

Gradients of Forage Biomass and Ungulate Use Near Wildlife Water Developments

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Abstract

The addition of wildlife water developments (i.e., catchments) to arid areas may concentrate foraging by desert ungulates and decrease forage availability near catchments. We looked for gradients in forage biomass and use by mule deer (*Odocoileus hemionus*) and bighorn sheep (*Ovis canadensis*) along dry riparian streams near catchments. We measured forage biomass and pellet group density in transects following vegetation along edges of desert washes near catchments and in control washes with catchments >3 km away. Ungulate use, as reflected by pellet group density, was greatest in washes with catchments in place >3 years. There was some evidence for a gradient in pellet density in spring (slope = -0.012, $P = 0.088$) and summer (slope = -0.013, $P = 0.015$), and for differences between catchment and control transects in all seasons (13–46 pellet groups/ha, $P \leq 0.077$). We found no evidence of an effect of catchments on forage biomass in nearby washes: we detected no gradient in forage biomass nor an overall difference between washes with catchments and those without ($P > 0.15$). Desert ungulates used washes near catchments in our study area but had minimal effects on nearby vegetation. (WILDLIFE SOCIETY BULLETIN 34(3):620–626; 2006)

Key words

bighorn sheep, California, catchment, forage, mule deer, *Odocoileus hemionus*, *Ovis canadensis*, piosphere, Sonoran Desert.

Wildlife managers in the southwestern United States have managed habitat for desert ungulates under the assumption that free water is a limiting factor (Broyles 1995, Rosenstock et al. 1999). Land managers have attempted to remedy this presumed water limitation for populations of mule deer, bighorn sheep, and other wildlife by building wildlife water developments (i.e., catchments) using 3 main goals: to expand ungulate distribution into areas that otherwise may be suitable but are unoccupied or seasonally occupied because of scarce or absent free water; to improve population performance by providing reliable free water in areas where undeveloped water sources (e.g., rock basins, springs) become seasonally dry; and to mitigate for loss of water sources via human-caused changes in the environment (Rosenstock et al. 1999). Ungulates use catchments when they are available; for example, mule deer change distribution and movements relative to catchments and have been observed to use water from catchments as often as 1–2 times per 24 hours during hot, dry weather (Hervert and Krausman 1986, Hazam and Krausman 1988, Rautenstrauch and Krausman 1989, Boroski and Mossman 1996, 1998). Desert ungulates may even continue to visit catchments after the summer rainy season has begun; Rosenstock and Rabe (2002) found that catchment use remained high until October when ambient temperatures became cooler.

While there is abundant evidence that desert ungulates use catchments, studies to evaluate effects of catchments on ungulate demography and range use are still necessary (Broyles 1995). For example, increasing water availability may focus foraging around catchments and cause decreases in local forage abundance (Krausman and Czech 1998); during times of water scarcity,

ungulates may stay close to water rather than range more widely for forage, creating a limiting effect of scarce forage near catchments (Corfield 1973). If catchments concentrate foraging, the effect should be evident in the vegetation surrounding catchments: a gradient in forage biomass with distance from a catchment (i.e., a piosphere; Lange 1969), or a difference in forage biomass between areas near catchments and areas away from catchments. Our objective was to evaluate whether ungulates have concentrated their activity around catchments and whether there was a detectable influence on forage biomass as a consequence.

Study Area

We conducted this research in the Lower Colorado River Valley subdivision of the Sonoran Desert, eastern Imperial County, California, USA (33°00'N, 114°45'W). Elevations ranged from sea level to 664 m at Quartz Peak. Summer temperatures frequently exceeded 45°C, and winter temperatures seldom were below freezing. Annual mean precipitation in Imperial County was 73 mm and highly variable (range 4–216 mm; 1914–2002; Imperial Irrigation District, unpublished data). The size of the study area was approximately 1,100 km².

Plant species in our study area were typical of the Lower Colorado River Valley subdivision (Turner 1994). Three vegetation associations existed in the study area: mountain (57% of area), piedmont (33%), and xeroriparian (11%; Andrew et al. 1999). Common species in the mountain association included burro-weed (*Ambrosia dumosa*), creosote bush (*Larrea tridentata*), brittle-bush (*Encelia farinosa*), and ocotillo (*Fouquieria splendens*; Andrew 1994). Creosote bush was dominant in piedmont associations, but burro-weed, brittle-bush, matchweed (*Gutierrezia microcephala*), and palo verde (*Parkinsonia florida*) also occurred

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there (Andrew 1994). More than 90 percent of plant biomass occurred in the xeroriparian association (Marshal et al. 2005), where common species were desert-ironwood (*Olneya tesota*), catclaw (*Acacia greggii*), cheese bush (*Hymenoclea salsola*), and palo verde.

