Influences on Release-Site Fidelity of Translocated Elk

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Abstract

Several eastern states are considering the restoration of free-ranging elk populations via translocation from western populations. Optimal habitat immediately surrounding release sites has been found to enhance elk reintroduction success in western states. Little information exists, however, to aid eastern managers in identifying release sites with the highest chance of restoration success. We monitored the movements of 415 translocated elk released at three sites in southeastern Kentucky to identify landscape characteristics that enhance release-site fidelity. The distance elk moved after release differed among sites (F2,322 = 4.63, p = 0.01), age classes (F2,322 = 4.37, p = 0.01), and time intervals (F2,322 = 4.704, p < 0.001). At 6 and 12 months post-release, adults (15.81 ± 17.32 and 16.38 ± 20.29) and yearlings (13.91 ± 16.44 and 14.61 ± 21.11) moved farther than calves (8.06 ± 14.03 and 9.37 ± 14.40). The release site with the highest fidelity was privately owned, 15% open, and had the highest amount of edge compared with the other release sites. The two remaining sites contained large amounts of expansive openland or forest cover with lower amounts of edge. Additionally, both sites were publicly owned and experienced a higher degree of human-generated disturbance compared with the site to which elk were most faithful. When selecting release sites, managers should avoid areas dominated by a single cover type with little interspersion of other habitats. Rather, areas with high levels of open-forest edge (approximately 5.0 km/km2) and limited-human disturbance will likely enhance release-site fidelity and promote restoration success.

Key words: Cervus elaphus, disturbances, elk restoration, Kentucky, landscape, release-site fidelity, surface mining, translocation.

Introduction

Elk (Cervus elaphus) restoration efforts have recently increased in the eastern United States (Phillips 1997; Didier & Porter 1999; McClafferty & Parkhurst 2001). An understanding of landscape characteristics that encourage site fidelity of translocated elk is important, but this aspect of restoration has not been well documented. An ideal landscape for a restored elk herd may simply be one containing sufficient green forage (Leopold 1918), a 60:40 ratio of forage to cover (Thomas et al. 1976), sufficiently large areas for calving, feeding, and avoiding humans (Lyon & Thomas 1987), or one with adequate nutrition and security (Wisdom & Cook 2000). Such descriptions may be accurate, but likely vary due to inherent habitat differences among landscapes (McCorquodale 1991). Further, they are too broad to be used in developing specific land management objectives.

Human disturbances limit habitat use in western elk populations (Irwin & Peek 1979; Ferguson & Keith 1982; Kuck et al. 1985; Cassirer et al. 1992), and may affect release-site fidelity of translocated herds. Information regarding the effects of anthropogenic disturbances on elk behavior is essential to minimize these impacts (Lyon & Ward 1982). This is especially true for small, translocated populations where every individual may be important to the success of population establishment.

We examined translocated elk movements at three release sites in southeastern Kentucky where land use, topography, road density, and human disturbance varied. We predicted that release-site fidelity in Kentucky elk would increase proportionally with the amount of non-forested land and decrease with increasing human disturbance such as coal mining, logging, recreational viewing, and off-road vehicle use. Our objectives were to (1) quantify release-site fidelity of translocated elk, and (2) identify landscape features that encourage release-site fidelity. This information may help managers to limit elk movement from restoration areas and reduce the likelihood of conflicts with humans by choosing appropriate release sites.

Study Area

The southeastern region of the state was selected as the restoration zone because of its low human population and distance from row crops and major urban centers (Larkin
et al. 2001). Active- and reclaimed-surface mines, the Daniel Boone National Forest, and private forests dominate the landscape. Mountaintop removal for coal and subsequent reclamation have converted rugged topography into gently sloping grasslands. The restoration zone is 93% forested, 6% reclaimed-surface mines, and 1% agriculture (Maehr et al. 1999). The 14-county restoration zone covers 1.04 million hectares in the Cumberland Plateau physiographic region (Maehr et al. 1999). Narrow, winding ridges, steep slopes, and narrow valleys characterize the original topography of the restoration zone (McFarlan 1943). Elevations range from 244 to 1260 meters above sea level (Overstreet 1984).

