

Use of water developments by female elk at Theodore Roosevelt National Park, North Dakota

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Development of water sources for wildlife is a widespread management practice with a long history; however, needs of wildlife and availability of water depend on myriad interacting factors that vary among species and localities. Benefits are therefore situational, establishing a need for evaluation of water use in varied settings. We used global-positioning-system (GPS) collars and time-lapse videography to estimate the distribution of elk (*Cervus elaphus*) activity and frequency of water-development use at Theodore Roosevelt National Park, North Dakota, during June–September, 2003–2006. Elk were located further than expected from the Little Missouri River and did not preferentially use areas near developments. Of 26,081 relocations obtained at 7-h intervals, 88% were >800 m and 74% were >1600 m from permanent surface water. Elk were videotaped at water developments on 90 occasions during 19,402 h of monitoring but used water in only 52% of cases ($SE = 5.3\%$). The probability of detecting elk at developments during visits was 0.51 ($SE = 0.08$). Nevertheless, elk tracked with GPS collars at 15-min intervals approached to within 100 m of developments on only 2.7% ($SE = 0.6\%$) of 766 days, and approached randomly selected locations nearly as frequently ($\bar{x} = 2.2\%$, $SE = 0.13\%$). Our results do not rule out use of drinking water by elk at THRO; however, elk were not dependent on water from developments or the Little Missouri River. Prevailing perceptions of water use by elk derive primarily from general associations of elk activity with locations of water sources. Technological advances that permit nearly continuous, precise monitoring present an opportunity to improve understanding of water use by elk, incidental to other investigations.

Key words: elk, *Cervus elaphus*, distribution, North Dakota, Theodore Roosevelt National Park, videography, water developments, water use

Development of water sources for wildlife is a widespread—but costly and controversial—management practice. From 1940 to 1999, government agencies and private conservation groups constructed approximately 6,000 developments in arid regions of 10 western states (Rosenstock et al. 1999). Developments also have been constructed by federal agencies and private conservation groups, and in less arid areas, including the northern Great Plains. By 1988, the annual cost of maintenance by the Arizona Game and Fish Department reached \$1034/site (deVos and Clarkson 1990, Broyles 1995). In Arizona, the construction cost for a typical water development ranged from \$25,000 to \$50,000 by 1992 (Mouton and Lee 1992).

For decades, needs of ungulates for free water, hence benefits of developments, seemed logical and self-evident (Brown 1998, Rosenstock et al. 1999). Indeed, developments were used frequently by wildlife (Brown 1998, Rosenstock et al. 2004). Observation and radio-tracking often revealed associations between activity or distribution and locations of water sources (Mackie 1970, McCorquodale et al. 1986, Hervert and Krausman 1986). Abundance or distribution of some species reportedly increased concurrently as water sources were developed (deVos and Clarkson 1990, Rosenstock et al. 1999). Since the 1990s, however, high costs and competing interests in management of natural areas have motivated greater scrutiny of evidence and interpretations (Broyles 1995, Bleich 2005, Krausman et al. 2006).

In fact, water needs of North American ungulates are not well understood (Smith and Krausman 1988, Cain III et al. 2006). Lacking access to free water, ungulates employ physiological and behavioral adaptations to reduce water needs while maintaining normal body temperatures (Sargeant et al. 1994, Cain III et al. 2006). Developments may also be used preferentially when natural sources of water, including succulent forage, could suffice. Use of developments is therefore insufficient evidence of a population-level benefit. Evidence for effects on vital rates or abundance is still largely anecdotal (Brown 1998, Krausman et al. 2006). If concentrating ungulates at water sources leads to adverse effects on vegetation, increased predation, or disease, development of water sources for wildlife could even be counterproductive (Broyles 1995).

Controversy surrounding development of water sources for wildlife first emerged, and continues most prominently, in the desert southwest. Polarized views of water management testify to difficulties that are inherent in documentation of water needs and potential effects of water availability on populations. The behavioral and physiological adaptability of ungulates, environmental variability, availability of replicate sites and populations, and costs of experimental control have been difficult to overcome (Cain III et al. 2008). For small populations of large mammals, process variation is likely to obscure any effect on vital rates. Rare events that are unlikely to be observed during a given study may have serious population consequences if they occur (e.g., Swift et al. 2000).