We delineated 4 seasons that coincided approximately with annual patterns of temperature and precipitation: cool-rainy or winter (Jan–Mar), hot-dry or spring (Apr–Jun), hot-rainy or summer (Jul–Sep), and cool-dry or autumn (Oct–Dec). Ungulates in the area were mule deer and bighorn sheep (0.19/km² and 0.14/km², respectively; V. C. Bleich, California Department of Fish and Game [CDFG], unpublished data), and feral ass (*Equus asinus*; 0.38/km²; A. Neibergs, Bureau of Land Management, unpublished data). Medium-sized herbivores included black-tailed jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus audubonii*), and desert tortoise (*Gopherus agassizii*).

Methods

From April 2002 to February 2003, we compared forage biomass in xeroriparian associations along dry stream beds (i.e., washes) adjacent to 8 catchments and in 8 washes ≥ 3 km to the nearest catchment (16 wash sites in total). We sampled only xeroriparian associations because of the scarcity of plants outside these areas (Marshal et al. 2005) and the tendency of desert ungulates to concentrate their use there (Krausman et al. 1985). We selected washes so that each catchment wash could be paired with a control wash (i.e., no catchment) of similar size and topography. This allowed us to limit the influence of these potentially confounding variables when looking for the influence of variables of interest. Five of the 8 catchments (old sites) had been constructed before 1997. Water became available in the other 3 (new sites) in 2001.

We established one transect at each of the 16 wash sites. Each transect was 3,000 m long and followed the edge of the xeroriparian vegetation heading down-wash. For catchment sites, transects originated at the point on the edge of the wash nearest the catchment. We placed 7 groups of 20 plots, each plot measuring 1 \times 1 m and 2 m high. Each group of 20 plots was placed at 500-m intervals 0–3,000 m from the catchment. Ten plots were on each side of the wash, with the first plot after a random starting point and the rest every 20 m thereafter. Each group of 20 plots allowed for a more precise estimate of vegetation characteristics at each 500-m interval from a catchment or its paired control wash-interval. We based our decision to use 3-km transects on distances deer and sheep are found from catchments during times of year when water is scarce. Outside of the hot-dry season, deer and sheep may range widely; however, this generally is not the case during the water-limited season (Hervert and Krausman 1986, Andrew et al. 1999). Further, because many ungulates focus their activity on a single location during the hot-dry season, we expected that—if vegetation impacts did occur—we would detect them nearest water sources.

For each plot, we estimated browse biomass (i.e., green leaves and twigs of shrubs and trees) by a modification (Marshal et al. 2005) of the comparative yield method (Haydock and Shaw 1975). We visually assessed the amount of forage in each plot and assigned a rank from 0 to 4 by increments of 0.5. Zero represented a plot with no forage (either completely empty or with only

inedible larger stems), 1 represented a plot 25% full of forage, 2 represented a plot 50% full of forage, 3 represented a plot 75% full of forage, and 4 represented a plot 100% full of forage. To estimate biomass, we clipped ≥ 6 plots representing each rank, dried the samples, and used linear regression to establish a relationship between rank of the plot and browse biomass of forage it contained. The relationship for forage biomass (g/m²) in washes was biomass = exp(3.42 + 0.85[rank]) ($F_{1,65} = 105.27$, $P < 0.001$, $R^2 = 0.62$; Marshal et al. 2005). Ground cover (i.e., forbs and grasses) occurred rarely and only after abnormally high precipitation. We did not encounter them in measurable quantity during this study. Succulent plants (e.g., cactus [*Opuntia* spp. and others]) occurred in the study area mostly outside the xeroriparian associations and did not occur in our plots. As a consequence, forage biomass estimates we report consisted entirely of browse. We estimated biomass every 3 months to quantify seasonal changes in forage availability around catchments. We gauged the level of combined use by deer and sheep on each transect by counting fecal pellet groups in 2 \times 20-m areas between each vegetation plot, along the edges of the sampled washes. Deer and sheep fecal pellets appear identical; therefore, we did not attempt to distinguish between the pellets of these 2 species. Observed pellets represented ≤ 3 months of accumulation. After we counted pellet groups, we buried them with sand or gravel from the wash bed or removed them from the pellet plots to avoid counting them more than once.

