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## Home Ranges of Elk in an Arid Environment

### Abstract

Home ranges of elk (*Cervus elaphus nelsoni*) inhabiting montane and coastal forests have been previously documented, but few estimates have been reported for elk occupying non-forested habitats. We analyzed the home ranges of elk inhabiting the treeless shrub-steppe of Washington using 782 relocations of eight radio-collared individuals during 1983 and 1984. Annual minimum convex polygon estimates averaged 161.4 km<sup>2</sup> for female elk and 163.1 km<sup>2</sup> for male elk. Annual ninety-five percent confidence ellipses averaged 305.1 km<sup>2</sup> for female elk and 284.6 km<sup>2</sup> for male elk. Seasonal home ranges of female elk decreased significantly each season from spring through fall. Large home ranges of elk in the shrub-steppe relative to elk in more mesic environments are hypothesized to be a strategy to compensate for low forage density in the arid shrub-steppe. These elk maintained large home ranges yet were reproductively successful, indicating that large home ranges can be an effective strategy for large herbivores faced with low food densities. We hypothesize that the success of these elk was mediated by the quantity rather than the quality of foraging areas in a prairie-like environment. Home range shapes appeared to be related to the availability of disturbance-free areas. A review of the literature suggested annual precipitation may be a relatively good predictor of home range sizes for elk.

### Introduction

Numerous home range estimates for North American elk have been published (Craighead *et al.* 1973, Waldrip and Shaw 1979, Hershey and Leege 1982, Jenkins and Starkey 1982, Irwin and Peek 1983, Edge *et al.* 1985), but these estimates have almost universally concerned elk inhabiting mesic montane or coastal forests. No data are available for elk inhabiting non-forested environments. In this paper, we report on home ranges of Rocky Mountain elk (*C. e. nelsoni*) inhabiting the arid, treeless shrub-steppe of Washington.

### Study Area

The study was conducted on the Arid Lands Ecology (ALE) Reserve, a 330 km<sup>2</sup> ecological reserve, associated with the U.S. Department of Energy's Hanford Site in southcentral Washington (46°30'N, 119°40'W). The ALE Reserve is bordered on the west and south by private rangeland and agricultural land, and on the north and east by paved public highways. Public access to the ALE Reserve is prohibited. The site is surrounded by a 110-cm barbed wire fence that did not restrict elk movements. The site is patrolled weekly by fixed-wing aircraft. The Hanford

Site is a federal nuclear materials production and processing area. However, facilities and personnel associated with these processes are limited to areas beyond the ALE Reserve boundaries.

Local vegetation of the ALE Reserve is climax-dominated by big sagebrush (*Artemisia tridentata*) and bluebunch wheatgrass (*Agropyron spicatum*), Sandberg bluegrass (*Poa sandbergii*), or cheatgrass brome (*Bromus tectorum*) (McCorquodale *et al.* 1986). Historical rangefires have removed the sagebrush canopy from approximately 90 percent of the reserve. Limited riparian vegetation occurs at several small springs in the western part of the reserve.

The physiography of the site has been described in detail by McCorquodale *et al.* (1986). Elevations range from 150 to 1,090 m. The arid site receives less than 16 cm of precipitation annually.

The elk population of the ALE Reserve was established by natural colonization during the winter of 1972. The population increased from 27 to 55 elk during this study ( $r = 0.36$ ), due entirely to reproduction (McCorquodale *et al.* 1988).

### Methods

Eight adult (4 F: 4M) radio-collared elk were relocated 782 times by ground or aerial tracking (92 percent of locations verified visually)

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between January 1983 and September 1984. Female elk were relocated three times weekly (minimum) from April through September and twice monthly during winter. Male elk were relocated twice weekly (minimum) from April through September and twice monthly during winter. Thirty-seven percent of locations were obtained from 0500 to 0900 hours, 38 percent from 0900 to 1300, and 22 percent from 1300 to 1700. We were careful not to disturb collared elk while radio-tracking, and we noted few extraneous disturbances to elk during this study. Elk locations were referenced to the nearest 100 m of the Universal Transverse Mercator System. Elk were not located more than once daily in order to reduce autocorrelation of relocations (Swihart and Slade 1985).

