

Group size dynamics of female Roosevelt elk in Redwood National and State Parks, California

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Key words: *Cervus elaphus*, Roosevelt elk, growth rate dynamics, population dynamics, Redwood National and State Parks

Roosevelt elk, *Cervus elaphus roosevelti*, have inhabited the area in and around Prairie Creek and lower Redwood Creek drainages in Redwood National and State Parks for at least a century (Harper et al. 1967). In this small (<60 km²) geographic area, five distinct groups of elk have been identified (Franklin et al. 1975, Bowyer 1981, Jenkins and Starkey 1982, Weckerly et al. 2004). These groups are mainly comprised of females, juveniles and sub-adult males, and we refer to them as female groups. The individuals in these groups are socially bonded and may spend their entire lives together (Leib 1973, Franklin et al. 1975, Weckerly 1999, Bowyer 2004). The high degree of social bonding may be associated with the landscape configuration and arrangement of habitats, lack of timber harvest or forest fires that alter composition of habitats, and availability of foraging habitat (Jenkins and Starkey 1982, Weckerly 2004). Foraging habitat for elk in this landscape is primarily grassland that occurs in discrete patches in the lowlands of the coastal redwood (*Sequoia sempervirens*) forest; forage in grasslands is of much higher quality and more abundant than in forests (Jenkins and Starkey 1982, Weckerly 1999).

Since the female groups in the Prairie Creek and lower Redwood Creek drainages occupy a small geographic area, the environmental settings experienced by each group of elk likely are similar and, if that is the case, temporal changes in group sizes should also be similar. If temporal variation among group sizes is correlated, the five herds can be considered as a single unit for management purposes. If temporal variation among groups is not correlated, then management options for each female group should be considered separately from the others. Our study was conducted in order to ascertain whether or not temporal variation in sizes of female groups was correlated across 14 years.

The Prairie Creek and lower Redwood Creek drainages are located in the western portion of Redwood National and State Parks (RNSP; 41° 20' N, 124° 2' W), Humboldt County, California (Figure 1). To include the Gold Bluffs Beach herd, our study extended 3 km to the west of the Prairie Creek drainage and to the north of the lower Redwood Creek (Franklin et al. 1975). The climate is maritime, and extreme seasonal variations are rare;



FIGURE 1.—Map of the Prairie Creek and Lower Redwood Creek drainages in Redwood National and State Parks, Humboldt County, California, showing herd ranges of Roosevelt elk described in this paper. The ranges were delineated based on locations where elk were observed from 1997–2010. There were 10 counts each year (except for 1998 and 1999 when only 5 counts occurred) for the Boyes and Davison groups, and one to four counts each year of the other groups.

annual temperatures range from an average of 7.2° C in winter to an average of 20.5° C in summer. Average rainfall is 175 cm per year. The Prairie Creek and lower Redwood Creek drainages are composed of a series of meadows interspersed within temperate rainforests, and are strongly influenced by coastal fog, especially in the summer. The forests within RNSP are dominated by coastal redwood and Sitka spruce (*Picea sitchensis*). Other common tree species include bigcone Douglas-fir (*Pseudotsuga menziesii*), tanoak (*Lithocarpus densiflorus*), western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*) and red alder (*Alnus rubra*). The groups of elk occupied a series of grasslands (meadows) that exist within an area of approximately 60 km² (Weckerly 1996). Meadow vegetation is composed of annual and perennial grasses and forbs, including California oat grass (*Danthonia californica*), soft chess (*Bromus hordeaceus*), redtop (*Agrostis alba*), and bracken ferns (*Pteridium aquilinum*) (Weckerly et al. 2001).

