Using movement ecology to inform translocation efforts: a case study with an endangered lekking bird species

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Abstract

Translocation projects are often hindered by frequent or long-distance movements made by released animals. Studies identifying how and why animals move after release can inform future translocations and supplement the growing body of literature on translocation biology. We used radiotelemetry to compare movement behavior in 58 resident and 54 translocated endangered greater prairie-chickens (*Tympanuchus cupido*) that were collected approximately 500 km from the release area. Translocated birds tended to traverse larger areas than resident birds and their movements were elevated immediately following release. We found no evidence of directional orientation in the movements of translocated birds, and thus concluded that prairie-chickens were not homing toward their original capture locations. Rather, post-translocation movements of greater prairie-chickens were more likely associated with exploration. Our results also suggested that 54% of translocated females and 19% of translocated males may permanently emigrate from a release site. We recommend that greater prairie-chicken conservationists consider summer releases and larger release cohorts to account for the individuals that emigrate from the establishment site. Based on our findings, we further suggest that a greater number of future translocation projects consider the utility of evaluating post-release movements as a means of informing translocation decisions.

Introduction

The purpose of many translocation projects is to establish self-sustaining populations at release sites (Scott & Carpenter, 1987; Griffith *et al.*, 1989). However, translocation projects often fail due to frequent and large movements made by released animals (Griffith *et al.*, 1989; Miller *et al.*, 1999; Snyder, Pelren & Crawford, 1999). Large post-release movements can reduce chances for successful population establishment as individuals become isolated and unable to find mates (i.e. Allee effect; Allee, 1931; Courchamp, Berec & Gascoigne, 2008; Armstrong & Wittmer, 2011), or through increased exposure to predation (Yoder, Marschall & Swanson, 2004). Although post-release dispersal and exploratory movements have been well documented, particularly in translocation projects involving birds (Toepfer, Eng & Anderson, 1990; Armstrong *et al.*, 1999; Tweed *et al.*, 2003; Coates, Stiver & Delehanty, 2006; Le Gouar *et al.*, 2008; Kesler *et al.*, 2012), few studies have quantitatively assessed factors with the potential to drive these movements (Le Gouar, Mihoub & Sarrazin, 2012).

The causes of elevated post-release movements are equivocal. Translocated individuals may simply be exploring the release site in an attempt to identify suitable resources (Kesler *et al.*, 2012). Some studies also indicate that movements are caused by directional navigation toward the original capture sites (Miller & Ballard, 1982; Dickens *et al.*, 2009; Tsoar *et al.*, 2011) or attempts at gaining knowledge about novel surroundings (Reinert & Rupert, 1999). Further, movement differences among translocated individuals suggest that internal states, such as stress-coping mechanisms or willingness to accept a new habitat, might motivate movement (Stamps & Swaisgood, 2007; Dickens *et al.*, 2009; Kennedy & Marra, 2010).

Post-translocation movements may be additionally affected by the phenology and sex of released individuals as movements of resident birds often differ between sexes and seasons (Patten, Pruett & Wolfe, 2011). As with other birds, natal and breeding dispersal movements in grouse are often biased heavily toward females, particularly during the early spring when female grouse are searching for potential mates or nest sites (Greenwood, 1980; Gratson, 1988; Svedarsky,

1988; Small, Holzwart & Rusch, 1993; Martin, Stacey & Braun, 2000). In contrast, during the early spring resident males remain close to favored leks and only make infrequent large-scale movements (Hamerstrom Jr & Hamerstrom, 1949; Patten *et al.*, 2011). These same patterns have indeed been observed in translocated grouse as well; translocated females were found to have greater movements than males (Toepfer, 1988; Musil, Connelly & Reese, 1993; Coates *et al.*, 2006).

