Effects of site characteristics, pinyon-juniper management, and precipitation on habitat quality for mule deer in New Mexico

Louis C. Bender, Extension Animal Sciences and Natural Resources, New Mexico State University, Las Cruces, New Mexico 88003, USA

Jon C. Boren, Extension Animal Sciences and Natural Resources, New Mexico State University, Las Cruces, New Mexico 88003, USA

Heather Halbritter, Extension Animal Sciences and Natural Resources, New Mexico State University, Las Cruces, New Mexico 88003, USA

Shad Cox, Corona Range and Livestock Research Center, New Mexico State University, Corona, New Mexico 88003, USA

Abstract: Wildlife enterprises are increasingly important to ranch income in the western United States. Habitat management practices that facilitate wildlife are needed for optimal management of multiple-use ranches, particularly for economically important species, such as mule deer (*Odocoileus hemionus*), that are declining throughout much of their range. We tested the effects of vegetation cover type, site characteristics, pinyon-juniper management treatments, and precipitation on body condition and size of spring-summer-autumn (SSA) home ranges of mule deer to assess habitat quality on the Corona Range and Livestock Research Center (CRLRC), a multiple-use research ranch in eastcentral New Mexico. Accrual of lean tissue and body fat reserves in does was positively associated with use of mechanically cleared juniper, pinyon-juniper woodland, and savannah and increased annual and spring (April to June) precipitation. Size of SSA home ranges of does was negatively associated with use of pinyon-juniper woodland and savannah and mechanically cleared pinyon-juniper stands, indicating that habitat quality was positively associated with use of these types. Conversely, size of SSA home ranges was positively related to use of short grass prairie (does), proportion of short grass prairie in SSA ranges (bucks), and areas of low forage production classes (does, bucks). Overall, habitat quality for deer on CRLRC was most positively associated with a mix of thinned and unmanaged pinyon-juniper habitat. Conversely, habitat quality was negatively associated with use of short grass prairie, which is the most common (77%) vegetation cover type on CRLRC. Management for deer habitat should focus on increasing forage, particularly shrub communities, by opening pinyon-juniper communities while maintaining sufficient area in unmanaged woodland for cover. Deer responses are likely to be greater if management focuses on sites of higher forage production potential within 200 m of unmanaged pinyon-juniper stands.

Key words: condition, habitat, human–wildlife conflicts, mule deer, New Mexico, pinyon-juniper

Wildlife enterprises are increasingly important to ranch income in the western United States, and, thus, habitat management practices that facilitate wildlife are needed for optimal management of multiple-use ranches, particularly for economically important species, such as mule deer (*Odocoileus hemionus*; Figure 1), which are declining throughout much of their range (Heffelfinger and Messmer 2003). The mission of New Mexico State University's Corona Range and Livestock Research Center (CRLRC) wildlife enterprises program is to produce and maintain viable mule deer and pronghorn (*Antilocapra americana*) populations that contribute economically toward the support of the CRLRC, a multiple-use, working ranch

located in eastcentral New Mexico. Significant declines in size of the mule deer population on CRLRC (539 during 2005 to 191 in 2008; Bender et al. 2011) and throughout the West present an economic and ecological challenge for managers.

Declines in mule deer are likely associated with decreases in habitat quality (Heffelfinger and Messmer 2003; Wakeling and Bender 2003; Bender et al. 2007*a,b*; Hoenes 2008; Bender et al. 2011, 2012). On both public and private lands, changes in composition and structure of vegetation, including expansion of pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.), invasion of other noxious or exotic plants, or responses to repeated or prolonged droughts are common

Figure 1. Mule deer. (*T. A. Blake, courtesy U.S. Fish and Wildlife Service*)

range management challenges that can strongly affect the quality of habitat for mule deer (Lutz et al. 2003, Heffelfinger et al. 2006, Bender et al. 2007*b*). Managers typically use mechanical, herbicide, and prescribed fire treatments to manipulate pinyon-juniper and other habitats for free-ranging herbivores (Lutz et al. 2003). However, results of these treatments have emphasized responses of plant communities (Wood et al. 1970, Clary et al. 1974, Short et al. 1977, Severson and Medina 1983, Lutz et al. 2003), while fundamental responses of wildlife, such as mule deer, have rarely been rigorously evaluated (but see Bender et al. 2007*a,b*; Lomas and Bender 2007; Hoenes 2008).

Condition of mule deer has been shown to be fundamental to production and survival of young, survival of adults, individual development, and susceptibility to predation; condition, in turn, is primarily a result of nutrition as mediated by security (disturbance) effects (Bender et al. 2007*a,b*; Lomas and Bender 2007; Hoenes 2008; Bishop et al. 2009; Bender et al. 2011, 2012). Because individual performance is fundamental to population performance, measures of individual condition provide a direct assessment of responses to habitat changes, and, thus, condition can be used to

demonstrate effects of management on habitat quality. Previous work on mule deer in both northcentral New Mexico (Bender et al. 2007*b*) and the San Andres Mountains of southcentral New Mexico (Hoenes 2008) has shown that accrual of body reserves is related to only a few attributes of the habitat available to deer, and, thus, provides a powerful tool to identify critical habitats and effective management strategies.

Because the fundamental effects of pinyon-juniper and other rangeland management practices on mule deer are poorly known (Bender et al. 2007*b*, Hoenes 2008), we evaluated the effects of pinyon-juniper management and other environmental influences (i.e., vegetation types, forage production) on performance of mule deer on the CRLRC. Additionally, amount and timing of precipitation can also strongly affect condition and performance of mule deer in the arid Southwest (Bender et al. 2007*a,b*; Lomas and Bender 2007; Hoenes 2008; Bender et al. 2011, 2012). Consequently, our specific objectives included assessing the effects of: (1) habitat characteristics and management practices on condition of mule deer; (2) habitat characteristics and management practices on size of spring-summer-autumn (SSA) home ranges of mule deer; and (3) precipitation on condition, productivity, and size of SSA home ranges of mule deer.