We analyzed data separately for each 3-month period to limit potential confounding influences of seasonal change in plant phenology. Our sample unit was 1 group of 20 plots at each 500-m interval. For each interval on each transect, we calculated mean forage biomass and density of pellet groups (i.e., $1 \bar{x}$ was based on 20 plots within a single interval). Then, for each pair of transects, we calculated the difference in means at each interval between the catchment transect and control transect (i.e., control – catchment for forage biomass, catchment – control for pellet group density). We performed all analyses on the differences between means (i.e., $7 \bar{x}$ differences per pair of transects). In separate analyses, we used differences in forage biomass and differences in pellet group density as response variables in a multiple regression model that included transect age (i.e., old site, new site) as a categorical explanatory variable and interval as a continuous explanatory variable. If a gradient existed in biomass on catchment transects, we predicted the differences between catchment and control to decrease with distance. If old transects experienced greater effects of forage removal by ungulates, we predicted the difference to be larger for old-catchment pairs than for new-catchment pairs. If a gradient existed in pellet group density on catchment transects, we predicted the differences between catchment and control to increase with distance. If old transects experienced greater use by ungulates, we predicted the difference to be larger for old-catchment pairs than for new-catchment pairs.

Results

There was weak evidence for a gradient in pellet density at catchment washes in spring ($P = 0.088$), and strong evidence for a gradient in summer ($P = 0.015$; Tables 1, 2). Pellet density decreased with distance from the catchment (Fig. 1). Mean

Table 1. Summary of pellet group density (pellet groups/ha) along desert washes, Imperial County, California, USA, 2002–2003.

Age	Treatment	n	Spring		Summer		Autumn		Winter	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE
Old	Control	35	19.9	5.8	25.0	4.9	11.4	2.8	30.7	5.7
	Water	35	275.0	28.4	220.0	19.9	80.7	10.1	210.0	16.9
New	Control	21	17.9	6.4	28.6	6.2	8.3	3.1	61.9	10.4
	Water	21	0.0	0.0	10.7	3.9	17.9	4.5	34.5	7.6

difference in pellet group density decreased by 0.012 (SE = 0.0068) and 0.013 (SE = 0.0053) groups/ha, in spring and summer, respectively, for every 1-m increase in distance from a catchment (Table 2). Although there was no evidence of a gradient in autumn or winter ($P > 0.48$; Table 2, Fig. 1), there was evidence in all seasons that difference in overall pellet group density was greater for old sites than for new sites ($P < 0.077$; Table 2).

We summarized forage biomass by season, catchment age, and treatment (Table 3). We found no evidence for a gradient in forage biomass with distance from catchments in any of the 4 seasons ($P > 0.15$; Table 4, Fig. 2). In summer, overall biomass was 7.4 g/m² greater along old transects than along new transects (SE = 2.03; Table 4). Because distance to catchment did not appear to influence biomass, we further investigated differences in summer between control and catchment transects within transect age; we fit a linear model using only the categorical catchment age explanatory variable. Biomass along new control transects was 3.9 g/m² less than along new catchment transects (SE = 1.60, $t_{54} = 2.42$, $P < 0.019$), and biomass along old control transects was 3.6 g/m² less than along old catchment transects (SE = 1.24, $t_{54} = 2.90$, $P = 0.005$). We did not detect overall biomass differences in the other 3 seasons ($P > 0.75$; Table 4).

Discussion

We found no effects on forage biomass that could be attributed to presence of catchments, despite strong evidence for ungulate use of washes near older catchments. Krausman and Czech (1998) suggested that adding water to areas with limited forage might result in declines of ungulate populations if forage, rather than water, was the limiting resource. It is clear that some catchments attracted ungulates and that those ungulates occurred in nearby washes more than in washes without catchments. If forage is

limiting for these ungulates, an impact should have occurred on nearby forage biomass, but we did not detect an impact.