Our study aimed to elucidate factors influencing post-release movements of translocated individuals and to inform future translocation efforts by comparing the movement behavior of a population of translocated greater prairie-chickens (*Tympanuchus cupido*) to the movement behavior of a population of resident birds. We assessed the area traversed and the movement rates of translocated and resident birds. Additionally, we tested for homing movement behavior by evaluating whether there was alignment in post-translocation movement directionality and the direction of the original capture location. We predicted smaller traversal areas and movement rates for males as male greater prairie-chickens' movements are typically minimal early in the breeding season (Hamerstrom Jr & Hamerstrom, 1949; Patten *et al.*, 2011) and they exhibit fewer instances of transience and breeding dispersal than females (Small, Holzwart & Rusch, 1993; Martin, Stacey & Braun, 2000). Resident female greater prairie-chickens tend to exhibit breeding dispersal prior to nesting (Greenwood, 1980; Gratson, 1988; Svedarsky, 1988; Small, Holzwart & Rusch, 1993; Martin *et al.*, 2000), and thus we expected greater movement areas as well as higher movement rates immediately prior to laying. Translocation investigations have previously described two general patterns of movement, including an exploratory pattern and a homing pattern. Exploration is characterized by general outward and undirected moves, followed by returns to release sites (Reinert & Rupert, 1999; Kesler *et al.*, 2012). Therefore, we predicted that exploration in prairie-chickens would be evidenced by expanded movement areas and greater and more frequent movements in translocated prairie-chickens than in residents (e.g. Moehrenschlager & Macdonald, 2003). We predicted that homing behavior, in which individuals attempt to return to the donor sites on which they were first captured (Miller & Ballard, 1982; Dickens *et al.*, 2009; Tsoar *et al.*, 2011), would be characterized by movement directions biased toward the original capture locations.

Methods

Study area

Prior to the 20th century, native prairie vegetation covered approximately 27–40% of the state of Missouri (Schwartz, 1945; Christisen, 1985). However, the introduction of mechanized agriculture intensified land use at the expense of native prairie habitat (Svedarsky *et al.*, 2000). Today, only about 1% of the state is covered with scattered tracts of native prairie (Mechlin, Cannon & Christisen, 1999). Our study took place in some of these last remaining tracts of native grasslands. We conducted research between March and August in 2010 and 2011 in Taberville Prairie (578 ha; 38°3'N, 93°58'E) and Wah'Kon-Tah Prairie (1213 ha; 37°54'N, 93°59'E) within the Taberville and El Dorado prairie-chicken focus areas in St. Clair and Cedar counties in Missouri (Fig. 1). The native prairie in the Taberville and El Dorado focus areas was managed and owned by the Missouri Department of Conservation and The Nature Conservancy. Management consisted of a spatiotemporal combination of
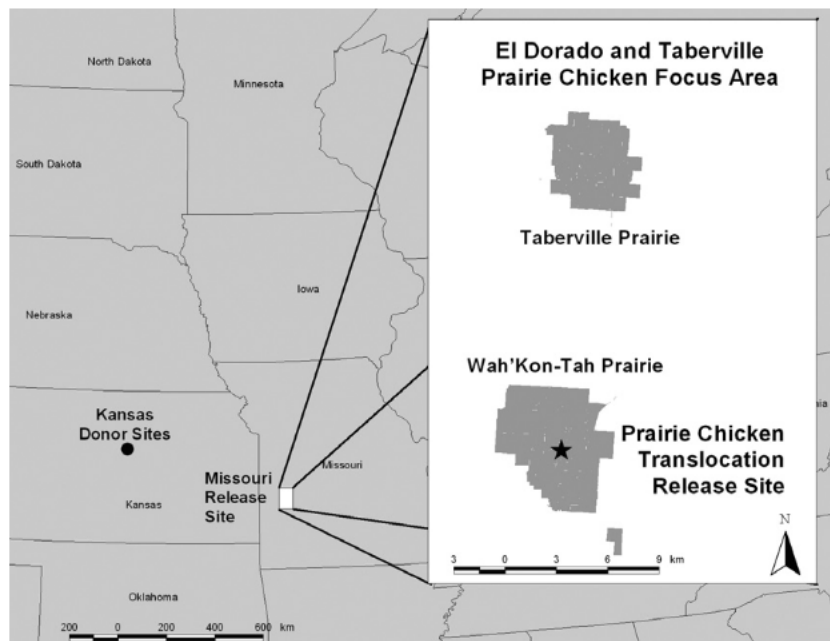

Figure 1 Map depicting donor and translocation release sites for greater prairie-chickens in 2010 and 2011. Inset shows spatial arrangement of grassland restoration areas on Taberville and Wah'Kon-Tah Prairies.

herbicide treatments of invasive and exotic plants, prairie restoration (with locally collected seed), patch-burn grazing by cattle (*Bos primigenius*) and high mowing (L. Gilmore, Missouri Department of Conservation, pers. comm.).