Study area

The CRLRC (34° 15′ 36″ N, 105° 24′ 36″ W) is an 11,290-ha working research ranch owned and operated by New Mexico State University. Located approximately 22.5 km east of the village of Corona, New Mexico, CRLRC has an average elevation of 1900 m; mean annual precipitation across the research center is 40 cm, most of which occurs in July and August during high-intensity, short-duration convectional thunderstorms. A number of soil associations are present; valley floor soils have been classified as Sampson loams (0% to 5% slope) and are deep and well-drained. Gently sloping soils (2 to 15% slope) included in the Penistaja-Travessilla, Plack-Dioxice, and Plack-Penistaja associations dominate the uplands and tend to be shallow to moderately deep. The Stroupe-Deama association includes the steep (30 to 75% slope) mesa sides and rock outcrops.
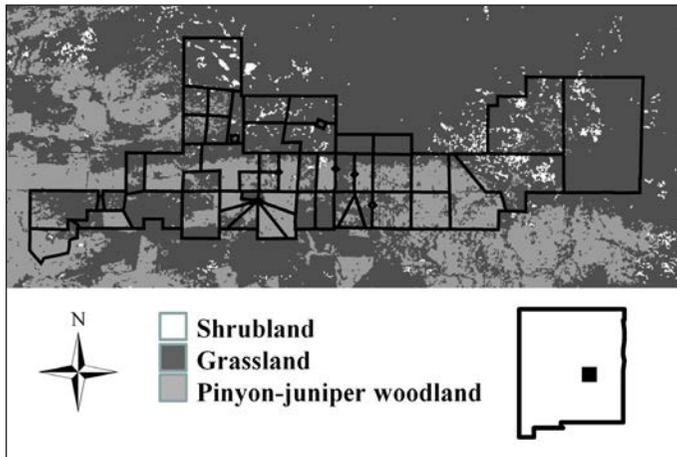
Figure 2. Major vegetation types present on the Corona Range and Livestock Research Center, eastcentral, New Mexico.

Vegetation is composed primarily of perennial grassland interspersed with sparse to dense pinyon pine (*Pinus edulis*) and 1-seed juniper (*Juniperus monosperma*) woodlands and limited, scattered shrublands (Figure 2).

Methods

Deer capture

We captured ≥1.5-year-old mule deer each December, 2005 to 2007, and April, 2006 to 2007. Deer were captured by aerial darting and net-gunning from a Bell 206B Jet Ranger helicopter. We immobilized individuals using 1.5 to 1.8 mg carfentanil citrate and 50 to 75 mg xylazine hydrochloride per deer. We blindfolded deer to minimize stress during handling and treated them intramuscularly with penicillin G procaine (3 ml), vitamin B (3 ml), MUSE (vitamin E and selenium, 1 ml), and subcutaneously with an 8-way *Clostridium* bacterin (i.e., a solution of killed or weakened bacteria used as a vaccine; 1 ml). Upon completion of processing, we antagonized immobilants with 3 ml of naltrexone (1/2 subcutaneously, 1/2 intravenously) and 4 ml of tolazoline or 2 ml atipamezole intravenously.

We aged deer as yearling or adult based on tooth wear and replacement (Robinette et al. 1957) and fit deer with mortality-sensitive radio-collars (Advanced Telemetry Systems, Asanti, Minnesota).

Individual condition

We collected a variety of size and condition indices that spanned the continuum from most readily mobilized (subcutaneous fat) to least (structural lean tissue). We measured subcutaneous rump fat thickness at its thickest point immediately posterior to the cranial process of the tuber ischium (pin bone; MAXFAT) using a SonoVet 2000 portable ultrasound with a 5-mHz probe. Approximate body fat (BF) was estimated for does only (predictive equations have not been developed specifically for bucks) using BF = 5.68 + 5.93 × MAXFAT (cm; Stephenson et al. 2002). Because the above equation can predict body fat down to only 5.7%, we also used a rump body condition score (rBCS; Bender et al. 2007a) to predict BF when no subcutaneous rump fat was present, where BF = 3.444 × rBCS – 0.746 (r^2 = 0.83; n = 27; Bender et al. 2007a). This relationship was derived from Rocky Mountain mule deer captured in northcentral and eastcentral New Mexico (Bender et al. 2007a) and allowed determination of levels of BF below levels where subcutaneous fat is fully catabolized. We estimated rBCS by palpating the sacral ridge and soft tissue of the rump near the base of the tail and scored measurements on a scale of 1 to 5 in intervals of 0.25, where 1 = emaciated and 5 = obese (Cook 2000, Bender et al. 2007a).

We measured the depth of the longissimus dorsi (loin) muscle at the thickest part between the twelfth and thirteenth ribs (LOIN) and estimated a withers body condition score (wBCS; Cook 2000; Bender et al. 2007a) to index catabolism of lean muscle tissue. Last, we also measured body mass using a spring scale and heart girth (GIRTH) to index size of deer. We compared condition indices among captures using ANOVA (Zar 1996), specifically testing the year × lactation interaction for adult does because of the negative impacts of lactation on accrual of condition (Hoenes 2008) and using only year as an effect for bucks. Condition of deer converges over winter so that individuals enter spring in similar condition regardless of lactation status the previous autumn (Clutton-Brock et al. 1982, Hoenes 2008,

Table 1. Mean and SE of condition indices for adult doe and buck mule deer at the peak of condition in late-autumn on the Corona Range and Livestock Research Center, New Mexico. Indices are presented by lactation status for adult does.