Data were collected from September through February each year from 1997 to 2010. Elk were counted by FWW and park biologists one to ten times each year (Weckerly 1996, 2007). Because female groups inhabit distinct meadows most of the time, sighting probabilities of females are high (≥ 0.90) (Franklin et al. 1975, Jenkins and Starkey 1982, Weckerly 2007). Hence, the probability of detecting all females, juveniles and sub-adults in a group was quite high across four or more counts (e.g., the probability of detecting all elk was 0.99 across four counts, $1 - (1 - 0.9)^4 = 0.99$), and we treated our count data as a reliable index to group sizes. The highest count was accepted as the group size for any particular year. Elk groups were identified by name based on the area they utilized: Boyes, South Operations Center (SOC), Gold Bluffs, Levee, and Davison. The Boyes and Davison groups were counted by FWW and the SOC, Gold Bluffs, and Levee groups were counted by park biologists. Growth rate for each year was calculated using the standard geometric growth rate formula, N_{t+1}/N_t , where t is the year.

The growth rates for the five groups were estimated using Excel. Pearson's correlation coefficients were estimated between growth rates of all possible pairs of groups. We also tested whether correlation coefficients were statistically significant (P -value < 0.05 ; Sokal and Rohlf 2012).

There was a general decline in size of all five groups over 14 years (Figure 2). The largest number of animals occurred in the Levee group, which had 38 females in 2000. In 2010, the Boyes group consisted of only two individuals. The Boyes group had the lowest average annual growth rate at 0.79. The group with the highest average growth rate was the Levee group (1.03, $SD = 0.26$). The three other groups showed similar average growth over the 13 years of the study, Davison (0.97, 0.15), SOC (0.97, 0.17) and Gold Bluffs (0.98, 0.30).

We did not detect any strong correlations between the growth rates of nine out of the ten pairwise comparisons (Table 1), but there was a significant negative correlation between the SOC and Boyes groups. We view that correlation as spurious for two reasons. First, these two groups were the farthest apart of all the herds (Figure 1). We are hard pressed to offer ecological reasons why these groups should have growth rates that were associated, while groups that are closer to each other had uncorrelated growth rates. Additionally, because there was only one significant correlation detected among the ten correlations estimated, the single significant correlation might be due to random chance (Sokal and Rohlf 2012).

The geographic area in which the groups exist is relatively small (< 60 km²), and the ecological conditions throughout the region where the groups exist are probably similar;

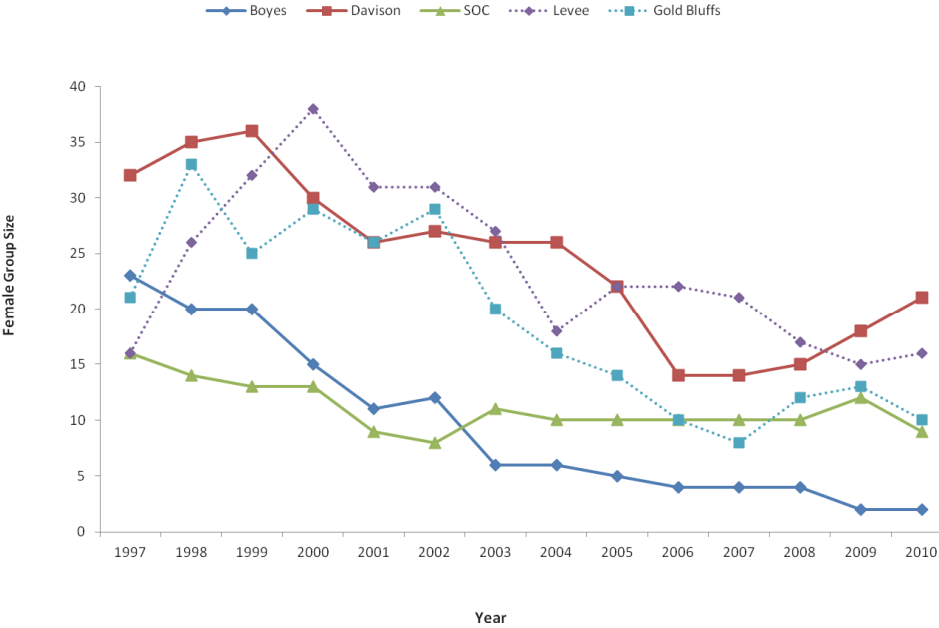


FIGURE 2.—Line plot showing the maximum group size of each of the five female groups of elk in the Lower Prairie Creek drainage of Redwood National and State Parks, Humboldt County, California, 1997–2010.