The only difference we found in forage biomass occurred in summer, but that finding was unexpected (i.e., for old and new sites, control transects had less biomass than catchment transects), and the magnitude of the differences may not have been of biological consequence. Rainfall and its effects on forage biomass are spatially and temporally heterogeneous (Marshall et al. 2005). In the Sonoran Desert, precipitation often falls in discreet strips resulting in patches of green vegetation that may have much higher forage biomass than areas of the desert outside the path of a “strip-rain.” Although we designed this study to use pairs of washes that were as similar as possible except for the presence of a catchment, summer strip-rains may have occurred on one of a pair of washes, affecting forage biomass in a way unrelated to presence of catchments.

We did not find a trend in pellet group density in autumn and winter, and this was not surprising. Native ungulates in our study area tend to remain close to catchments during the hot-dry season when water is most scarce, a common pattern in the southwestern United States (Hervert and Krausman 1986, Rautenstrauch and Krausman 1989, Andrew et al. 1999). In addition, we found gradients in the hot-rainy season. Whereas we expected animals to move away from catchments toward areas of green-up caused by summer rains (Rautenstrauch and Krausman 1989), ungulates in our study appeared to stay close to water during summer. However, summer rainfall during our study did not begin until after we completed the summer sampling period, and water remained scarce through much of that season. This late timing of summer rainfall was unexpected, and as a result, spring and summer forage conditions were more similar than usual.

Some time may be necessary for ungulates to find newer catchments in our study area. New catchments had provided water for a year by the time this study began. Throughout the study,

Table 2. Results of multiple regression analysis showing effect of distance (m) from catchment (i.e., slope of regression model) on pellet density (pellet groups/ha), and effect of age (i.e., old vs. new catchments) on difference in pellet group density between catchment and control sites, Imperial County, California, USA, 2002–2003.

Season	Parameter	Estimate	SE	t ratio	df	P value
Spring	Distance	-0.012	0.0068	-1.74	52	0.088
	Age [old - new]	46	13.7	3.35	52	0.002
Summer	Distance	-0.013	0.0053	-2.52	53	0.015
	Age [old - new]	45	11.0	4.06	53	<0.001
Autumn	Distance	-0.003	0.0035	-0.72	53	0.475
	Age [old - new]	13	7.3	1.80	53	0.077
Winter	Distance	-0.003	0.0057	-0.57	53	0.568
	Age [old - new]	45	11.7	3.84	53	<0.001