Year	Index[1]	Dry does Mean	SE	Lactating does Mean	SE	Bucks Mean	SE
2005	rBCS	2.21	0.20	1.88	0.13	2.80	0.37
	wBCS	3.27	0.24	3.31	0.28	3.70	0.34
	MAXFAT	0.23	0.10	0.00	0.00	0.56	0.30
	LOIN	3.64	0.15	3.81	0.12	4.10	0.14
	GIRTH	87.3	1.10	87.3	0.5	100.0	4.40
	BF	7.06	0.59	5.68	0.35	—	—
2006	rBCS	2.22	0.13	1.83	0.08	3.63	0.33
	wBCS	3.71	0.92	3.58	0.30	4.19	0.12
	MAXFAT	0.17	0.08	0.00	0.00	1.45	0.34
	LOIN	3.68	0.08	3.70	0.15	4.30	0.13
	GIRTH	87.6	1.0	88.7	2.7	106.0	3.30
	BF	6.69	0.48	5.61	0.23	—	—
2007	rBCS	2.10	0.26	1.67	0.33	3.92	0.30
	wBCS	3.58	0.21	3.58	0.17	4.42	0.83
	MAXFAT	0.28	0.12	0.00	0.00	1.67	0.32
	LOIN	3.94	0.09	3.67	0.09	4.37	0.19
	GIRTH	89.2	0.9	84.0	1.00	103.3	3.00
	BF	7.32	0.73	4.99	1.15	—	—

[1]rBCS = rump body condition score; wBCS = withers body condition score; MAXFAT = maximum subcutaneous rump fat thickness (cm); LOIN = depth of the longissimus dorsi muscle (cm); GIRTH = heart girth (cm); and BF = approximate body fat (%).

Piasecke and Bender 2011). Thus, we were able to treat does as independent samples annually, regardless of recapture history.

Habitat delineation and mapping

We used a vegetation association map of the CRLRC area (U.S. Geological Survey ReGAP vegetation classification), which identified 13 vegetation associations on the study site, of which six showed coverage of >0.1%: North American desert active and stabilized dune (0.6%); southern Rocky Mountain pinyon-juniper woodland (0.8%); southern Rocky Mountain juniper woodland and savannah (19.7%); Colorado Plateau mixed low sage shrubland (0.2%); Intermountain Basins semidesert shrub-steppe (1.9%); and western Great Plains short grass prairie (76.7%).

We derived forage production classes and pinyon-juniper management practices for CRLRC pastures from GIS coverages developed by McDaniel et al. (2002). Pinyon-juniper treatments included mechanical clearing of approximately 1,619 ha prior to 1989 and broadcast herbicide (tebuthiuron) treatments at 0.57 kg/ha in autumn on an additional 712 ha in 1995. Forage production classes were similar to Natural Resources Conservation Services forage production classes used in soil surveys (http://soils.usda.gov) and classified potential forage production based on soils given average precipitation, where F1 = 0–150 kg/ha; F2 = 150–300 kg/ha; F3 = 300–450 kg/ha; F4 = 450–600 kg/ha; and F5 = 600–750 kg/ha (McDaniel et al. 2002).

Precipitation

We used precipitation data collected from 3 automated and 7 manual weather stations distributed across CRLRC. We summed annual precipitation (e.g., total amount received from January of year$_t$ through December of year$_t$) and cumulative precipitation during each of 4 seasons based on biological relevance to deer (Bender et al. 2007*a*; Hoenes 2008; Bender et al. 2011, 2012). These seasons included (1) conception–parturition (January to June), when deer need to minimize overwinter condition

loss and later require increased nutritional quality as the fetus begins to grow (Wakeling and Bender 2003); precipitation during this period has been strongly linked to survival in cervids (Bender 2007; Hoenes 2008, Bender et al. 2011, 2012); (2) late-gestation-parturition (April to June), when energy requirements associated with late-gestation greatly increase deer nutritional requirements (Wakeling and Bender 2003); (3) lactation (July to September), the period of greatest nutritional demand on does (Wakeling and Bender 2003); and (4) post-lactation (October to December), when does need to recover energy reserves prior to winter and bucks enter the rut. We used totals from the nearest station for each individual deer's SSA range in analyses of precipitation effects on habitat quality.

Deer locations

We visually located deer using ground tracking as frequently as possible with the goal of obtaining locations on a weekly basis with emphasis on SSA locations because of the importance of this period in accrual of endogenous energy reserves (Verme and Ullrey 1984; Wakeling and Bender 2003; Bender et al. 2007*a,b*). We recorded locations using a hand-held Geographic Positioning System (GPS), and we mapped locations using the Geographic Information System (GIS) software package ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, California). We recorded date, time, group size, sex, and age composition, cover type, habitat type, and observed behavior (i.e., foraging, bedded, etc.) for each observation of radio-collared deer.

SSA home ranges

Because we were interested in the influences of environmental and management practices on the ability of mule deer to accrue endogenous energy reserves, we analyzed only SSA ranges of deer with the SSA period defined as following the early spring capture (late March, when deer are at their seasonal low in terms of body condition (Bender et al. 2007*a,b*; Hoenes and Bender 2012) and immediately prior to the late autumn capture (early December, when deer are at their seasonal peak in condition; Bender et al. 2007*a,b*; Hoenes and Bender 2012). We built 95% minimum convex

polygon (MCP) SSA home ranges (Kie et al. 1996) after determining the minimum number of locations to adequately estimate seasonal home range size by plotting size as a function of number of locations (Bender et al. 2007*b*).

Habitat quality

We used analysis of covariance (ANCOVA; Zar 1996) to identify the effects of home range composition (proportion of habitat types within SSA home ranges), habitat use (proportion of locations of deer during the SSA period by habitat type), precipitation, forage production class, and pinyon-juniper management history (for the latter two, proportion of SSA locations in each site class or management category) on doe condition in autumn while accounting for the influence of lactation status (Bender et al. 2007*b*, Hoenes 2008). We used linear regression (Zar 1996) to identify the effects of these same variables on buck condition. Because size of home ranges is also a surrogate for quality (Bender et al. 2007*b*), we similarly modeled sizes of SSA home ranges as a function of these same variables. For significant relationships, we present normalized parameter coefficients to allow relative comparison of effect size within sexes.

Results
Health and condition

We captured, recaptured, and assessed for condition of 63 individual adult mule deer (53 individually radio-collared [46 does and 7 bucks]; the remainder were used only for condition data and were released without a radio collar), from December 2005 to 2007. Numbers of radio-collared deer annually (2006 to 2008) were 18, 27, and 19 does, and 5, 6, and 5 bucks, respectively. Mean annual body condition of does and bucks was poor (Table 1; Bender et al. 2007*a*; Bender et al. 2011, 2012). Although lactating does were consistently in poorer condition than dry does for most condition indices each year (Table 1), no indices of condition varied among does by year × lactation status ($F_{5, 46} \leq 1.1$; $P \geq 0.37$), likely because all does were in extremely poor condition each year (Table 1) and consequently sample sizes of lactating does were low (3 to 4 annually). Bucks had significantly more subcutaneous fat (MAXFAT [$F_{2, 9} = 3.4$; $P = 0.08$])

in 2006 and 2007 as compared to 2005, while all other indices did not differ among years ($F_{2,9} \leq 2.8$; $P \geq 0.12$).