Despite uncertain effects on animal populations, observed use of developments by wildlife in the southwest has encouraged development of water sources in more temperate regions as well. Need remains for knowledge of use in temperate environments because

developments clearly do not improve survival, enhance fecundity, or modify distribution if they are not used by the species they are intended to benefit. An understanding of use under conditions that span the range of circumstances encountered in practice can therefore help direct conservation dollars toward projects with greatest potential for benefit.

Development and maintenance of water sources for elk (*Cervus elaphus*) in the northern Great Plains exemplifies extension of a costly management practice to a species and environment where even the potential for benefit is uncertain. We thus used global-positioning-system [GPS] collars and videography to (1) describe relations between the distribution of activity and locations of permanent water sources and (2) estimate rates of use for water developments by female elk at Theodore Roosevelt National Park (THRO), North Dakota.

MATERIALS AND METHODS

Study area.—Theodore Roosevelt National Park encompassed 18,756 ha of unglaciated badlands topography (Laird 1950) near Medora, North Dakota (46° 57' 17" N, 103° 28' 19" W). Most of the area was mixed-grass prairie dominated by needle-and-thread (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), threadleaf sedge (*Carex filifolia*) and various forbs; however, stands of juniper (*Juniperus scopulorum*) occurred on some north-facing slopes and stringers of green ash (*Fraxinus pennsylvanicus*) were associated with draws. Stands of cottonwood (*Populus deltoides*) occurred along the Little Missouri River (Hanson et al. 1984). During our study, known sources of permanent surface water included the Little Missouri River, 6–7 functioning water developments, and 3 permanent springs that were not developed (Figure 1; water was not available at SEC

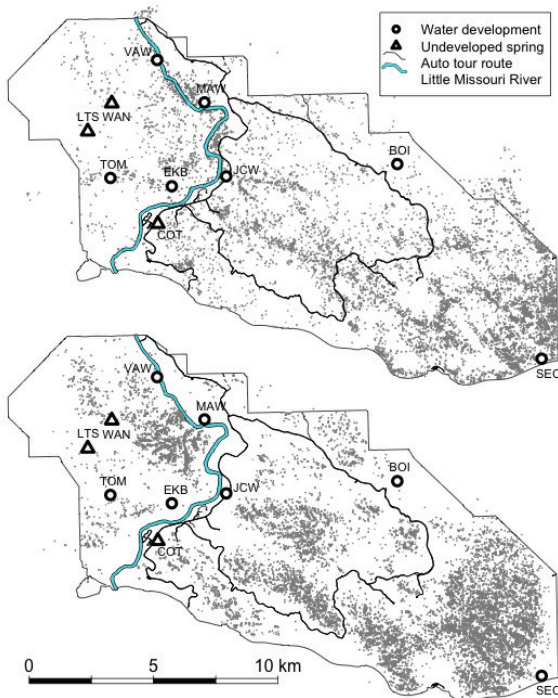


FIGURE 1.—Nighttime (top, $n=10,737$) and daytime (bottom, random subsample of 10,737 from $n = 15,344$) distributions of locations for 91 elk marked with global positioning system collars at Theodore Roosevelt National Park, North Dakota, during June through September, from 2003 to 2006. To enhance contrast, shading of each point is proportional to nearest neighbor distance; i.e., points are darkest in regions of greatest point density.

during 2003). Developments consisted of modified springs and seeps or shallow artesian wells that fed 1,200–2,000 liter fiberglass or concrete tanks. Tanks were installed during the 1960s as part of the wildlife management program (Berkley et al. 1998), but also served to prevent degradation of springs and seeps by livestock (NPS files).

Elk numbers in January ranged from approximately 500 in 2003 to 850 by 2006 (Sargeant and Oehler 2007). Other large herbivores included bison (*Bison bison*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), pronghorn (*Antilocapra americana*), and feral horses (*Equus caballus*). Bison and horses were confined to the park by a 1.8–2.4-m woven-wire boundary fence. Other species could traverse the boundary through several man-made wildlife crossings.