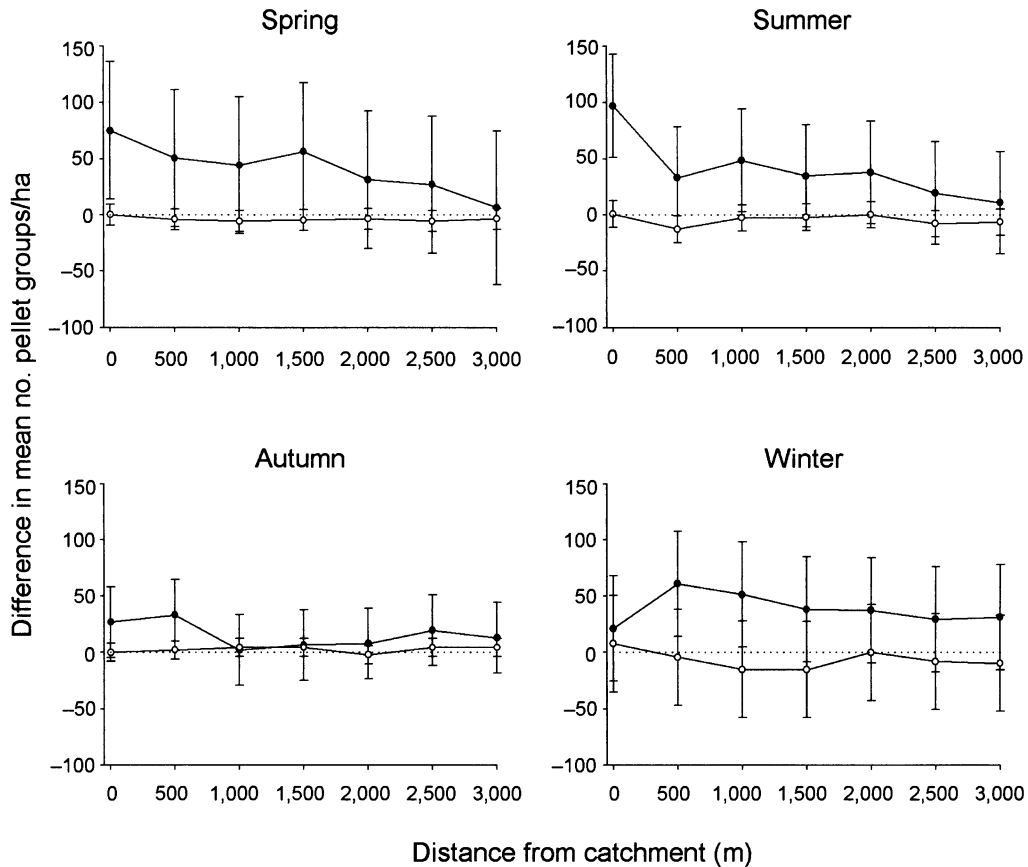


Figure 1. Difference in pellet group density (catchment – control) and 95% confidence intervals with distance from catchment for old (●) and new (○) catchment sites, Imperial County, California, USA, 2002–2003.

there was no indication that ungulates used the new catchments, based on remote camera, track, and pellet data (J. P. Marshal, University of Arizona, unpublished data). The rate at which deer and bighorn sheep found catchments varied in other studies. For example, in some instances, mule deer moved within 1 year to new water sources (Remington et al. 1984); in others, they had not begun to use them within 4 years (Krausman and Etchberger 1995). Because there was no evidence of ungulate use along new catchment washes, ungulates probably had not found these water sources, nor had the opportunity to affect nearby vegetation.

Gradients in forage biomass caused by high densities of foraging ungulates (generally livestock) have been found around water sources. In addition to overall plant abundance changes (Fusco et al. 1995), there have been reported effects on plant species composition (Moleele and Perkins 1998), plant demography (Andrew and Lange 1986), and soil nutrient composition (Turner

1998, Fernandez-Gimenez and Allen-Dias 2001). With the exception of vegetation effects attributed to feral ass, little information is available on vegetation impacts in U.S. desert areas caused by wild ungulates, particularly associated with water developments. Impacts of feral ass are widespread where these animals are abundant and might not be affected by locations of water sources (Douglas and Leslie 1996). Feral ass occurred in our study area. In the past, feral ass heavily used the catchments that were a part of this study, and it is possible they influenced plant biomass around the catchments. Since 2000, ass-proof fences have excluded these animals from catchments while allowing use by native wildlife (Andrew et al. 1997b). As a result, feral ass remained in areas neighboring our study area (>10 km distant) where water was available to them. It is possible that we studied vegetation that was recovering from effects of herbivory by feral ass. If true, we would expect the differences in forage biomass

Table 3. Summary of forage biomass (g/m²) along desert washes, Imperial County, California, USA, 2002–2003.

Age	Treatment	n	Spring		Summer		Autumn		Winter	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE
Old	Control	35	15.1	1.0	13.6	1.0	19.8	1.2	13.4	1.0
	Water	35	13.4	0.9	9.8	0.9	22.3	1.2	16.6	1.3
New	Control	21	13.9	1.2	10.4	1.2	17.7	1.5	11.4	1.2
	Water	21	12.5	1.1	14.2	1.3	21.0	1.5	13.9	1.3