Annual and seasonal home range estimates were obtained by the minimum convex polygon method (MCP) (Odum and Kuenzler 1955) and by 95 percent bivariate normal confidence ellipses (CE) (Jennrich and Turner 1969). These methods were used to calculate most published estimates of elk home ranges and we selected them to enhance the comparability of our estimates.

Seasonal home ranges were calculated for spring (April-May), summer (June-August), and fall (September-October) by year. Winter home ranges were not reported due to small sample sizes; winter data were included in annual estimates. Annual estimates were calculated for 1983 and 1984.

Minimum daily mobility within the home range for female elk was indexed by calculating

the distance between consecutive day locations. These data were analyzed on the same seasonal basis as the home range data.

The null hypothesis that annual and intra-seasonal home ranges did not vary between years was tested using paired t-tests and estimates from three female elk monitored both years. The hypothesis that inter-seasonal home ranges did not vary was tested with a Kruskal-Wallis test and nonparametric multiple comparisons (Zar 1974: 156-157). Statistical tests were not conducted using data from male elk due to the small number of males marked (2 each year).

Data from this study and several others were used to test the hypothesis that precipitation influences elk annual home range size. The relationship was evaluated using simple least squares linear regression after precipitation was transformed ( $1/x$  of precipitation) to improve the linearity of the relationship. The hypothesis was tested using a t-test for slope of the regression ( $H_0: b = 0$ ). We limited the regression to polygon (minimum convex or minimum area) estimates since home range estimates are influenced by estimation method (Anderson 1982) and because more polygon estimates were available in the literature.

## Results

Sizes of annual home ranges for female elk were not significantly different between years [ $P > 0.20$  (MCP),  $P > 0.50$  (CE)], so annual estimates were pooled (Table 1). No significant differences were detected between spring ranges ( $P > 0.50$  both methods), summer ranges [ $P > 0.20$  (MCP),

TABLE 1. Home range estimates (km<sup>2</sup>) for elk on the ALE Reserve, Washington ( $\bar{X} \pm 1$  SE)

	Female Elk				Male Elk			
	N	Loc <sup>a</sup>	MCP <sup>b</sup>	CE <sup>c</sup>	N	Loc <sup>a</sup>	MCP	CE
Annual	7	85	161.4 $\pm$ 8.5	305.1 $\pm$ 23.3	3	51	163.1 $\pm$ 17.4	284.6 $\pm$ 47.2
Spring	7	20	125.3 $\pm$ 9.2	368.1 $\pm$ 43.0 <sup>d</sup>	2	12	60.7 $\pm$ 7.3	226.8 $\pm$ 15.5
Summer	7	44	95.2 $\pm$ 6.1	190.5 $\pm$ 8.8	3	25	117.7 $\pm$ 26.6	277.2 $\pm$ 99.8
Fall	7	12	25.3 $\pm$ 2.4	83.7 $\pm$ 11.7	3	11	25.0 $\pm$ 2.4	87.4 $\pm$ 23.7

<sup>a</sup>Mean number of locations per individual.

<sup>b</sup>Minimum Convex Polygon.

<sup>c</sup>Confidence Ellipse.

<sup>d</sup>Spring CE larger than annual CE due to the greater effect of outliers when location number is small.

$P > 0.10$  (CE)], or fall ranges [ $P > 0.20$  (MCP),  $P > 0.10$  (CE)] between years, so data from the two years were pooled for inter-seasonal comparisons. Spring home ranges were significantly larger than both summer and fall ranges ( $P < 0.01$  both methods), and summer ranges were significantly larger than fall ranges ( $P < 0.01$  both methods).