The primary vegetation in eastern Kentucky is mixed-mesophytic forest. It is characterized by 30 canopy tree species including American beech (Fagus grandifolia), yellow-poplar (Liriodendron tulipifera), basswood (Tilia spp.), sugar maple (Acer saccharum), northern red oak (Quercus rubra), white oak (Quercus alba), eastern hemlock (Tsuga canadensis), and yellow buckeye (Aesculus octandra) (Braun 1950). Common understory species include eastern redbud (Cercis canadensis), flowering dogwood (Cornus florida), spicebush (Lindera benzoin), and pawpaw (Asimina triloba). Mixed-mesophytic forests occur on moist, well-drained sites (Braun 1950). Ridge-tops, southwestern facing slopes, and areas with rocky shallow soils are characterized by Oak-Hickory (Quercus-Carya) and Oak-Pine (Quercus-Pinus) communities (Overstreet 1984).

Strip-mining and subsequent reclamation have created herbaceous openings of up to 5000 ha in eastern Kentucky. Common plants in these openings include Kentucky-31 tall fescue (Festuca arundinacea), bush clover (Lespedeza spp.), perennial ryegrass (Lolium perenne), and orchardgrass (Dactylis glomerata). These artificial habitats produce an average of 573 kg/ha of available forage (Teutsch 2000), and are capable of supporting 0.28–0.83 domestic cow–calf units per hectare (Bos taurus) in optimal body condition (Teutsch 2000).

The climate is temperate humid continental (Overstreet 1984) with an average annual temperature of 13°C (Hill 1976), a mean winter temperature of 4°C, and a mean summer temperature of 24°C (McDonald & Blevins 1965). Annual precipitation averages 117 cm and is evenly distributed throughout the year (Hill 1976). Average snowfall is 51 cm but accumulation rarely remains for more than a few days (McDonald & Blevins 1965).

Release Sites
The Cyprus-Amax Wildlife Management Area (Cyprus) in Perry County is a 7,400-ha coal mine with approximately 2,000 ha of reclaimed grassland and 1,000 ha of active mining (37°24′53″/83°07′07″). Although the remainder of the wildlife management area is deciduous forest, the area contained approximately 30% reclaimed grassland when the study was conducted. The area was open to the public and supported human uses such as hunting, fishing, wildlife viewing, and horseback riding.

The Orr mining property (Orr) in Harlan County is a mosaic of second and third growth forests (89%), an active coal mine (3%), and reclaimed grasslands (7%) (36°53′18″/83°29′23″). This site was closed to the public and experienced little human activity other than mining.

The Redbird Wildlife Management Area (Redbird) in Leslie County is jointly managed by the Kentucky Department of Fish and Wildlife Resources (KDFWR) and the U.S. Forest Service, and comprises 9,200 ha of the Daniel Boone National Forest (37°07′50″/83°27′53″). Approximately 95% of the area is second and third growth forest. The remainder consists of 15 small openings (<2.5 ha) most of which (n = 12) are maintained for wildlife. Redbird was the only release site with predominantly uninterrupted forest and was least impacted by human settlement and extractive industry. Redbird is bisected by two roads and is open to the public for most of the year. Human activities include off-road vehicles and hunting. A logging moratorium was in effect during the study.

Methods

Capture, Translocation, and Monitoring
Elk were captured during the winters of 1998–2000 in Kansas, Utah, and Oregon. Details regarding capture methods and disease-testing protocol can be found in Larkin et al. (2003). If determined to be disease free and in good health, each elk was fitted with a very high frequency radio-collar (Telonics Inc., Mesa, AZ, U.S.A.; Lotek Wireless Inc., Newmarket, Ontario, Canada; Telemetry Solutions, Concord, CA, U.S.A.) equipped with a mortality sensor programmed to activate after 4 hr of inactivity. Elk were then loaded into livestock trailers and transported approximately 3000 km nonstop to eastern Kentucky, where they were released immediately upon arrival.

Monitoring of radio-collars began within 24 hr post-release. Elk were located once per week from fixed-wing aircraft unless weather conditions precluded telemetry flights. Transmitters in mortality mode were investigated as soon as possible and dead animals were examined for causes of death (Unsworth et al. 1993). Locations were recorded as Universal Transverse Mercator (UTM) coordinates.

Release-Site Fidelity
Individual elk movements from a release site were calculated from UTM coordinates of the telemetric locations of elk and the UTM coordinates of a given release site. If an animal died or it was recaptured and returned to the release site within 1 year, the location of mortality or recapture was used in calculating distance moved (Ruth et al. 1998). Otherwise, we measured the longest distance...
moved from the release site for each elk. Animals for which radio contact was lost, and for those that died due to capture-related injuries were not included in the analyses. We used SAS (SAS Institute, Cary, NC, U.S.A.) to perform a repeated measures multivariate analysis of variance to evaluate sex, age, and release-site effects on the distance elk moved from release sites at 1, 6, and 12 months post-release. If differences were detected among age classes or between sexes, we reanalyzed the data to evaluate differences within age or sex classes among release sites. Results are presented as mean ± SD and were considered different if \( p \leq 0.05 \).