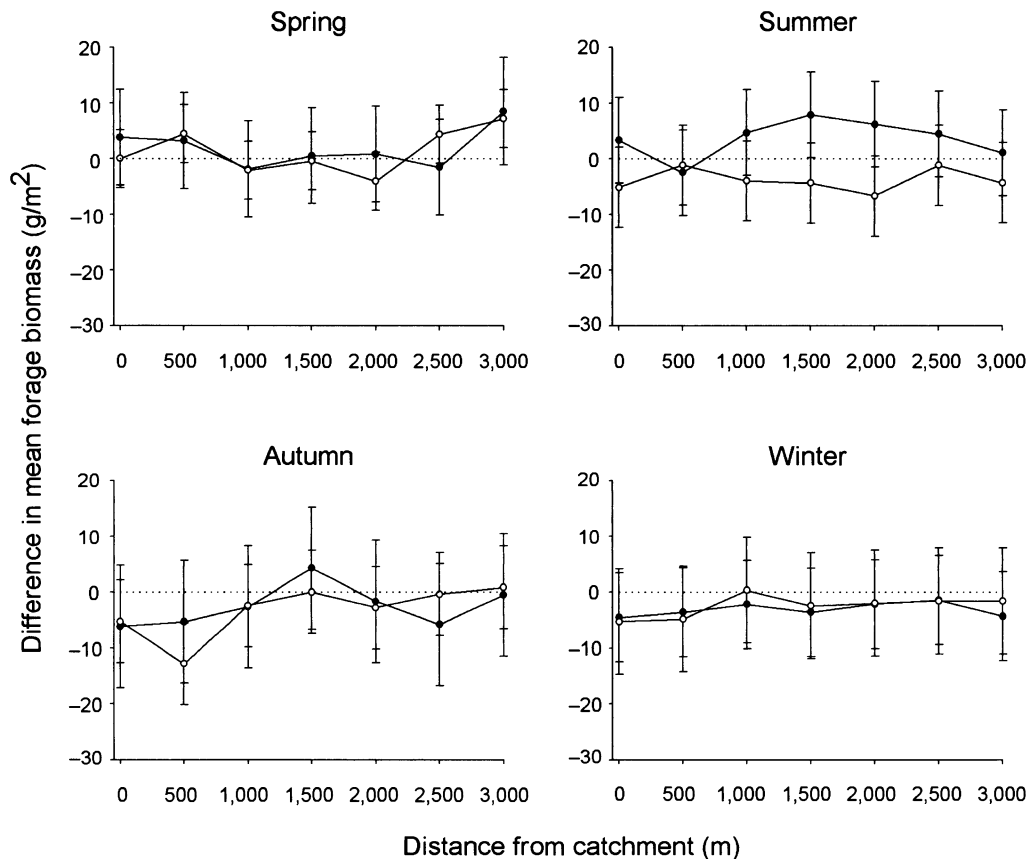


Figure 2. Difference in forage biomass (control – catchment) and 95% confidence intervals with distance from catchment for old (●) and new (○) catchment sites, Imperial County, California, USA, 2002–2003.

between catchment and control washes to have been more apparent. Because we did not detect these differences, the influence of feral ass on our findings was probably minimal.

Management Implications

Many of the vegetation changes described in piosphere studies resulted from heavy grazing that primarily affected perennial grasses and forbs (Fusco et al. 1995). Where woody species were mentioned, they usually were undesirable plants that occurred in response to removal of more desirable plants (Molelele and Perkins 1998). However, Brits et al. (2002) found piosphere effects on woody vegetation in areas used by native ungulates in Kruger National Park, South Africa, where gradients in forage biomass

and tree and shrub density occurred around catchments. Our failure to find evidence of such effects might be the consequence of foraging effects by wild ungulates that occurred at lower densities (Thompson and Bleich 1993, Andrew et al. 1997a), focusing of fewer foraging animals around catchments, and resulting smaller impacts on vegetation. In addition, foraging impacts in our study area may have affected plant species composition, causing a gradient in high-quality forage species rather than in biomass. Future research into piosphere effects around desert wildlife catchments should consider species composition changes as well as biomass changes.

Concerns about effects of wildlife water developments on wild ungulates and desert ecosystems often involve the importance of

Table 4. Results of multiple regression analysis showing effect of distance (m) from catchment (i.e., slope of regression model) on forage biomass (g/m^2), and effect of age (i.e., old vs. new catchments) on difference in pellet group density between catchment and control sites, Imperial County, California, USA, 2002–2003.

Season	Parameter	Estimate	SE	t ratio	df	P value
Spring	Distance	0.001	0.001	0.63	52	0.528
	Age [old – new]	-0.417	2.200	-0.19	52	0.850
Summer	Distance	0.000	0.001	0.38	53	0.706
	Age [old – new]	-7.440	2.034	-3.66	53	<0.001
Autumn	Distance	0.002	0.001	1.44	53	0.155
	Age [old – new]	-0.738	2.708	-0.27	53	0.786
Winter	Distance	0.001	0.001	0.63	53	0.534
	Age [old – new]	0.643	2.080	0.31	53	0.759

the interactions between ungulate populations and forage. Certainly, water alone does not sustain ungulate populations in areas where forage availability is insufficient. Without an understanding of this interaction, water developments could be detrimental to ungulate management (Krausman and Czech 1998). Where ungulates regularly used catchments in our study, there was no evidence of an association between wildlife water developments and reduced forage availability.

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