Individual home range polygons were similar since the population consisted of one major social group and since there was a high degree of relatedness between individuals (McCorquodale *et al.* 1988). The majority of unmarked elk on the reserve were continually associated with the marked elk except during subgrouping periods (spring, parturition, and rut), suggesting our marked elk were representative of the population. Home ranges generally conformed to the shape of the reserve (Figure 1). Elk were never located on other parts of the Hanford Site, but some did occasionally move onto adjacent private rangeland to the west. Male elk were more frequently relocated beyond the reserve's boundaries, but one marked female spent a considerable part of June and July 1984 off the reserve before returning during August. Elk located off the reserve eventually returned in every case.

Distances between consecutive day locations were greatest in spring ( $3523.0 \pm 586.3$  m [1 SE],  $n = 49$ ), smallest in summer ( $2185.7 \pm 155.3$  m,  $n = 173$ ), and intermediate in fall ( $3010.7 \pm 358.9$  m,  $n = 39$ ). Movements were more variable in spring than during the remainder of the year.

Home range data from several elk populations suggested that annual precipitation influences elk home range sizes, with home ranges decreasing with increasing precipitation ( $t = 13.6$ ,  $df = 5$ ,  $P = 0.0001$ ) (Figure 2). The relationship is also significant without our data ( $t = 3.7$ ,  $df = 4$ ,  $P = 0.02$ ). Including our data,  $r^2 = 0.97$ ; excluding our data,  $r^2 = 0.77$ .

## Discussion

Annual and seasonal home ranges of elk on the ALE Reserve were approximately 3-10 times larger than those reported in the literature for elk in forested regions (Craighead *et al.* 1973, Franklin and Lieb 1979, Waldrip and Shaw 1979, Jenkins and Starkey 1982, Irwin and Peek 1983, Edge *et al.* 1985), (Martinka 1969, Craighead *et al.* 1973, Schoen 1977, Bowyer 1981). Distances between

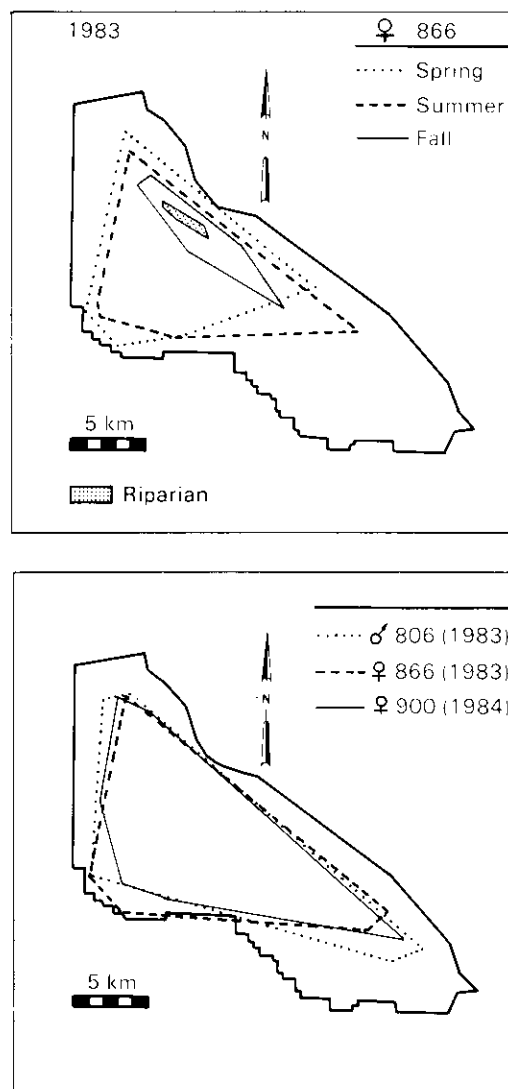


Figure 1. Annual and seasonal home range polygons of radio-collared elk on the Arid Lands Ecology Reserve, Washington, 1983-84.

consecutive day locations for the ALE population were 2-5 times greater than the same distances measured for elk populations inhabiting forested habitats (Harper 1971, Craighead *et al.* 1973, Hanley 1980, Bowyer 1981).