The climate at THRO was semi-arid. Warm days and cool nights were typical during the summer. Daytime highs averaged 22°C during June and September and 29°C during July and August, with average nighttime lows of 9°C and 14°C for the same periods. Relative humidity ranged from 43% (average daytime low) to 84% (average nighttime high) during June, and from 32% to 77% during July–September. Annual precipitation was approximately normal (41 cm [National Oceanic and Atmospheric Administration 2010]) in 2003 (38 cm) and 2005 (40 cm), and less-than-normal in 2004 (26 cm) and 2006 (20 cm). Precipitation was less than normal (21 cm) during June–September of 2004 (15 cm), 2005 (19 cm), and 2006 and greater than normal in 2003 (26 cm) (National Park Service 2014).

Methods.—We used GPS radio-telemetry collars (Advanced Telemetry Systems, Isanti, Minnesota, USA) to relocate female elk at nominal 15-min or 7-h intervals during June–September. Marked elk were captured in February with a helicopter and net gun by Leading Edge Aviation of Clarkston, Washington, USA. Captures were distributed throughout THRO, approximately proportional to elk numbers in the western, central, and eastern reaches of the park. We monitored each marked elk for approximately 10 months, then used remotely triggered release mechanisms to recover collars and download data stored in collar memory. Research protocols were approved by the Research Advisory Committee and Animal Care and Use Committee at the U.S. Geological Survey Northern Prairie Wildlife Research Center.

Some elk that wintered within THRO occupied summer ranges up to 70 km from the park and did not have access to water sources we studied (G. A. Sargeant, unpublished data). We therefore restricted our analysis to non-migratory residents. We used locations obtained at 7-h intervals to estimate proportions of time spent in the park and to relate the distribution of elk activity to the distribution of permanent sources of surface water. To document approaches to developments and undeveloped springs, we computed minimum distances to water from line segments connecting 24-h sequences of locations obtained at 15-min intervals (trajectories). For comparison, we also computed the minimum distance from each trajectory to 1000 points selected at random from within the area used by the same elk during the same year. To minimize potential for failing to detect visits to developments, we excluded trajectories spanning <23 h. We used characteristic hulls with minimum edge lengths of 0 (Duckham et al. 2008) and locations obtained at 7-h and 15-min intervals to delineate areas used by individual elk. We used characteristic hulls because they do not require equal sampling intervals and do not fragment or extend beyond data when sample sizes are large, yet follow contours of irregularly shaped ranges.

Elk marked with GPS collars could potentially visit water developments during 15-min intervals between relocations, and approaches were not necessarily motivated by interest in water. Hence, rates of detection near developments could have either underestimated or

overestimated use. We used time-lapse video cameras to document behavior of elk at water developments from 0300 to 2100 Mountain Standard Time during June–September, 2003–2004. When elk approached to within approximately 50 m of developments, we recorded the site, date, time of arrival and departure, minimum group size, group composition (males, females, young; uncertain), and whether or not the observation involved water use. To minimize effects on elk, we concealed video systems behind topographic features or vegetation 75–200 m from developments and visited weekly, during midday, for routine maintenance and to exchange videotapes. We used video records to estimate durations of visits and proportions of visits that involved use of developments. We used a parametric bootstrap procedure to estimate bias resulting from visits that occurred during intervals between locations (Appendix D).

We assigned GPS telemetry locations to 6 intervals defined with respect to civil twilight. Civil twilight begins in the morning and ends in the evening when the sun is 6° below the horizon, and refers to the period when objects generally can be distinguished without artificial light (U. S. Naval Observatory 2011). “Night” began in the evening at civil twilight and ended at “dawn.” Dawn described an interval centered about sunrise, beginning with civil twilight and lasting 60 (September 30) to 80 min (ca. 21 June). Similarly, “dusk” began 30 min to 40 min before sunset and ended 60 to 80 minutes later, with civil twilight. “Morning,” “midday,” and “evening” partitioned the period between dawn and dusk into three intervals of equal length (collectively, “daytime”).