Comparison of Release-Site Characteristics

We used ArcView 3.2 with Patch Analysis and Geoprocessing Wizard extensions (ESRI 1999), Kentucky National Land Cover Data (KNLCD), and our knowledge of each site to quantify 12 landscape characteristics within a 314 km² area (10-km radius circle) centered around each release site. We selected this distance because it is the width of an average adult elk home range in Kentucky (J. L. Larkin unpublished data). Eleven of the 12 release-site characteristics were measured using ArcView 3.2 and the Patch Analysis extension. These included percent forested cover, forest-edge density (km/km²), number of forest patches, mean forest patch size, percent openland, openland-edge density (km/km²), stream density (³rd order) (km/km²), distance to nearest road, road density (km/km²), number of active mines, and distance to nearest active mine. Degree of public access (high, medium, and low) was determined for each release site based on ownership (public or private), accessibility (gated or ungated), and types of human activities permitted (e.g., mining, hunting, horseback riding, etc.). These 12 variables were selected due to their influence on elk behavior and ecology in established populations (Thomas et al. 1976; Irwin & Peek 1979; Ferguson & Keith 1982; Kuck et al. 1985; Lyon & Thomas 1987; Cassirer et al. 1992; Wisdom & Cook 2000). KNLCD were developed from 1988 to 1994 30-meter Landsat thematic mapper data acquired by the Multi-Resolution Land Characterization Consortium (Murray State University, Murray, KY, U.S.A.). Ground-truthing of KNLCD in 1999 indicated 80% accuracy (D. Zourarkis, Kentucky Natural Resources and Environmental Protection Cabinet, 1999, personal communication). To further ensure accuracy of the KNLCD, we used 1995 aerial photographs (Kentucky Natural Resources and Environmental Protection Cabinet) and aerial flights from 1998 to 2001 of the area surrounding each release site. Errors detected in the imagery were corrected before analysis.

Because of small sample size (\( n = 3 \) release sites), we did not statistically test for effects of landscape features on release-site fidelity. Rather, we tabularized the 12 landscape characteristics for each release site and qualitatively discussed the trends associated with the degree of site fidelity exhibited by elk.

<table>
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<th>Release Site</th>
<th>Adult Bulls</th>
<th>Adult Cows</th>
<th>Yearling Bulls</th>
<th>Yearling Cows</th>
<th>Calf Males*</th>
<th>Calf Females*</th>
<th>Total</th>
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<td>10</td>
<td>23</td>
<td>7</td>
<td>16</td>
<td>104</td>
</tr>
<tr>
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<td>190</td>
<td>20</td>
<td>68</td>
<td>73</td>
<td>66</td>
<td>415</td>
</tr>
</tbody>
</table>

*Translocated calves were ≥8 months of age at time of translocation.

Results

Number of Elk Released

During the first year of elk restoration, 168 radio-collared elk were translocated from Kansas (\( n = 9 \)) and Utah (\( n = 159 \)) and released at Cyprus (Table 1). Forty-seven (28%) elk died within 6 weeks post-release from capture-related injuries and were not included in the analyses. In addition, 22 (13%) died within 1 year post-release from automobile collisions (\( n = 3 \)), poaching (\( n = 2 \)), out-of-zone removal of problem elk by KDFWR (\( n = 2 \)), disease (\( n = 2 \)), and unknown causes (\( n = 13 \)). Malfunctioning transmitters resulted in the partial exclusion of seven (4%) elk from the analyses. At the end of 1 year, 89 (53%) elk released at Cyprus had functioning transmitters.

During the second year of the study, 143 radio-collared elk were translocated from Utah and released at Orr (Table 1). Three (2%) elk died within 6 weeks post-release from capture-related injuries and were not included in the analyses. In addition, five (3%) died within 1 year post-release from automobile collisions (\( n = 2 \)), poaching (\( n = 1 \)), and unknown causes (\( n = 2 \)). Ten (7%) elk lost their collars before 1 year and were partially excluded from the analyses. At the end of 1 year, 125 (87%) of the elk released at Orr had functioning transmitters.