Modeling of doe condition indicated that only GIRTH was associated with cover type composition of SSA ranges. GIRTH was negatively related to the amount of desert dunes ($F_{1,8} = 4.7$; $P = 0.06$; effect = –0.41), mixed low sage shrubland ($F_{1,8} = 4.5$; $P = 0.066$; effect = –0.36), and mixed salt desert scrub ($F_{1,8} = 7.5$; $P = 0.03$; effect = –0.58) in doe SSA ranges. The proportion of SSA locations in dunes ($F_{1,8} = 6.9$; $P = 0.03$; effect = –0.57), mixed low sage shrubland ($F_{1,8} = 7.5$; $P = 0.03$; effect = –0.58), and semi-desert shrub steppe ($F_{1,8} = 3.4$; $P = 0.10$; effect = –0.49) was similarly negatively related to GIRTH in mule deer

Table 2. Relationships between use of habitat types and the composition of home ranges with size of spring-summer-autumn (SSA) home ranges on the Corona Range and Livestock Research Center, New Mexico. Presented are normalized coefficients and direction of effect of habitat types on size of SSA home ranges (– = negatively related to size of SSA home ranges; + = positively related to size of SSA home ranges; ns = nonsignificant effect at P = 0.10).

Home range attribute	Habitat type	Buck	Doe
Use	Active and stabilized dunes	ns	ns
	Pinyon-juniper woodland	–	ns
	Mixed low sage shrubland	–	+0.24
	Juniper woodland and savannah	ns	–0.38
	Semi-desert shrub steppe	ns	+0.34
	Shortgrass prairie	ns	+0.28
Composition	Active and stabilized dunes	ns	ns
	Pinyon-juniper woodland	ns	ns
	Mixed low sage shrubland	ns	ns
	Mixed salt desert scrub	ns	ns
	Juniper woodland and savannah	ns	ns
	Semi-desert shrub steppe	ns	ns
	Shortgrass prairie	+0.22	ns

does, while the proportion of locations in semi-desert shrub steppe was also negatively related to wBCS ($F_{1,8} = 5.7$; $P = 0.05$; effect = –0.72) and LOIN ($F_{1,8} = 3.4$; $P = 0.10$; effect = –0.56) in adult does. Conversely, proportion of locations in juniper woodland and savannah was positively related to GIRTH ($F_{1,8} = 4.7$; $P = 0.06$; effect = 0.55) in mule deer does. No other detectible relationships between vegetation cover types and doe condition were present. We were unable to model buck condition as a function of SSA range characteristics because of small (3) sample sizes.

Among site characteristics, GIRTH of mule deer does was positively related to high forage production class (F4: $F_{1,8} = 7.4$; $P = 0.026$; effect = 0.58). Approximate BF of adult does was negatively related to low forage production class (F2; $F_{1,8} = 6.4$; $P = 0.04$; effect = –0.52). No condition indices of adult does were related to use of areas of herbicide-treated juniper ($F_{1,8} \leq 2.2$; $P \geq 0.18$). Proportion of locations in SSA ranges in areas of mechanically cleared juniper were positively related to GIRTH ($F_{1,8} = 3.7$; $P = 0.09$; effect = 0.31) and BF ($F_{1,8} = 4.7$; $P = 0.06$; effect = 0.39). No other condition indices were associated with use of mechanically cleared

juniper in SSA ranges ($F_{1,8} \leq 0.2$; $P \geq 0.67$).

For adult does, accrual of rBCS, wBCS, MAXFAT, GIRTH, and BF was not associated with any measure of precipitation ($F_{1,49} = 2.7$; $P = 0.113$). Accrual of LOIN was positively associated with increased precipitation during late-gestation (April to June; $F_{1,49} = 3.1$; $P = 0.087$; effect = 0.21). No measures of condition of adult bucks were associated with any measure of seasonal or annual precipitation ($F_{1,10} = 2.6$; $P = 0.14$).

Home range modeling

We were able to adequately model (minimal number of locations for SSA home ranges = 15 based upon plots of home range size as a function of number of locations) complete SSA home ranges for 32 does and 9 bucks. Size of doe SSA ranges was not related to habitat type composition of SSA home ranges ($F_{1,30} = 0.8$; $P = 0.39$; Table 2). Size of SSA home ranges was positively related to the proportion of locations in mixed low sage shrubland ($F_{1,30} = 3.8$; $P = 0.060$), semi-desert shrub steppe ($F_{1,30} = 3.9$; $P = 0.07$), and shortgrass prairie ($F_{1,30} = 2.8$; $P = 0.10$). Conversely, size of doe SSA ranges was negatively related to proportion of locations in pinyon-juniper woodland and savannah

Table 3. Relationships between use of ecological site characteristics and pinyon-juniper treatments on spring-summer-autumn (SSA) home range size on the Corona Range and Livestock Research Center, New Mexico. Presented are normalized coefficients and direction of effect of attribute on size of SSA home ranges (– = negatively related to size of SSA home ranges; + = positively related to size of SSA home ranges; ns = nonsignificant effect at $P = 0.10$).

Range attribute	Class	Buck	Doe
Ecological site class	Forage production class 1	+0.21	+0.29
	Forage production class 2	ns	ns
	Forage production class 3	ns	ns
	Forage production class 4	ns	−0.32
	Forage production class 5	–	ns
Pinyon-juniper treatments	Herbicide	ns	ns
	Mechanical	–	−0.47

($F_{1,30} = 3.5$; $P = 0.070$). Size of buck SSA ranges was positively related to the proportion of short grass prairie ($F_{1,7} = 4.6$; $P = 0.07$) in SSA ranges, but was not related to the proportion of locations within cover types comprising SSA ranges ($F_{1,7} < 1.7$; $P > 0.24$; Table 2).