RESULTS

Our analysis included 91 resident female elk ($n = 19$ –28 annually) that were located within THRO on 91 to 100% (median $[\tilde{x}] = 99.7\%$) of occasions. Areas used seasonally by individuals ranged in size from 11 to 57 km² ($\tilde{x} = 31$ km², interquartile range $[IR] = [27$ km², 37 km²], $n=91$). Elk foraged during the night in gentle terrain of valley bottoms, prairie dog towns, or in uplands along the eastern boundary of the park (Figure 1, top), then moved into adjoining, more rugged terrain for the day (Figure 1, bottom). Park-wide, daytime elk activity was concentrated in areas that were distant from roads or concealed by topography and not near permanent sources of surface water. Distances from locations to the Little Missouri River ($\tilde{x} = 9097$ m, $IR = [2924$ m, 12,232 m]) were much greater than expected ($\tilde{x} = 4180$ m, $IR = [1624$ m, 8174 m]), and 57% of elk (52) used areas that did not intersect the river. Observed distances from locations to developments and springs ($\tilde{x} = 2919$ m, $IR = [1706$ m, 4269 m]) were similarly greater than expected distances ($\tilde{x} = 2417$ m, $IR = [1295$ m, 3767 m]). Elk were located >800 m from permanent sources of surface water in 88% of cases, and >1600 m in 74% of cases.

We obtained 19,402 h of video at 7 developments (6 in 2003 and 7 in 2004) and observed elk on 90 occasions. Elk were observed drinking from developments on 47 occasions (52%, $SE = 5.3\%$). Elk that used water typically visited developments singly or in pairs (53% of visits, $SE = 5.3\%$); however, minimum group sizes ranged from 1 to 50, and 21% of observations accounted for 65% of visits by individuals. Female elk that used water developments remained within view of cameras (typically within 50 m) for >15 min in 25% of cases and for >8 min in 50% of cases. Approximately 51% ($SE = 8\%$) of visits by collared elk should, therefore, have encompassed >1 GPS relocation, and locations typically were accurate to within 35 m (95% of reference locations).

We analyzed 766 trajectories (140 in 2003, 209 in 2004, 164 in 2005, and 253 in 2006) that provided nearly complete records of movement. Each of these spanned ≥ 23 h, and elapsed time between locations was 15 min for 97% of 67,783 intervals. Elk typically traveled 4.8 to 7.7 km (*IR* daily). The median travel distance from the center of nighttime activity to the center of midday activity the following day was 1.1 km (*IR* = [0.7 km, 1.8 km]). Distances between centers of activity exceeded 1600 m on 30% and 2400 m on 13% of dates.

Despite the extent of daily movements, elk typically did not approach permanent water sources (Figure 2). Trajectories approached to within 100 m of developments on just 21 occasions (2.7% of trajectories, *SE* = 0.6%) and were located nearly as often (2.2% of traces, *SE* = 0.13%) within 100 m of points selected at random. Approaches occurred during dawn (3), dusk (3), or at night (14), but were distributed among years and developments (i.e., 3–6 approaches per year; 1–4 approaches per development). Trajectories did not approach undeveloped springs.