Estimates of home range size tend to inflate as relocations are added until an asymptote is reached. Probability ellipse estimates tend to be less sensitive to number of relocations than are polygon estimates (Anderson 1982, Eberhardt *et*

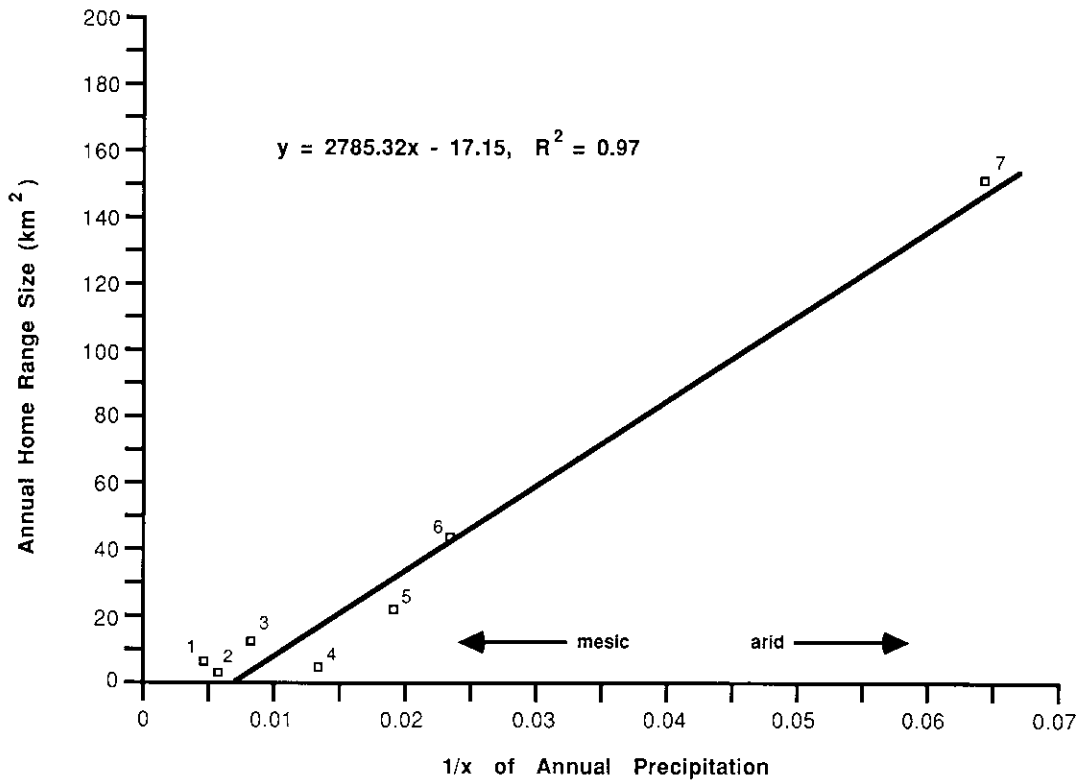


Figure 2. Linear regression of annual home range size for elk and annual precipitation (transformed  $1/x$ , where  $x = \text{cm}$ ). Data are from: 1. Janz and Becker (1986); 2. Franklin and Lieb (1979); 3. Irwin and Peek (1983); 4. Waldrip and Shaw (1979); 5. Craighead *et al.* (1973); 6. Edge *et al.* (1985); 7. this study.

*al.* 1984). Our fall home range estimates may be conservative due to the small number of relocations; however, our mean number of relocations per individual during fall represents knowledge of their location on 20 percent of all possible days within the season. Our spring sample of relocations was small relative to summer, but additional relocations in spring would only have inflated the home range estimates, thus increasing the significance of differences between spring and summer ranges.