Size of deer SSA ranges was positively related to very low herbaceous forage production class (F1 – does: $F_{1,30} = 3.8$; $P = 0.06$; bucks: $F_{1,7} = 6.4$; $P = 0.04$; Table 3). Only relatively high forage production class (F4) was associated with decreasing size of SSA ranges of does ($F_{1,30} = 3.5$; $P = 0.07$), and no site characteristics were related to decreasing SSA home range size for bucks ($F_{1,7} \leq 1.4$; $P \geq 0.28$; Table 3).

Neither adult doe ($F_{1,30} = 0.3$; $P = 0.59$) or adult buck ($F_{1,7} = 0.5$; $P = 0.50$) SSA home range size was related to use of herbicide-treated juniper. Size of adult doe SSA home ranges was negatively related to the proportion of SSA locations in areas of mechanically cleared juniper ($F_{1,30} = 3.9$; $P = 0.06$). No bucks were ever located in areas of mechanically cleared juniper. Last, neither sizes of SSA home range of adult does ($F_{1,30} \leq 0.7$; $P \geq 0.42$) or adult bucks ($F_{1,7} \leq 0.5$; $P \geq 0.50$) were related to any measures of seasonal or annual precipitation.

Discussion

The nutritional status of individuals is the first parameter affected by resource limitations (Hanks 1981, Gaillard et al. 2000). On CRLRC, lactating does were never able to accrue >5.7% BF in any year, well below condition levels that mule deer are capable of accruing (>20% BF;

Oliver 1997). Even dry does were able to accrue only >7% BF in only 2 of 3 years, highlighting the nutritional stress faced by adult does on CRLRC. In contrast, bucks were able to accrue much more subcutaneous fat and other reserves in all years (Table 1). These differences occurred despite bucks entering SSA in poorer condition than does (Bender et al. 2011) and were likely related to different habitat use patterns and lower nutritional quality requirements of adult bucks (Wakeling and Bender 2003, Hoenes 2008).

Commonalities among SSA home range composition and use, modeling of condition, and modeling of SSA home range size indicated that cleared pinyon-juniper and pinyon-juniper woodlands and savannahs provided the best habitat for mule deer on CRLRC, whereas short grasslands and xeric shrublands provided the least value for mule deer. Precipitation also influenced the quality of habitats on CRLRC, although timing of precipitation was important; does showed slightly increased muscle mass (LOIN) as spring (April to June) precipitation increased. However, the effect of existing vegetation on deer condition was likely more important than precipitation, as adult does continued to exhibit poor body condition and population performance even during years of adequate and well-timed precipitation (Table 1) and the effect size of habitat influences on condition were ≥1.5 times greater than the effect of precipitation. Similarly, bucks were able to achieve higher condition than does despite experiencing the same precipitation patterns.

Home range, habitat use, and condition

Pinyon-juniper woodlands and savannahs comprised only 20% of the landscape of CRLRC but comprised approximately 25% of SSA ranges, and use of these types was associated with increased condition of does and decreased size of SSA home ranges. Further, doe use of mechanically cleared juniper sites, which are savannah-like, was also positively associated with increased condition of does. Although production of high-quality herbaceous forages is frequently low in pinyon-juniper woodlands, they typically show relatively high diversity and availability of browse species as compared to most other vegetation types in eastern and southern New Mexico (Bender et al. 2007*b*, Hoenes and Bender 2012). Browse is the main constituent of mule deer diets (Boeker et al. 1972, Krausman et al. 1997), and diversity and abundance of key browse species is a critical component of mule deer habitat (Wallmo 1981, Heffelfinger et al. 2006). Browse is of even greater importance for mule deer in arid environments, such as the CRLRC, due to high annual variability associated with the production of forbs (Kemp 1983, McKinney 2003, Hoenes and Bender 2012). On CRLRC, cover of browse species preferred by mule deer was greatest in pinyon-juniper woodlands (11%), pinyon-juniper savannah (17%), and short grasslands (16%). Similarly, positive associations of mechanically cleared pinyon-juniper with habitat quality, as opposed to herbicide-treated pinyon-juniper, likely reflected forage availability, as mechanically cleared stands had greater cover of preferred browse species (10% versus 2%; Bender 2012).

Size of SSA home ranges of adult does was inversely related to the proportion of locations in pinyon-juniper woodlands and savannahs in SSA home ranges. In general, smaller home ranges are usually associated with better habitat quality (Robinson and Bolen 1984), and this relationship is often attributed to food availability, with individuals in food-rich habitats being able to meet energetic requirements over smaller areas (Harestad and Bunnell 1979, Widmer et al. 2004). This is especially pronounced in ungulate species that are primarily browsers and located in woodland-shrubland communities dominated by browse species (Saïd and Servanty 2005). Consequently, use of open pinyon-juniper stands and mechanically cleared juniper resulted in does on CRLRC accruing greater size and muscle mass, which was positively related to their survival (Bender et al. 2011). Overall, however, condition of adult doe mule deer was poor (Table 1); despite the positive associations with open pinyon-juniper types, deer were not able to acquire diets approaching optimal quality in pinyon-juniper communities on CRLRC.

The role of pinyon-juniper woodlands in providing cover for mule deer has been well documented (Clary et al. 1974; Short et al. 1977; Wallmo and Regelin 1981; Lutz et al. 2003; Bender et al. 2007*b*), and >88% of locations of radio-collared mule deer were < 200 m from unmanaged pinyon-juniper stands that averaged 62% cover of pinyon-juniper (L. Bender, unpublished data). Densities and cover of woody species associated with pinyon-juniper demonstrate that pinyon-juniper woodlands provide the best cover attributes of any habitat type for mule deer in the Southwest (Bender et al. 2007*b*, Hoenes and Bender 2012). Further, doe-use of pinyon-juniper in SSA ranges coincides with fawning, and hiding cover for fawns is an attribute of mule deer habitat that does consistently select (Wallmo 1981, Short et al. 1977, Severson and Medina 1983, Heffelfinger et al. 2006). The ability of pinyon-juniper woodlands and savannahs to provide cover and, thus, minimize disturbance likely contributed to their positive relationship with doe condition and habitat quality as indexed by size of SSA home ranges on CRLRC.