During the third year, 104 radio-collared elk were translocated from Utah (\( n = 47 \)) and Oregon (\( n = 57 \)) and released at Redbird (Table 1). Eighteen (17%) elk died within 6 weeks post-release from capture-related injuries and were not included in the analyses. An additional 15 (14%) animals died within 1 year from automobile collisions (\( n = 4 \)), meningeal worm (Parelaphostrongylus
tenuis) (n = 2), out-of-zone removal (n = 2), feral dog (Canis familiaris) predation (n = 1), and unknown causes (n = 6). Three (3%) elk lost their collars before 1 year and were partially excluded from the analyses. At the end of 1 year, 68 (65%) elk released onto Redbird had functioning transmitters.

Release-Site Fidelity

As only three adult male elk were translocated to Kentucky, this age class was excluded from the analysis. The distance elk moved differed among release sites (F2,322 = 4.63, p = 0.01), age classes (F2,322 = 4.37, p = 0.01), and time intervals (F2,322 = 40.74, p < 0.001)(Table 2; Fig. 1). After 1, 6, and 12 months, elk released at Orr moved a shorter distance than elk released at Cyprus and Redbird (Table 2). After 1 year post-release, the proportion of elk that remained within 10 km of each site was 53, 55, and 82% for Cyprus, Redbird, and Orr, respectively. At 6 and 12 months post-release, adults (15.81 ± 17.32 and 16.38 ± 20.29, respectively) and yearlings (13.91 ± 16.44 and 14.61 ± 21.11, respectively) moved farther from release sites than calves (8.06 ± 14.03 and 9.37 ± 14.40, respectively). Sex effects were not detected in our study (F1,322 = 0.18, p = 0.67). No interactions between release site and age class (F4,322 = 0.82, p = 0.51), release site and sex (F2,322 = 0.10, p = 0.91), or release site and time-post-release (F1,322 = 0.87, p = 0.48) were detected.

We observed similar trends in distance moved within each age class. At 1, 6, and 12 months post-release, adults, yearlings, and calves released at Orr moved shorter distances than those released at Cyprus and Redbird. Although greater fidelity at Orr was apparent among age classes (Table 2; Fig. 1), within-age class release-site effects were statistically significant only for adults (F2,155 = 5.67, p = 0.004), but not for yearlings (F2,66 = 1.56, p = 0.22) or calves (F2,104 = 1.42, p = 0.25).

Comparison of Release-Site Characteristics

Redbird had the most forest (90%) within 10 km of the release site (Table 3; Fig. 2c). The area surrounding Orr was also extensively forested (84%), but the landscape was more fragmented than at Redbird (Table 3; Fig. 2b). There were nearly twice as many forested patches surrounding Orr and Cyprus sites than Redbird. However, mean forest patch sizes surrounding Orr (28 ha) and Cyprus (27 ha) were nearly half the mean of forest patches surrounding Redbird (54 ha).

The amount of non-forested land within 10 km of each release site ranged from 9420 ha (30%) for Cyprus to 2826 ha (9%) for Redbird (Table 3; Fig. 2). Cyprus had twice as much openland compared with Orr, but the latter had more edge. The structure and composition of edge varied from abrupt mature forest-grassland edge to more gradual transitions between mature forest-shrub-grassland. Common plant species found in transitional edge habitats included red maple (Acer rubrum), eastern redbud, American beech, black locust (Robinia pseudoacacia), blackberry (Rubus spp.), green brier (Smilax spp.), multiflora rose (Rosa multiflora), and bush clover.

Stream densities ranged from 0.19 km/km² at Orr to 0.40 km/km² at Cyprus. Road densities were similar among all three sites and ranged from 0.33 to 0.36 km/km². The nearest paved roads were 5, 4, and 0 km from Cyprus, Orr, and Redbird, respectively. The elk release site at Redbird was less than 200 m from a paved two-lane U.S. highway. Mining activity was greatest surrounding Cyprus where the nearest active coal mine was 1 km, and where five other active surface mines were within 10 km of the release site. The nearest active mine at Orr was 2.5 km and there was only one active mine within 10 km of the release site. No mining occurred within 10 km of Redbird. Because Cyprus and Redbird were public wildlife management areas with at least four access points each, we ranked the degree of human access as high for both sites. The privately owned Orr site had two access points that were gated, and thus received a low score for human access.