Study species

The greater prairie-chicken is a lekking species of grouse that is highly dependent on native prairie habitat for survival and persistence (Christisen, 1972). At the time of our study, there were no more than 500 endangered greater prairie-chickens remaining in the state of Missouri, and it was believed that a large portion of this number existed within the Taberville and El Dorado prairie-chicken focus areas (Jamison & Alleger, 2009). Our study took place in the middle of a 5-year translocation project that was aimed at restoring the area's greater prairie-chicken populations with translocations from Kansas. Prior to our study, releases had already occurred in the spring and summer of 2008 and 2009 in Wah'Kon-Tah Prairie. Thus, over 90% of our radio-tagged population consisted of birds established from previous translocations.

Capture, radio-tagging and release

We trapped resident greater prairie-chickens immediately before and during the onset of breeding on the booming grounds in Wah'Kon-Tah Prairie in 2010 from 23 March to 15 April using modified walk-in traps (Schroeder & Braun, 1991). We trapped resident birds in 2011 from 18 January to 29 January on agricultural fields using corn (*Zea mays*) bait and modified walk-in traps (Schroeder & Braun, 1991). We trapped translocated birds on various leks in Ottawa, Saline, Lincoln, McPherson and Ellsworth counties in Kansas between 23 March 2011 and 12 April 2011 (Fig. 1). Within 6–12 h of capture, birds were banded, evaluated by a certified veterinarian, transported in small animal carriers to El Dorado Springs, Missouri, by automobile (*c.* 470 km), radio-tagged and hard released in Wah'Kon-Tah Prairie. We fitted all captured birds with necklace-style radiotelemetry tags equipped with a 12-h mortality switch.

Radiotelemetry

We tracked radio-tagged resident greater prairie-chickens from 24 March 2010 to 23 August 2010 ($n_{females} = 11$, $n_{males} = 18$) and from 12 March 2011 to 11 August 2011 ($n_{females} = 15$, $n_{males} = 14$), and translocated birds from 23 March 2011 to 11 August 2011 ($n_{females} = 28$, $n_{males} = 26$). We considered marked birds to be residents if they were first trapped on the Missouri study sites, or if they had been translocated to the area during the previous field season, because those individuals had explored local resources throughout the winter and entered the breeding season with that knowledge. We used vehicle-mounted null-peak telemetry units equipped with electronic compasses (Cox *et al.*, 2002) to track radio-marked birds. Observers searched the area and obtained locations using handheld telemetry units

if birds could not be located from vehicles (3-element Yagi antenna, Advanced Telemetry Systems, Isanti, Minnesota, USA). We searched for each bird daily during a randomly selected 3-h period (06:00–09:00 h, 09:00–12:00 h, 12:00–15:00 h, 15:00–18:00 h, 18:00–21:00 h, 21:00–24:00 h) within 7.5 km of Taberville or Wah'Kon-Tah Prairie. Consecutive locations for each bird were separated by at least 8 h. We recorded three to six bearings for each location (the first and last of which were separated by ≤ 35 min) and used the directional bearings to triangulate bird locations with the program LOAS (Location of a Signal, Version 4.0, Ecological Software Solutions LLC, Hegymagas, Hungary). Bearing groups with nonintersecting vectors were eliminated. We removed locations with an estimated error ellipse greater than 2 ha in size to reduce the potential effects of inaccurate locations (e.g. Kesler & Haig, 2007; Coulombe, Kesler & Gouni, 2011). Together, excluded bearing groups represented less than 5% of the total dataset. We attempted to locate birds that were outside of the 7.5-km buffer once each week by circling the zone in vehicles, and we often searched as far as 20 km outside this buffer. Prairie-chickens that could not be located were classified as missing, and searches for missing birds were conducted on a daily basis throughout every tracking time period both inside and outside the 7.5-km buffer by setting telemetry receivers (ATS; R4500S) to scan during daily travels. We also incorporated helicopter flights to aid in searches for missing birds (April 2010, April 2011, May 2011 and July 2011).