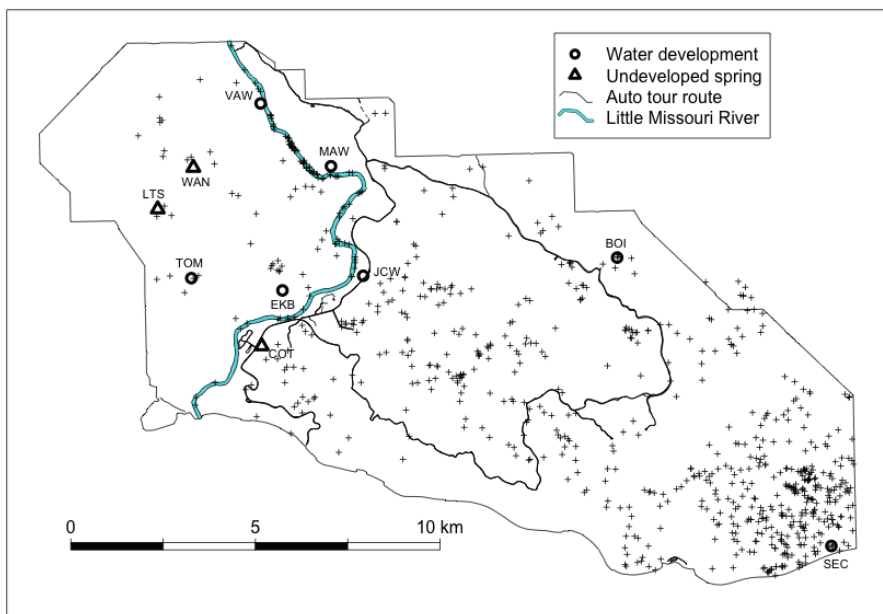


FIGURE 2.—Nearest location to a water development (BOI, EKB, JCW, MAW, SEC, TOM, VAW), permanent spring (COT, LTS, WAN), or the Little Missouri River for each of 766 24-h sequences of locations obtained at 15-min intervals for 91 female elk at Theodore Roosevelt National Park, North Dakota, during 2003–2006.

DISCUSSION

Expansion of elk populations into arid shrubsteppe, woodland, and forest habitats of the western U.S. has been credited, in substantial part, to development of water sources for wildlife (Rosenstock et al. 1999). More generally, lactating female elk are thought to be seasonally dependent on surface water (Delgiudice and Rodiek 1984, Skovlin et al. 2002). However, water needs have been inferred almost entirely from observed associations between elk activity and locations of natural or developed water sources (e.g., Mackie

1970, Delgiudice and Rodiek 1984, McCorquodale et al. 1986). Contrasting results from THRO suggest a need to further evaluate use of water developments in varied settings and invite scrutiny of evidence for perceived water needs.

Use by target species is an implicit presumption in much discussion of water developments. However, fundamental questions usually remain unanswered (e.g., effects on survival, reproduction, movements, distribution, and habitat use) because use is not an assurance of benefit. With limited understanding of water needs and availability of water from other sources, and without *a priori* knowledge of movements and distribution, preference and association cannot be distinguished from need or causation (Larsen et al. 2012). Interpretation is clearer when developments rarely are used. At THRO, elk approached developments too infrequently to suspect a substantial effect on vital rates or distribution.

Elsewhere, use of developments has been related to site characteristics and discouraged by the presence of feral horses (Ostermann-Kelm et al. 2008, Shields et al. 2012). Similarly, accessibility of the river and avoidance of roads could have discouraged use of some developments we studied. However, elk used areas adjacent to roads at night, when most observed approaches occurred, and we did not observe substantial variation in use that might indicate preference for secluded sites, greater need for sites far from the river, or avoidance of horses (which used predominantly BOI [70% of videotaped visits; G. A. Sargeant, unpublished data]). Regardless, greater use of developments could not have produced substantial gains in survival or reproduction, which approached maxima for elk (Sargeant and Oehler 2007).

Neither our results for THRO nor previous studies of habitat selection support general conclusions about benefits of developments or water needs of elk. On one hand, lack of association with permanent sources may not rule out periodic access to undocumented sources of drinking water. At THRO, for example, heavily eroded clay soils and ever-changing topography are distinctive features of the badlands habitat. These features contribute to formation of ephemeral, locally fed seeps or rainwater pools in gully bottoms (Berkley et al. 1998). On the other hand, use of areas near natural water sources is insufficient evidence of water use because proximity to water often is associated with other features that may attract elk (e.g., low elevation, moist soils, cool microclimates, and green or growing vegetation). In Arizona, for example, Delgiudice and Rodiek (1984) concluded that availability of succulent, digestible forage probably influenced elk preference for areas near water. Similarly, water developments are likely to be situated in areas with characteristics that encourage use by wildlife and facilitate water collection.

Although habitat use may not be indicative of habitat requirements or reveal purposes of habitat selection (Peek et al. 1982, Cook et al. 1998), associations between elk activity and locations of water suggest broader purposes than access to drinking water. Despite the wide distribution and interspersed areas used during day and night, elk at THRO often traveled >1.6 km from nighttime to daytime centers of activity. Elk in southeastern Idaho traveled considerably further to feed at night in cropland ($\bar{x} = 4.4$ km; Strohmeier and Peek [1996]). Despite association of activity with locations of natural springs, the average distance between locations on consecutive days was >2 km for elk inhabiting the Arid Lands Ecology reserve in southcentral Washington (McCorquodale et al. 1989). Given such mobility, water needs alone do not necessitate strong selection for areas very near water (i.e., 0.2–0.8 km; examples in Skovlin et al. 2002).