TABLE 1.—Pearson’s correlation coefficients among growth rates for female elk groups in the Lower Prairie Creek Drainage of Redwood National and State Parks, Humboldt County, California, 1997–2010. Numbers in italics are the associated *P*-values.

Group	Group			
	Boyes	Davison	SOC	Levee
Davison	0.13			
	<i>0.66</i>			
SOC	-0.63	<-0.01		
	<i>0.02</i>	<i>0.99</i>		
Levee	0.10	0.02	-0.17	
	<i>0.75</i>	<i>0.95</i>	<i>0.59</i>	
Gold Bluffs	0.11	0.34	-0.11	0.38
	<i>0.71</i>	<i>0.26</i>	<i>0.72</i>	<i>0.21</i>

thus, it is reasonable to expect synchrony in group size changes. Gogan and Barrett (1994) showed that fecal nitrogen values, an indicator of diet quality, were similar for animals from the Boyes and Gold Bluffs groups. Weckerly et al. (2004) showed that cropping rates of females from the Boyes and Davison groups that foraged in different meadows were similar. Also, risk from predators should be similar, as elk predators such as mountain lions and black

bears exist throughout the Prairie Creek and lower Redwood Creek drainages (Harper et al. 1967). Nonetheless, there are also dissimilarities among the areas in which the groups exist. For example, the Boyes group inhabits a meadow intersected by U.S. Highway 101 and individuals are at a higher risk of collision with vehicles. Individuals in the Gold Bluffs area may wander out of the park and, thus, be more vulnerable to harvest on properties that lie adjacent to the parks. This is also true of the SOC and Levee herds, from which some animals have been taken by hunters when they leave the parks.

Uncorrelated growth rates among the herds in such a small geographic area may be due to the ecological conditions within the Prairie and lower Redwood Creek drainages. Site fidelity has been noted before in elk groups, especially among the female members (Jenkins and Starkey 1982, Weckerly 1996, Van Dyke et al. 1998, Weckerly et al. 2001, Millsaugh et al. 2004). Ecological reasons that have been postulated for this behavior include the benefits that the group receives through the maintenance of site fidelity and social bonding. Social bonding among females promotes knowledge transfer of prime foraging patches and how to lower the risk of predation (Harper et al. 1967, Franklin and Leib 1979, Millsaugh et al. 2004). The climate in the Prairie Creek and lower Redwood Creek drainages in Redwood National and State Parks is relatively consistent and forage is available throughout the year (Harper et al. 1967). There might be few benefits to forage acquisition for groups that venture out of their occupied meadow.

We conclude there was little temporal synchrony among groups in abundance dynamics. Maximum size of all five groups declined from the late 1990s to 2010. However, both the Davison and Levee group showed an early increase in group size, with Davison showing a general increase in individuals from 2006 to 2010 and Levee from 2009 to 2010 (Figure 2). The Boyes group may have gone extinct in 2011 (F. W. Weckerly, unpublished data). Since a general decline in group size is evident within the elk groups in the Prairie and lower Redwood Creek drainages, annual monitoring of each individual group is warranted.

Monitoring of the female groups in the Prairie and lower Redwood Creek drainages can be conducted with less logistical burdens and cost than conventional aerial survey techniques. Due to the high sighting probabilities of females, counts do not need to be adjusted for imperfect detection when estimating group size. Since adult female survival often has the greatest impact on population persistence in polygynous species (Gaillard et al. 1998), monitoring of female group sizes will provide useful information on long-term distribution, abundance, and viability of elk in the lower Prairie and Redwood Creek drainages (Weckerly 1996, Weckerly et al. 2004). Even in a small geographic area, group dynamics of distinct elk herds can behave differently.

ACKNOWLEDGMENTS

We thank Redwood National and State Parks for their assistance and cooperation over the years and to the many park biologists that collected data. Also, FWW was assisted in the field by A. Duarte, J. Hunt, R. Keleher, M. Longoria, R. Luna, M. O'Dell, M. Ricca, K. Richardson, S. Robinson, S. Shelton and G. Street. We thank Phil Julian for creating Figure 1.

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