Home range size within a species typically increases with decreasing food density (McNab 1963). Primary production on the ALE Reserve is approximately 1/5 that of temperate forests (Whittaker and Likens 1973, Rickard 1985). Variation in home range size amongst elk inhabiting a range of environments from very mesic to arid appears to be strongly influenced by precipitation which largely determines primary production (Figure 2). A general trend towards increasing home

range size with increasing aridity has been noted for a variety of mammals by Harestad and Bunnell (1979). Home ranges of mule deer (*Odocoileus hemionus*) on the Hanford Site also tended to be larger than those of deer studied in more mesic habitats (Eberhardt *et al.* 1984).

An animal's home range may reflect social factors as well as food density. Thus, as demonstrated by McCullough (1969), Varland *et al.* (1978), Franklin and Lieb (1979), and Edge *et al.* (1986), the home ranges of distinct social groups of elk are often disjunct in areas supporting multiple social groups. Since the ALE Reserve elk exclusively occupied their range, their home ranges may have lacked social constraints operating in areas supporting multiple social groups. In the shrub-steppe there also tend to be few natural geographic barriers such as drainage divides which might constrain elk movements.

Female elk home ranges and daily movements on the ALE Reserve were largest during spring

when plants were growing, while movements and home ranges appeared to decrease in summer. We hypothesize that this reflects increasing constraints on elk movements with the onset of summer drought. Summer and fall ranges of lactating elk became increasingly smaller areas centered around permanent water sources and riparian habitat (Figure 1) (McCorquodale *et al.* 1986). As grasses and forbs desiccated by early fall, succulent forage was available only in riparian habitats. Elk also showed a preference for bedding in sagebrush-dominated habitats during the heat of summer, and these areas were limited to 10 percent of the ALE Reserve (McCorquodale *et al.* 1986). Although food density was low in the shrub-steppe and elk home ranges large, these elk were reproductively quite successful (McCorquodale *et al.* 1988). This suggests that a large home range can be an effective herbivore strategy when food densities are low. We hypothesize that these elk may be successful on the basis of the quantity rather than the quality of foraging areas. In the shrub-steppe, there may be few areas that compare with mesic forest meadows in terms of forage production, but nearly the entire landscape produces forage in the absence of an overstory canopy. Locally, food densities were low, but potential foraging areas were extensive in the prairie-like habitat of the ALE Reserve.

While home range size appeared to be largely determined by forage production, home range shape and orientation appeared to be strongly influenced by the availability of disturbance-free areas. In the absence of extensive security cover, elk largely confined their activities to the secluded ALE Reserve, perhaps compensating for a lack of security cover by locating their home ranges within a large disturbance-free zone. Elk did not use other parts of the Hanford Site where human activity associated with energy technology was common. Elk were also reluctant to use agricultural lands bordering the reserve, at least during daylight hours; however, elk did occasionally use adjacent private rangeland where human activity was not common.

These results suggest that although the shrub-steppe biome is capable of supporting viable elk populations, relatively large, disturbance-free areas of contiguous habitat may be required for successful colonization.