Size of SSA home ranges of deer increased as use of short grass prairie and xeric shrublands increased. Short grasslands on CRLRC were dominated by stands of perennial gramas (*Bouteloua* spp.) and were the most common vegetation type on our study area, covering approximately 77% of the site. Because of its abundance, the negative association between short grasslands and deer habitat quality was particularly relevant. While short grasslands produce forage species used by mule deer (cover of preferred browse = 16% on CRLRC; L. Bender, unpublished data), often in significant quantities (Bender et al. 2007, Hoenes and Bender 2012), cover is lacking (Bender et al.

2007*b*, Hoenes and Bender 2012). Cover is an important component of mule deer habitat (Short et al. 1977, Wallmo 1981, Wallmo and Regelin 1981, Severson and Medina 1983, Heffelfinger et al. 2006). Cover minimizes energy expenditures associated with disturbances and also reduces vulnerability to predation (Smith and LeCount 1979, Severson 1981, Lutz et al. 2003, Bender et al. 2007*b*, Lomas and Bender 2007). Lack of cover provided by trees and shrubs in grasslands is a likely explanation for their positive association with increasing size of SSA home range size and hence negative association with habitat quality (Bender et al. 2007*b*, Hoenes 2008).

Hoenes (2008) found that mule deer showed increased use of grama grasslands that were associated with deciduous shrublands and pinyon-juniper woodlands, both of which provided cover and browse and were consistently used in excess of their availability in his study area in the San Andres Mountains of southcentral New Mexico. Use of grasslands by mule deer, thus, may be increased in areas where cover is available in adjacent habitat types, similar to relationships seen in northcentral New Mexico (Bender et al. 2007*b*). On CRLRC, virtually all use of short grass prairie by mule deer was within 200 m of pinyon-juniper or other cover.

Negative associations with condition of deer and positive associations with increased SSA home range sizes indicated that xeric shrublands (i.e., mixed low-sage shrubland, mixed salt-desert scrub, semi-desert shrub-steppe) were of low quality for deer. Many xeric shrublands are characterized by poor forage and cover characteristics (Bender 2007, Hoenes and Bender 2012) that likely limits their value to mule deer. However, some of these cover types (i.e., semi-desert shrub-steppe, mixed low-sage) often have useful browse species (i.e., winter fat [*Krascheninnikovia lanata*], apache plume [*Fallugia paradoxa*], fourwing saltbush [*Atriplex* canescens], etc.) as important components of their flora. Thus, we are unsure of the reasons behind the negative relationships with deer habitat quality on CRLRC. Most of the mixed low sage and semi-desert shrub steppe was associated with poorer soils on CRLRC, possibly contributing to their negative association with mule deer habitat quality.

Influence of precipitation

Condition of adult does was positively, albeit weakly, related to increased precipitation during spring (April to June), and survival of adult does was likewise benefited by increased precipitation during winter and spring (January to June and April to June; Bender et al. 2011). Adult does face increased energetic requirements at the onset of late-gestation (Verme and Ullrey 1984, Wakeling and Bender 2003). If precipitation and consequently green forage is absent during this period, a doe mobilizes its body reserves in an attempt to provide the fetus with adequate nourishment (Verme and Ullrey 1984, Landete-Castillejos et al. 2003), thus, lowering her condition. Increasing nutritional requirements associated with late-gestation likely accounted for the positive relationship between autumn condition of does and cumulative precipitation during late-gestation (April to June). In most regions where mule deer are found, forage availability is limited during late winter months, and individuals must rely primarily on fat reserves for energy through winter (Mautz 1976). However, winters in central New Mexico are relatively mild compared to winters in more northern climates, with snow accumulation typically low and most precipitation occurring as rainfall. Consequently, some annual forb species (winter annuals) germinate and grow in response to precipitation during late winter and early spring (Guo and Brown 1997, Hoenes 2008). Production of winter and early-spring annuals may provide mule deer in CRLRC with a forage resource that allows them to slow condition losses, which may be particularly important given that deer entered winter in extremely poor condition on CRLRC (Table 1).

Management implications

Poor condition of adult doe mule deer on CRLRC indicated that overall habitat quality for mule deer was poor, as further evidenced by low survival and poor productivity of mule deer on CRLRC (Bender et al. 2011). Of existing habitat attributes on CRLRC, only pinyon-juniper woodlands and savannahs were positively associated with condition and habitat quality of doe mule deer on CRLRC, and most deer use was <200 m from pinyon-juniper stands. Consequently, management strategies should be aimed at enhancing forage

attributes of these cover types to increase the productivity of mule deer on CRLRC. Mechanical thinning (Van Hooser et al. 1993, Stevens and Monsen 2004) and prescribed burns (Hobbs and Spowart 1984, Monsen et al. 2004, Stevens and Monsen 2004) are 2 strategies that can increase the quantity and quality of forage species associated with woodland communities to benefit mule deer by freeing nutrients for herbaceous and shrub species, and decreasing the successional status of shrub communities. However, treatments must be carefully designed to maintain adequate cover attributes, or deer-use may actually decline (Bender et al. 2007b, Hoenes and Bender 2012, Bender 2012). Management strategies that maintain 25% of home ranges in unmanaged (high cover, i.e., >60% on CRLRC) pinyon-juniper and provide a mixture of thinned stands of 10 to 30% cover likely provide an acceptable balance between cover and forage, particularly if unmanaged stands are within 200 m of any point on thinned stands (Bender 2012). Additionally, treatments associated with areas of higher forage production classes would likely show greater positive effects on mule deer habitat. In contrast, herbicide treatment of pinyon-juniper had no positive benefit to mule deer habitat quality on CRLRC, likely because treatments also killed other woody vegetation and, thus, lowered both forage and cover attributes of treated stands.

Short grasslands contain significant quantities of palatable herbaceous forages and browse, but were of low overall quality for mule deer likely because they lacked cover. Management actions to enhance the quality of grasslands for mule deer include prescribed burns to enhance the forb component (Ford and McPherson 1996) and establishment of woody shrub patches near or adjacent to locally rugged topography (Severson 1981, Bender et al. 2007b) to provide a cover component. Treatment areas are likely to see a greater response from deer if located <200 m from areas providing cover for mule deer. Because many carpeted shrubs are present through much of CRLRC's short grasslands, grazing exclosures may also be useful to encourage expansion and increased vertical growth of these shrubs, particularly because establishment of shrub communities is often more difficult than enhancing existing shrub communities (Stevens and Monsen 2004).