Discussion

The constraints associated with the objectives of elk restoration in Kentucky (Larkin et al. 2001) necessitated the release of elk at one release site annually during the first 3 years of the effort. Although this precluded the use of additional statistical analysis (i.e., multiple logistic regression or discriminant analysis) due to low sample size (n = 3), general patterns regarding demographics, landscape features, and release-site fidelity were apparent. Results of the demographic analysis support our inference that differences in fidelity among release sites likely were due to landscape composition and configuration rather than demographic effects. For example, adults and yearlings generally moved farther from release sites than calves, however, demographic trends were remarkably consistent among release sites and could not overtly account for the observed differences in site fidelity.

Contrary to our prediction, elk tended to abandon more open habitat (Cyprus) which they often prefer (Thomas et al. 1976; Whitaker & Hamilton 1998). Although none of the Kentucky release sites approached the 60:40 habitat ratio recommended by Thomas et al. (1976), the area with the most openland elicited the same site fidelity as the most forested (Redbird). Thus, there was no trend in the relationship between land cover characteristics and elk establishment. Clearly the amount of open, forage-producing habitat associated with a release site is insufficient, in and of itself, to predict the degree of site fidelity exhibited by elk.

Spatial configuration of habitat patches at the landscape level affect population and community-level processes (Harris 1984; Lidicker 1995; Hansson 2000; Ricketts 2001). For example, colonization of vacant habitat by translocated bighorn sheep (Ovis canadensis) in the intermountain west was facilitated by open vegetation and

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Table 2. Distance elk moved away from release sites 1, 6 and 12 months post-translocation to southeastern Kentucky.

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<th>Age</th>
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<th>Distance (km) at 6 months</th>
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<td>5.3</td>
<td>8</td>
<td>16</td>
<td>9.3</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td>81</td>
<td>6.2</td>
<td>2.4</td>
<td>0.6</td>
<td>11.3</td>
<td>82</td>
<td>14.7</td>
</tr>
</tbody>
</table>

*a* "All" means all elk released at a given site.

*b* "B" means both males and females of a given age class.

*c* Adult males were excluded from all analyses.
rugged broken terrain, and hindered by water barriers (Singer et al. 2000). The interspersion of plant communities within a landscape may be a better predictor of release-site fidelity for elk than the total amount of specific cover types. It is well established that the elk is an ecotonal species (Murie 1951), and that landscapes with a mosaic of forests and grasslands can support high elk densities (Skovlin 1982). However, a reduction in open habitat use by elk may occur with increasing distance from forest edge (Grover & Thompson 1986; Wisdom & Cook 2000). After 1 year, elk released at Orr exhibited a higher degree of site fidelity than elk released elsewhere. Although both Redbird and Orr landscapes consisted primarily of forest, mean forest patch size at Orr was only half of that found at Redbird. A large (4000 ha) contiguous forest and several large patches of reclaimed grassland in the Cyprus landscape reduced edge availability. Among the three release sites, Orr contained the most edge, which likely contributed to the high release-site fidelity of elk at this site.

Anthropogenic disturbance may cause elk to abandon migratory routes, home ranges, and preferred habitats (Geist 1982; Lyon & Ward 1982). Surface mining for coal may affect home ranges and movements of reintroduced elk through the use of heavy machinery, explosives, and subsequent habitat modification. Kuck et al. (1985) reported that elk calves subjected to simulated mine disturbances in Idaho moved greater distances, used conifers more, and occupied poorer habitat than calves not subjected to mining disturbances. Additionally, cow-calf pairs abandoned traditional calf-rearing areas when subjected to simulated mine disturbances (Kuck et al. 1985).

Active mines were more numerous and closer to Cyprus than to the other release sites. Elk released onto Cyprus also had a line-of-sight view of an active mine that was approximately 1 km from the release site. Some areas surrounding Cyprus were regularly disturbed by mining activities and were not used by elk during year 1. Despite these findings, no clear pattern emerged regarding the impact of mining on release-site fidelity of elk, and further discussion would be speculative. The extent to which elk were disturbed by mining in Kentucky and its impact on release-site fidelity remains unclear. Although mining may negatively affect elk behavior, herbaceous openings and edge created by mine reclamation will likely enhance elk range in Kentucky. Such was the case in Pennsylvania where reclaimed mineland provided elk with an important source of grasses and legumes in an otherwise forested landscape (Cogan 1996).