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### Literature Cited

- Anderson, D. J. 1982. The home range: a new non-parametric estimation technique. *Ecology* 63:103-112.
- Bowyer, R. T. 1981. Activity, movement, and distribution of Roosevelt elk during rut. *J. Mamm.* 62:574-582.
- Craighead, J. J., F. C. Craighead, Jr., R. L. Ruff, and B. W. O'Gara. 1973. Home ranges and activity patterns of non-migratory elk of the Madison Drainage herd as determined by biotelemetry. *Wildl. Monogr.* 33, 50 pp.
- Eberhardt, L. E., E. E. Hanson, and L. L. Cadwell. 1984. Movement and Activity Patterns of mule deer in the sagebrush-steppe region. *J. Mammal.* 65:404-409.
- Edge, W. D., C. L. Marcum, and S. L. Olson. 1985. Effects of logging activities on home range fidelity of elk. *J. Wildl. Manage.* 49:741-744.
- Edge, W. D., C. L. Marcum, S. L. Olson, and J. F. Lehmkühl. 1986. Nonmigratory cow elk herd ranges as management units. *J. Wildl. Manage.* 50:660-663.
- Franklin, W. L., and J. W. Lieb. 1979. The social organization of a sedentary population of North American elk: a model for understanding other populations. *In* M. S. Boyce and L. D. Hayden-Wing (eds.). *North American elk: ecology, behavior and management.* Univ. Wyoming, Laramie. Pp. 185-198.
- Hanley, T. A. 1980. Nutritional constraints on food and habitat selection by sympatric ungulates. University of Washington, Seattle. Ph.D. Dissertation.
- Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight—a reevaluation. *Ecology* 60:389-402.
- Harper, J. A. 1971. Ecology of Roosevelt elk. Report no. PR W-59-R. Oregon State Game Comm. Portland. 44 pp.
- Hershey, T. J., and T. A. Leege. 1982. Elk movements and habitat use on a managed forest in north-central Idaho. *Wildl. Bull. No. 10*, Idaho Dept. Fish and Game. 24 pp.
- Irwin, L. L., and J. M. Peek. 1983. Elk habitat use relative to forest succession in Idaho. *J. Wildl. Manage.* 47:664-672.
- Janz, D. W., and D. Q. Becker. 1986. Vancouver Island elk—animal and use characteristics. *In* D. L. Eastman (ed.). *Western states and provinces elk workshop: proceedings.* Oregon Dept. Fish and Wildlife, Portland. Pp. 279-305.
- Jenkins, K. J., and E. E. Starkey. 1982. Social organization of Roosevelt elk in an old-growth forest. *J. Mammal.* 63:331-334.
- Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. *J. Theor. Biol.* 22:277-337.
- Martinka, C. J. 1969. Population ecology of summer resident elk in Jackson Hole, Wyoming. *J. Wildl. Manage.* 33:465-481.

- McCorquodale, S. M., L. L. Eberhardt, and L. E. Eberhardt. 1988. Dynamics of a colonizing elk population. *J. Wildl. Manage.* 52:309-313.
- McCorquodale, S. M., K. J. Raedeke, and R. D. Taber. 1986. Elk habitat use patterns in the shrub-steppe of Washington. *J. Wildl. Manage.* 50:664-669.
- McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. *Univ. Calif. Publ. in Zoology*, Vol. 88, 209 pp.
- McNab, B. K. 1963. Bioenergetics and the determination of home range size. *Am. Nat.* 97:133-140.
- Odum, E. P., and E. J. Kuenzler. 1955. The measurement of territory and home range size in birds. *Auk* 72:128-137.
- Rickard, W. H. 1985. Biomass and shoot production in an undisturbed sagebrush-bunchgrass community. *Northw. Sci.* 59:126-133.
- Schoen, J. W. 1977. The ecological distribution and biology of wapiti, *Cervus elaphus nelsoni*, in the Cedar River watershed, Washington. University of Washington, Seattle. Ph.D. Dissertation.
- Swihart, R. K., and N. A. Slade. 1985. Influence of sampling interval on estimates of home range size. *J. Wildl. Manage.* 49:1019-1025.
- Varland, K. L., A. L. Lovass, and R. B. Dahlgren. 1978. Herd organization and movements of elk in Wind Cave National Park, South Dakota. *Nat. Resour. Rept. No. 13*, U.S. Dept. Interior, 28 pp.
- Waldrip, G. P., and J. H. Shaw. 1979. Movements and habitat use by cow and calf elk in the Wichita Mountains National Wildlife Refuge. *In* M.S. Boyce and L. D. Hayden-Wing (eds.). *North American elk: ecology, behavior and management*. Univ. Wyoming, Laramie. Pp. 177-184.
- Whittaker, R. H., and G. E. Likens. 1973. Primary production: the biosphere and man. *Human Ecol.* 1:357-369.
- Zar, J. H. 1974. *Biostatistical analysis*. Prentice-Hall, Inc. Englewood Cliffs, N.J., 620 pp.

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