Statistical analyses

Area traversed

We used minimum convex polygons (MCPs; Mohr, 1947) to represent the amount of area traversed by individual greater prairie-chickens between 24 March 2010 and 23 August 2010 and between 12 March 2011 and 11 August 2011. We were interested in indexing all areas traversed by birds, including those in extreme outbound movements, so MCPs were based on the entire set of observations rather than a subset (e.g. 95%). The MCPs have been used similarly in other studies to provide a measure of the search area and the magnitude of separation of an individual's locations (Doerr & Doerr, 2005; Kesler, Walters & Kappes, 2010). Only birds with ≥30 locations (n = 77) were included in the analysis to reduce the potential of small sample size bias (Garton *et al.*, 2001). We tested for differences between 2010 and 2011 residents using a least-squares means *t*-test (SAS Institute Inc., 2008). When no differences were identified we pooled 2010 and 2011 data for the analysis. We randomly selected a season for inclusion when individuals were tracked in multiple years (n = 7) to avoid pseudoreplication (Hurlbert, 1984).

The distribution of MCP areas was right skewed (many smaller MCPs and fewer larger MCPs), so we used a lognormal response distribution in analyses. We evaluated models representing competing hypotheses about the influence of sex (male, female) and residency (resident, translocated bird) on areas traversed by greater prairie-chickens

Table 1 Ordered ranking of models relating areas traversed by greater prairie-chickens to residency and sex. We present the number of parameters included in each model (K), unit departure from the top-ranked model (ΔAIC_c) and Akaike weight (ω_i; model probability given the set of candidate models). Analyses were based on movements of 70 birds in south-west Missouri between 12 March and 23 August

Model	K	ΔAIC_c	ω_i
Residency + Sex + Residency × Sex	5	0.00	0.80
Residency + Sex	4	3.13	0.17
Residency	3	6.16	0.04
Sex	3	11.87	0.00
Null	2	14.81	0.00

(Table 1). We fitted the data with generalized linear mixed models using a LaPlace approximation method to obtain parameter estimates (Bolker *et al.*, 2009) as this method allows for model assessment within a maximum likelihood framework (PROC GLIMMIX: SAS Institute Inc., 2008).

Movement rates

We calculated daily movement distances between paired telemetry locations separated by 1 day for each bird using Hawth's tools (Beyer, 2004) in ArcMap 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA). With the exception of the first week and last 2 weeks of our study, we averaged consecutive daily movements for each bird within each week of the breeding season ($n = 21$ weeks) to obtain a mean daily movement rate per week. We censored the first week and last 2 weeks of our study because of an insufficient amount of data representing all groups within the model for those time periods. We also censored one bird that died after one observation, other birds were censored after mortality ($n = 40$) or disappearance ($n = 13$), and individual birds were censored during weeks in which they were not represented by relocations. We tested for differences between movement rates in 2010 and 2011 resident birds using a least-squares means t-test (SAS Institute Inc., 2008). When no differences were identified data were pooled for the analysis. We randomly selected 1 of 2 years for birds that were tracked in multiple seasons ($n = 7$) to avoid pseudoreplication (Hurlbert, 1984).

Movement data were also right skewed, so we ran all models using a lognormal distribution. We included a random intercept variable for each radio-tagged individual to account for a lack of independence among repeated measures on individual birds (e.g. Richmond, Jockusch & Latimer, 2011). Inclusion of random effects in the model necessitated the selection of an appropriate structure that described the covariation between repeated observations on a given bird. Thus, we used the null model to test the appropriateness of three covariance structures, including an unstructured block diagonal structure, unstructured, and a constant residual structure (SAS Institute Inc., 2008). We fitted the data with generalized linear mixed models and again used a LaPlace approximation method to obtain

Table 2 Ordered ranking of models relating movement rates of greater prairie-chickens to residency (R), sex (S), week (W) and $week^2$ (W^2). For each model, we present the number of included parameters (K), unit departure from top-ranked model (ΔAIC_c) and Akaike weight (ω_i; model probability given the set of candidate models). Analyses were based on movements of 102 birds in south-west Missouri between 19 March and 12 August

