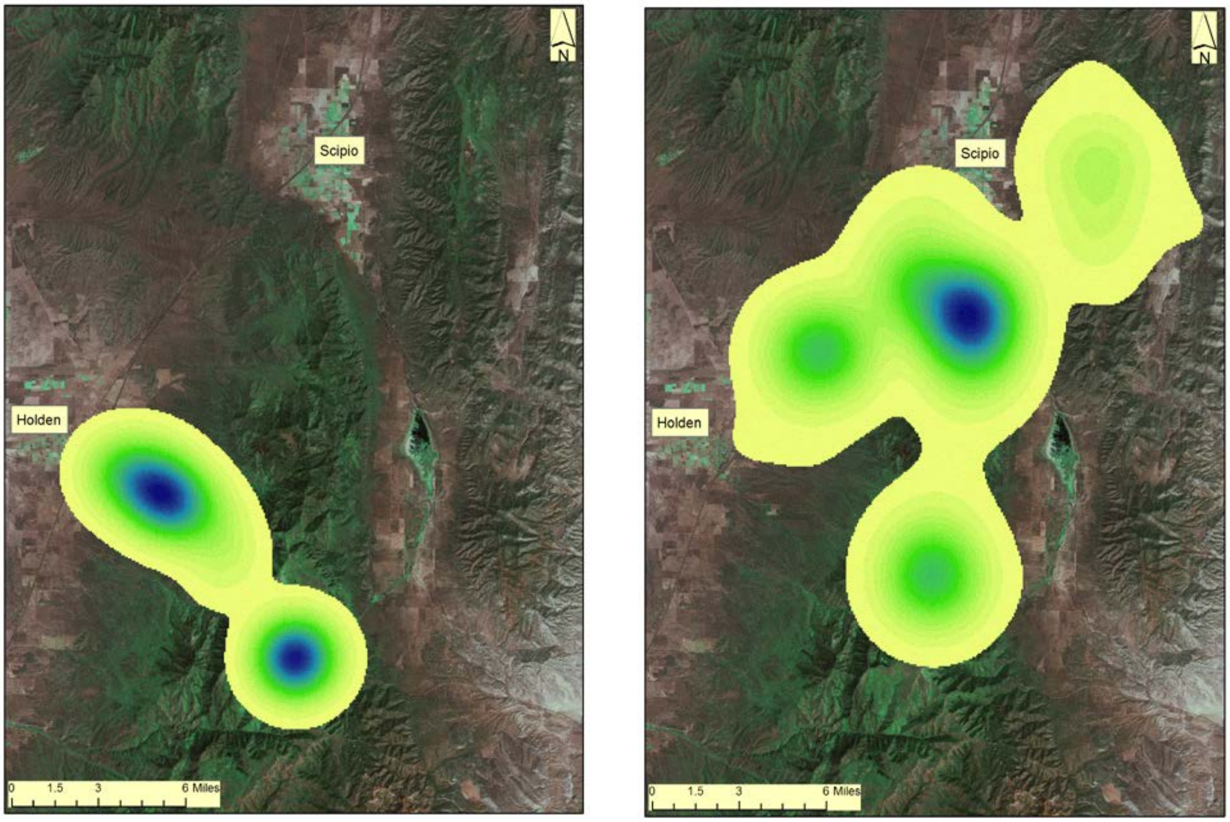

Figure 2-5. Two home range rasters depicting the average home range sizes, during 2013, for resident mule deer ($\overline{x}$ = 73 km^2; range 21-112 km^2; left map) and translocated mule deer during 2013 ($\overline{x}$ = 545 km^2; range 196-688 km^2; right map) on the Pahvant. Holden, Utah, USA was within 3 km of all release sites.