Regardless of treatments or habitat types managed, increasing cover of palatable shrubs on CRLRC should be a priority to maintain or increase mule deer numbers. Because of the effect of precipitation, particularly during January to June and April to June on deer survival, mule deer on CRLRC require an environmental buffer that can mitigate the negative impacts of drought years (Bender et al. 2007a, Bender et al. 2011). An abundant and diverse browse community is less susceptible to drought than are forbs (Hoenes and Bender 2012), and establishing such resources throughout CRLRC will make mule deer habitats far more drought tolerant, thereby reducing the severe declines seen in mule deer numbers in response to a combination of extremely low body condition and drought, particularly during late winter and spring (Bender et al. 2011).

Despite taking these measures, we are unsure to what degree these activities can increase condition and productivity of mule deer on CRLRC. Consistent positive relationships between deer survival and precipitation on CRLRC (Bender et al. 2011) indicated that deer are sensitive to seasonal precipitation patterns. However, the causal mechanism that this would operate through (i.e., increased individual condition) was only weakly detected on CRLRC during the same period. Possibly habitat quality had declined to levels where it was largely unresponsive to the amount and timing of precipitation seen during our study, or perhaps the timing and quantity of precipitation during our study were insufficient to be generate a response in mule deer condition (although survival was influenced). If the former is true, then activities short of extensive feeding may not enhance nutrition sufficiently to compensate for extant habitat conditions or dry years, and, thus, have little overall affect on condition. However, management actions, such as listed above, may increase survival and productivity during average or above average precipitation years, accelerating recovery of populations lowered by frequent drought (Bender et al. 2011).

Acknowledgments

University's Extension Animal Sciences and Natural Resources and Animal and Range Sciences Departments, and the New Mexico State University Agricultural Experimental Station. We thank M. Peterson, A. Cibils, T. Ross, K. McDaniel, and the remainder of the CRLRC research team for their contributions to this effort. All project activities were in agreement with NMSU IACUC Permit No. 2005-023.

Literature cited

Bender, L. C. 2007. Growth, health, and impacts of a pioneering elk herd on and adjacent to Chaco Culture National Historic Park, New Mexico, final report. U. S. Geological Survey and New Mexico Cooperative Fish and Wildlife Research Unit, Las Cruces, New Mexico, USA.

Bender, L. C. 2012. Guidelines for management of habitat for mule deer: pinyon-juniper, Chihuahuan desert, arid grasslands, and associated arid habitat types, circular 662. Cooperative Extension Service, New Mexico State University, Las Cruces, New Mexico, USA.

Bender, L. C., J. C. Boren, H. Halbritter, and S. Cox. 2011. Condition, survival, and productivity of mule deer in a semiarid grass-woodland in eastcentral New Mexico. Human–Wildlife Interactions 5:276–286.

Bender, L. C., B. D. Hoenes, and C. L. Rodden. 2012. Factors influencing survival of desert mule deer in the greater San Andres Mountains, New Mexico. Human–Wildlife Interactions 6:245–260.

Bender, L. C., L. A. Lomas, and J. Browning. 2007a. Condition, survival, and cause-specific mortality of adult doe mule deer in north-central New Mexico. Journal of Wildlife Management 71:1118–1124.

Bender, L. C., L. A. Lomas, and T. K. Kamienski. 2007b. Habitat effects on condition of doe mule deer in arid mixed woodland-grassland. Rangeland Ecology and Management 60:277–284.

Bishop, C. J., G. C. White, D. J. Freddy, B. E. Watkins, and T. R. Stephenson. 2009. Effect of enhanced nutrition on mule deer population rate of change. Wildlife Monograph No. 172.

Boeker, E. L., V. E. Scott, H. G. Reynolds, and B. A. Donaldson. 1972. Seasonal food habits of mule deer in southwestern New Mexico. Journal of Wildlife Management 36:56–63.

Clary, W. P., M. B. Baker Jr., P. E. O'Connell, T. N. Johnson Jr, and R. E Campbell. 1974. Effects of pinyon-juniper removal on natural resource products and uses in Arizona. U.S. Forest Service Research Paper RM-128. Ft. Collins, Colorado, USA.

Clutton Brock, T. H., F. E. Guinness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. University of Chicago Press, Chicago, Illinois, USA.

Cook, R. C. 2000. Studies of body condition and reproductive physiology in Rocky Mountain elk. Thesis, University of Idaho, Moscow, Idaho, USA.

Ford, P. L., and G. R. McPherson. 1996. Ecology of fire in shortgrass prairie in the southern Great Plains. Pages 20–39 in U.S. Forest Service General Technical Report RM-GTR-285. Ft. Collins, Colorado, USA.

Gaillard, J.-M., M. Festa-Bianchet, N. G. Yoccoz, A. Loison, and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics 31:367–393.

Guo, Q., and J. H. Brown. 1997. Interactions between winter and summer annuals in the Chihuahuan Desert. Oecologia 111:123–128.

Hanks, J. 1981. Characterization of population condition. Pages 47–73 in C. W. Fowler and T. D. Smith, editors. Dynamics of large mammal populations. Blackburn Press, Caldwell, Idaho, USA.

Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight–a reevaluation. Ecology 60:389–402

Heffelfinger, J. R., C. Brewer, C. H. Alcala-Galvan, B. Hale, D. Weybright, B. F. Wakeling, L. H. Carpenter, and N. L. Dodd. 2006. Habitat guidelines for mule deer: southwest desert ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies, Tucson, Arizona, USA.

Heffelfinger, J. R., and T. A Messmer. 2003. Pages 1–11 in J. C. deVos Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Press, Logan, Utah, USA.

Hobbs, N. T., and R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management 48:551–560.

Hoenes, B. 2008. Identification of factors limiting desert mule deer populations in the greater San Andres Mountains of southcentral New

Mexico. Thesis. New Mexico State University, Las Cruces, New Mexico, USA.