Model	K	ΔAIC_c	ω_i
$R + W + W^2$	6	0.00	0.85
$R + W + W^2 + S + R \times S$	8	3.55	0.14
$S + W + W^2$	6	9.08	0.01
$R + W + W^2$	5	106.73	0.00
$S + R + W$	6	108.55	0.00
$S + R + W + S \times R$	7	110.57	0.00
$S + W$	5	115.69	0.00
R	4	272.94	0.00
$S + R$	5	274.91	0.00
$S + R + S \times R$	6	276.64	0.00
Null	3	278.02	0.00
S	4	280.03	0.00

parameter estimates (PROC GLIMMIX: SAS Institute Inc., 2008). The covariance structure that elicited the lowest adjusted Akaike's information criteria (AIC_c) value was used for the following stages of analysis. Again, using generalized linear mixed models and a LaPlace approximation, we evaluated expanded models representing competing hypotheses about the influence of sex (male, female), residency (resident, translocated bird) and time (week) on the mean daily movement rates of greater prairie-chickens (Table 2). The continuous variable *week* represented 7-day weeks from 19 March to 12 August and was designed to test if movement rates were high at the beginning of the breeding season due to lek visitation and breeding dispersal. We also included a quadratic transformation of the variable *week* ($week^2$: $week_+ week^2$) to represent a model with higher movement rates in the beginning of the season, lower during the nesting period, and subsequent higher movement rates during brooding.

Model selection

We used an information-theoretic approach to rank competing models. We considered models with differences in scores (ΔAIC_c < 2 units below the top-ranked model to be the best approximating model (Burnham & Anderson, 2002). We further used the model weights (ω_i) to assess the plausibility of each model (Lebreton *et al.*, 1992; Burnham & Anderson, 2002). If we concluded more than one model was supported, we model averaged across supported models (ΔAIC_c < 2; Burnham & Anderson, 2002). We tested goodness of fit using the ratio of the Pearson chi-square statistic to its degrees of freedom (McCullagh & Nelder, 1989). For both models, assessing area traversed and assessing movement rates, values for this ratio (0.78 and 0.72, respectively) indicated good model fit and appropriate model selection. We further assessed the fit of top models through a visual

examination of the residuals and ascertained that they appeared normally distributed.

Movement directionality

To test whether the large post-release movements observed in translocated greater prairie-chickens provided evidence of homing or directed movement behavior, we analyzed azimuths of post-release dispersal movements and their correlation with azimuths for the last location obtained for each bird. All azimuths were calculated with the release site as the point of origin. We assessed initial azimuths for the first movement outside of a buffered MCP that encompassed the movements for all 2011 resident birds that spent the breeding season at the release site (Wah'Kon-Tah). The MCP was buffered on all sides by 371 m, which was the mean daily movement distance of 2011 resident birds. We assumed that movements over that distance were outside of the normal range of resident birds and were thus dispersal movements. We surveyed the directional azimuth for these movements ($n = 31$) with a SAS (SAS Institute Inc., 2008) macro (Kölliker & Richner, 2004) using Rayleigh's test for circular uniformity (Zar, 1999). We also tested for correlation between the azimuth of initial dispersal movements and the azimuth of birds' final locations by calculating the coefficient rt (Fisher & Lee, 1983) based on 5000 permutations using the same macro. Two birds went missing and three died immediately after their first post-release dispersal movement, so this analysis was only completed for 26 individuals.

Results

We observed 7 resident greater prairie-chicken mortalities (5 males, 2 females) from 24 March 2010 to 23 August 2010, 10 resident mortalities (2 males, 8 females) from 12 March 2011 to 11 August 2011, and 23 translocated bird mortalities (11 males, 12 females) from 23 March 2011 to 11 August 2011. We retrieved 80% of these birds post-mortem, of which 88% exhibited signs of predation including tooth marks on transmitters and plucked feathers.

Thirty-one of the 54 translocated birds that we tracked made large dispersal movements away from release sites (12 males, 19 females). Of the dispersers, seven males and four females subsequently returned to the release site, two females briefly remained at their dispersal destination and then moved again, three females disappeared after dispersal, three males and seven females died in the area to which they dispersed, and three males and two females remained at their dispersal location.