Correlation, rather than causation, is further suggested by preference for areas near water even in moderate environments. In northern Idaho, for example, more than 95% of locations during fall were within 400 m of water, coinciding with a decrease in use of higher elevations (Irwin and Peek 1983). Changes in distribution associated with changes in rainfall (Schoen 1977) may reflect effects on soil moisture and forage (Marcum and Scott 1985), rather than increased use of water sources during dry periods.

Finally, it seems that perceived water needs for lactation, which emerged as an explanation for observed habitat use, may not reflect elk physiology. For captive elk with ad libitum access to water and feed, milk volume began to decline about three weeks post-partum; by August, water volume of milk was 1.5 to 2.1 liters daily, or 0.6 to 0.9% of maternal body mass (calculations based on results of Robbins et al. [1981] and a birth date of 1 June [Hudson et al. 2002]). We could not find estimates for free-ranging elk; however, the marginal cost of lactation for black-tailed deer (*Odocoileus hemionus sitkensis*) was approximately 9% of total water transfer (Parker et al. 1993). As a percentage, the marginal cost of lactation is likely to be greater for species that are adapted for water conservation.

From our results and review, we conclude principally that water needs and water use by free-ranging elk and benefits of water developments are not well understood. Costs of constructing and maintaining developments establish a need to evaluate use, not only in arid environments, but also under diverse circumstances encountered in practice. The information need for elk management is not merely *whether* elk require drinking water or benefit from development of water sources (which we take as a given for sufficiently harsh environments), but when and where.

Noting the anecdotal and correlative nature of evidence for benefits of water developments, numerous authors have suggested a need for experimental evaluations (Ballard et al. 1998, Brown 1998, deVos, Jr. et al. 1998, Simpson et al. 2011). However, such experiments present formidable challenges under the best of circumstances (Krausman et al. 2006, Cain III et al. 2008). As our results show, observational study of animal movements can reveal a great deal about *potentials* for benefit when use of developments is not presumptive. We hope our work will encourage other investigators to explore relations between daily movements of elk and locations of water sources, leading to improved understanding of circumstances that encourage or discourage development of water sources for wildlife.

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**APPENDIX I: BOOTSTRAP ESTIMATION OF ELK VISITATION RATES
FROM GPS RELOCATIONS**

- 1) Transform durations of videotaped visits, t_i for i in $1:I$, to achieve an approximately normal distribution, i.e., $x_i = f(t_i)$, such that $x_i \sim N(\mu, \sigma)$.
- 2) Substitute estimates, $\hat{\mu}$ and $\hat{\sigma}$, for parameters μ and σ in sampling distributions for the mean and variance of x , i.e., $\bar{x} \sim N(\hat{\mu}, \frac{\hat{\sigma}}{\sqrt{n}})$ and $\frac{(n-1)s^2}{\hat{\sigma}^2} \sim \chi_{n-1}^2$ (Freund 1992). Use resulting distributions to generate $J=1000$ sets of simulated parameters, $\{\tilde{\mu}_j, \tilde{\sigma}_j\}$.
- 3) Generate I observations for each of the J sets of parameters by back-transforming random draws from a normal distribution, i.e., draw $\tilde{x}_{(j)i} \sim N(\tilde{\mu}_j, \tilde{\sigma}_j)$ and compute $\tilde{t}_{(j)i} = f^{-1}(\tilde{x}_{(j)i})$.
- 4) Compare each observation to a random number drawn from a uniform distribution, $\tilde{u}_{(j)i} \sim Unif(0, 15)$, representing the time elapsed from arrival at a development until the next scheduled GPS location. Each trial represents a “visit,” which was “detected” if $\tilde{t}_{(j)i} \geq \tilde{u}_{(j)i}$.
- 5) Compute the mean detection rate for each set of I simulated observations. Use the standard deviation of means to estimate the standard error of the grand mean.