Roads, motor vehicle use, and associated human activities impact elk habitat use and movements in the west.
Road densities were similar in all three release areas, however, differences in elk movement might be related to the way such roads are used. In Kentucky, release-site fidelity was lowest in public-use areas (Cyprus and Redbird), and highest on Orr where access was closed to the public. A higher degree of public access combined with landscape features that facilitated human–elk contact may have contributed to the observed differences in release-site fidelity. The few herbaceous openings in and around Redbird were adjacent to roads that were frequented by people in vehicles. Additionally, large, relatively flat reclaimed grasslands in the Cyprus landscape facilitated elk-viewing by people. Translocated elk on Cyprus were disturbed 10 times by humans and one time by hunting dogs during 60 days and 702-hr of observation (Olsson 2000). These disturbances resulted in elk seeking forested cover that was an average 875 m away (Olsson 2000). Human activities in the western U.S. usually result in temporary displacement of elk from preferred habitat (Irwin & Peek 1979; Ferguson & Keith 1982; Wright 1983; Cassirer et al. 1992). Human disturbances may have more serious effects on newly restored elk populations that may already be stressed from capture and translocation, lack social cohesiveness, and are unfamiliar with the landscape. Familiarity leads to occupation traditions that are important in determining site selection by group-forming animals such as elk (Morse 1980).

Potential Impacts on Population Establishment

Translocated herbivores generally exhibit a higher degree of release-site fidelity than omnivores and carnivores (Rogers 1988; Griffith et al. 1989). Although most of the elk that moved the farthest distances from Kentucky release sites were adults, their initial colonization movements were more like those of subadult dispersers than established residents (Wichrowski 2001; Larkin et al. 2002). Movement from an unfavorable site is worthwhile when the environmental conditions are better elsewhere (Gadgil 1971); however, if unfavorable conditions are continuous in space and time then the tolerance of suboptimal conditions may outweigh dispersal (Gadgil 1971). The ecological consequence of elk movement from release sites (colonization) is twofold. First, movement will influence the lifetime reproductive output of each individual because habitat quality dictates fecundity and survival. Secondly, it will influence the distribution of the population across the landscape and thus the colonization rate and total population size (Tyre et al. 1999). An exodus of animals from release sites may distribute elk widely across the restoration zone, but the resulting density of individuals may be insufficient to promote population growth and stability (Gogan & Barrett 1988; Schmitt & Aho 1988; Wabakken et al. 2001; Larkin et al. 2002). For example, reproduction during the first year of elk restoration in Kentucky was lower than expected because movements.
by several adult cows terminated in areas where mates were lacking (Larkin et al. 2002).

Colonizing individuals can also experience low survival (Errington 1946; Lidicker 1975; Ebenhard 1991). In a small, reintroduced population where translocation mortality may already be high, additive mortality associated with dispersal may reduce the population size below the establishment threshold. Demographic fluctuations associated with coincidental effects of high death rates and low birth rates in a small population could further reduce population size to a level that is unrecoverable (Gilpin & Soulé 1986; Lacy 1993).

Conclusion

Release-site fidelity of translocated elk in Kentucky appears to be influenced by a combination of disturbance and landscape structure. When selecting release sites, managers should avoid areas dominated by a single cover type with little interspersion of other habitats. Rather, areas with high levels of open-forest edge (approximately 5.0 km/km²) will likely enhance release-site fidelity and promote restoration success. Additionally, human access to potential release sites should be limited at least temporarily to allow translocated animals to adjust to their new environment. An understanding of translocated elk response to mining, roads, logging, recreational viewing, and off-road vehicle use should be a future research priority. Such studies may allow managers to avoid pitfalls of elk translocation and more rapidly achieve population establishment.

If a reintroduced elk population is required to stay within a limited range, managers may want to consider only translocating calves. In our study, calves (approximately 8 months old) exhibited a higher degree of release-site fidelity compared with adults and yearlings regardless of where they were released. However, we recommend using calves only in cases where restoration zones are extremely small. A lack of reproductively mature individuals during the early years of an elk restoration effort may inhibit population establishment. Successful reintroduction was enhanced by immediate reproduction by translocated elk in California (Gogan & Barrett 1988). By translocating only calves, reproduction will be curtailed because (1) it will take at least 2 years before calves reach reproductive maturity, and (2) offspring born to pregnant translocated adult females will be lost.

Finally, the low number of release sites (n = 3) examined in this study prevented a detailed statistical investigation of landscape factors that influence release-site fidelity. Funding, logistics, and time will likely limit any single agency from releasing elk to a sufficient number of sites, thus limiting any one agency's ability to experimentally examine optimal release-site characteristics. We recommend a collaborative effort among the Appalachian states that are actively restoring elk populations. A larger number of release sites and concomitant colonization data will allow the use of additional statistical analyses and strengthen our understanding of factors that influence release-site fidelity in restored elk populations.

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