Area traversed

The top-ranked model of area traversed included variables for residency, sex, and an interaction between the variables residency and sex (Table 1). The supported interaction indicated that the magnitude of difference in areas traversed by each sex differed between translocated and resident birds
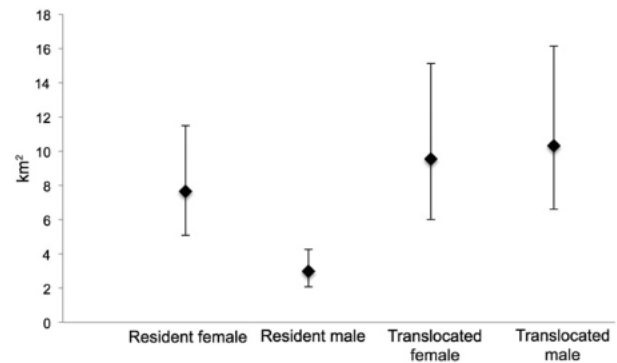

Figure 2 Model-based estimates of median area traversed by resident female ($n = 18$), resident male ($n = 23$), translocated female ($n = 14$) and translocated male ($n = 15$) greater prairie-chickens across a 152-day breeding season (March–August) in south-west Missouri. Whisker bars represent upper and lower 95% confidence intervals.

(Fig. 2). No differences were identified in area traversed by resident birds during 2010 and 2011 ($P = 0.21$), so data were pooled for both years. There did not appear to be a substantial difference between areas traversed by translocated females and translocated males. Parameter estimates illustrated the median area traversed by translocated birds (females: 9.55 km², 95% CI: 6.02–15.14; males: 10.34 km², 95% CI: 6.62–16.14), resident females (7.66 km², 95% CI: 5.10–11.51) and resident males (2.99 km², 95% CI: 2.09–4.28) (Fig. 2).

Movement rates

Unstructured covariance scored the lowest AIC_c value, and model ranking supported a top model that included the variables residency and $week^2$ (Table 2). Estimates of covariance were relatively small ($\hat{\beta} = 0.03$, SE = 0.01), although estimates of residual variation were larger ($\hat{\beta} = 0.80$, SE = 0.03). No differences were identified in the movement rates of resident birds during 2010 and 2011 ($P = 0.49$), so data were pooled for both years. Model-based predictions indicated that median movement rates (m/week) of translocated birds ($\hat{\beta} = 7.34 \pm 0.11$) were greater than those of resident birds ($\hat{\beta} = -0.21 \pm 0.07$) and that movement rates for all birds trended downward as the season progressed ($\hat{\beta}_{week} = -0.26 \pm 0.02$; $\hat{\beta}_{week}^2 = 0.01 \pm < 0.01$; Fig. 3). For example, model-based predictions indicate median movement rates of 765 m per week for resident birds and 940 m per week for translocated birds early in the breeding season (19 March–25 March). Predictions of the median movement rates late in the breeding season (6 August–12 August) are 227 m per week for residents and 279 m per week for translocated birds.

Movement directionality

Results did not indicate that translocated birds were moving in any single direction, or that large post-release movements
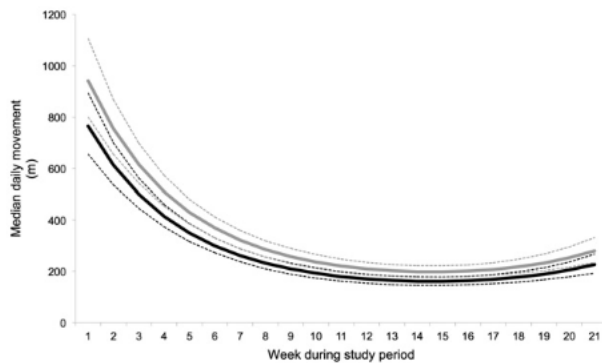
Figure 3 Plots of model-averaged predictions of median daily movements (m per week) for greater prairie-chicken resident and translocated birds between 19 March and 12 August. Black lines represent resident birds, gray lines represent translocated birds, and dotted lines represent upper and lower 95% confidence intervals.

predicted the direction of permanent dispersal from the area. Initial movement directions of the translocated birds did not differ from random ($P = 0.22$) and movement directions were uncorrelated with the initial capture location, or the direction of final locations ($n = 26$, $P = 0.93$).

Discussion

Our results suggested that post-release movements of greater prairie-chickens are largely translocation induced. The disparity in area traversed and in movement rates between translocated and resident birds immediately after release suggested that movements of translocated individuals were influenced by their release into an unfamiliar area. We also demonstrated that movement patterns did not align with homing behaviors orienting birds toward original capture locations.

When compared with resident birds, translocated birds had elevated movement rates and they also traversed larger areas. Model parameter estimates indicated a greater discrepancy between the area traversed by translocated birds and resident males than between the area traversed by translocated birds and resident females. However, female grouse are known to make large movements in search of mates or nesting sites during the breeding season and this could have caused the observed pattern (Gratson, 1988; Svedarsky, 1988; Small, Holzwart & Rusch, 1993; Martin et al., 2000).

Elevated movements of translocated individuals were previously observed in other translocation studies, and investigators suggested that the movements were used for navigational orientation, or for homing toward the original capture sites (Miller & Ballard, 1982; Dickens et al., 2009; Tsoar et al., 2011). Our results did not support homing in our population of greater prairie-chickens. However, we translocated birds >300 km and great distances have impeded homing in other studies (Van Vuren et al., 1997; Moehrenschlager & Macdonald, 2003). The general

outward and undirected movements of the translocated greater prairie-chickens, followed by returns to release sites, appeared similar to starburst-shaped exploratory movements documented in previous translocation and dispersal studies (Kesler et al., 2012).

Previous studies have suggested that territorial interactions with conspecifics or competition for limited and patchily distributed resources can influence post-release movements of translocated animals (Allen, Franzreb & Escano, 1993; Armstrong, 1995; Clarke & Schedvin, 1997; Dunham, 2000; Coates et al., 2006). Although prairie-chickens are generally not territorial, males do defend small areas on leks (Robel & Ballard, 1974). Moreover, the magnitude of prairie-chicken movements increases with rejection from a flock or a lack of openings in the social structure (Bowman & Robel, 1977; Svedarsky & Van Amburg, 1996), which suggests that similar social interactions might motivate movement in translocated birds.

Recent studies of natal dispersal provide an alternative explanation for the rapid and elevated exploratory movements we observed in translocated greater prairie-chickens. Dispersers often traverse and relocate to areas with habitat similar to natal ranges, a phenomenon labeled natal habitat preference induction (Davis, 2008; Mabry & Stamps, 2008; Cox & Kesler, 2012; Kesler & Walters, 2012). Translocated individuals could be considered to be forced dispersers, and Stamps & Swaisgood (2007) suggested that natal habitat preference induction may thus also apply to post-translocation movements. Individuals with a strong preference for the original capture site may leave the release site and search for areas similar to the original home range. Other individuals more likely to accept the release site conditions might still make smaller movements in an attempt to avoid an area they associate with a threatening experience (handling, translocation; Stamps & Swaisgood, 2007). Our study and others have documented similar variations in individual responses to translocations (Fritts, Paul & Mech, 1984; Cope, 1992; Tweed et al., 2003; Coates et al., 2006; Dickens et al., 2009; Fisher, Lambin & Yletyinen, 2009; Kesler et al., 2012).

Identifying approaches to eliminate translocation-induced movements, such as those observed in our study, seems unlikely. However, managers could mitigate the effects of post-release movements by increasing the release group size. As 37% of the released birds in our study departed from the area permanently, release groups that are as much as 159% the size of the target post-release population may be needed to counteract post-release dispersal. Greater prairie-chicken translocation projects could also experiment with the timing of release. Spring releases may not be the best choice for greater prairie-chickens; we observed the highest rates of movement in resident and translocated birds during this period. Additional research is needed to evaluate whether summer translocations might prove more effective because birds are molting during this time and might be less inclined to make large movements (Toepfer et al., 1990). Social structure in the summer months might also be less rigid than earlier in the breeding

season when females are establishing nesting territories and males are defending areas on leks.

Results from our study may be applicable to other translocation projects. Our results indicate that translocation elicits movement behaviors that differ substantially from the behaviors of resident birds that were not translocated, and thus suggest that relying on existing knowledge about natural history patterns for the guidance of translocation conservation programs might not always be appropriate. Rather, our results underscore the importance of conducting scientific studies to provide solid information about movements that can be used to guide translocation projects. If prerelease studies cannot be conducted because of a lack of release subjects (e.g. *Todiramphus cinnamominus cinnamominus*; Laws & Kesler, 2012), an adaptive approach could be employed which incorporates simultaneous movement-monitoring studies with conservation releases. Finally, we are enthusiastic about the potential utility of recently available higher resolution equipment based on satellite and global positioning systems, and about the associated analytical methods for assessing the resulting data (e.g. Bunnefeld *et al.*, 2011).

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