Hoenes, B. D., and L. C. Bender. 2012. Factors influencing foraging habitats of desert mule deer in the greater San Andres Mountains, New Mexico. Southwestern Naturalist 57:370–379.

Kemp, P. R. 1983. Phenological patterns of Chihuahuan desert plants in relation to the timing of water availability. Journal of Ecology 71:427–436.

Kie, J. G., J. A. Baldwin, and C. J. Evans. 1996. CALHOME: a program for estimating animal home ranges. Wildlife Society Bulletin 24:342–344.

Krausman, P. R., A. J. Kuenzi, R. C. Etchberger, K. R. Rautenstrauch, L. L. Ordway, and J. J. Hervert. 1997. Diets of desert mule deer. Journal of Range Management 50:513–522.

Landete-Castillejos, T., A. García, J. A. Gómez, and L. Gallego. 2003. Lactation under food constraints in Iberian red deer *Cervus elaphus hispanicus*. Wildlife Biology 9:131–139.

Lomas, L. A., and L. C. Bender. 2007. Survival and cause-specific mortality of neonatal mule deer fawns in northcentral New Mexico. Journal of Wildlife Management 71:884–894.

Lutz, D. W., B. F. Wakeling, L. H. Carpenter, D. Stroud, M. Cox, D. McWhirter, S. Rosenstock, L. C. Bender, and A. F. Reeve. 2003. Impacts and changes to mule deer habitat. Pages 13–62 *in* J. C. deVos Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Press, Logan, Utah, USA.

Mautz, W. W. 1976. Sledding on a brushy hillside: the fat cycle in deer. Wildlife Society Bulletin 6:88–90.

McDaniel, K., J., S. Hartung, S. Cox, R. McNeely, and G. Timmons. 2002. Brush management plan for New Mexico State University Corona Ranch. Department of Animal and Range Sciences, New Mexico State University, Las Cruces, New Mexico, USA.

McKinney, T. 2003. Precipitation, weather, and mule deer. Pages 219–237 *in* J. C. deVos Jr, M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: Issues and management strategies. Jack H. Berryman Press, Logan, Utah, USA.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004. Restoring western ranges and wildlands. U.S. Forest Service General Technical Report RMRS-GTR-136-VOL-2. Ft. Collins, Colorado, USA.

Oliver, M. N. 1997. California deer condition index: a field technique for scoring body condition. California Department of Fish and Game, Sacramento, California, USA.

Piasecke, J. R., and L. C. Bender. 2011. Patterns in the costs of lactation to body condition of free-ranging Rocky Mountain elk (*Cervus elaphus nelsoni*) populations. Pages 95–111 *in* V. K. Gupta and A. K. Verma, editors. Animal diversity, natural history, and conservation. Daya, New Delhi, India.

Robinette, W. L., D. A. Jones, G. Rogers, and J. S. Gashwiler. 1957. Notes on tooth development and wear of Rocky Mountain deer. Journal of Wildlife Management 21:134–153.

Robinson, W. L., and E. B. Bolen. 1984. Wildlife ecology and management. Macmillan, New York, New York, USA.

Saïd, S., and S. Servanty. 2005. The influence of landscape structure on female roe deer home-range size. Landscape Ecology 20:1003–1012.

Severson, K. E. 1981. Plains habitats. Pages 459–486 *in* O. C. Wallmo, editor. Mule and black-tailed deer of North America. University of Nebraska, Lincoln, Nebraska, USA.

Severson, K. E., and A. L. Medina. 1983. Deer and elk habitat management in the Southwest. Journal of Range Management Monograph No. 2. Society for Range Management, Denver, Colorado, USA.

Short, H. L., W. Evans, and E. L. Boeker. 1977. The use of natural and modified pinyon pine-juniper woodlands by deer and elk. Journal of Wildlife Management 41:543–559.

Smith, R. H., and A. Lecount. 1979. Some factors affecting survival of desert mule deer. Journal of Wildlife Management 43:657–665.

Stephenson, T. R., V. C. Bleich, B. M. Pierce, and G. P. Mulcahy. 2002. Validation of mule deer body composition using *in vivo* and post-mortem indices of nutritional condition. Wildlife Society Bulletin 30:557–564.

Stevens, R., and S. B. Monsen. 2004. Guidelines for restorations and rehabilitation of principle plant communities. Pages 199–294 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands. U. S. Forest Service General Technical Report RMRS-GTR-136-VOL-1. Ft. Collins, Colorado, USA.

Van Hooser, D. D., R. A. O'Brien, and D. C. Collins. 1993. New Mexico's forest resources. U.S. Forest Service Resource Bulletin INT-79. Missoula, Montana, USA.

Verme, L. J., and D. E. Ullrey. 1984. Physiology and nutrition. Pages 91–118 in L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Wakeling, B. F., and L. C. Bender. 2007. Influence of nutrition on mule deer biology and ecology. Pages 93–116 in J. C. deVos Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Press, Logan, Utah, USA.

Wallmo, O. C. 1981. Mule and black-tailed deer distribution and habitats. Pages 1–26 in O. C. Wallmo, R. E. McCabe, and L. R. Jahn, editors. Mule and black-tailed deer of North America.

University of Nebraska Press, Lincoln, Nebraska, USA.

Wallmo, O. C., and W. L. Regelin. 1981. Rocky Mountain and Intermountain habitats. Part 1: food habits and nutrition. Pages 387–398 in O. C. Wallmo, R. E. McCabe, and L. R. Jahn, editors. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Widmer, O., S. Saïd, J. Miroir, P. Duncan, J-M Gaillard, and F. Klein. 2004. The effects of Hurricane Lothar on habitat use of roe deer. Forest Ecology and Management 195:237–242.

Wood, J. E., T. S. Bickle, W. Evans, J. C. Germany, and V. W. Howard Jr. 1970. The Fort Stanton mule deer herd. Agricultural Experiment Station Bulletin 567. New Mexico State University, Las Cruces, New Mexico, USA..

Zar, J. H. 1996. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey, USA.

LOUIS C. BENDER is a senior research scientist with Extension Animal Sciences and Natural Resources at New Mexico State University. He received his Ph.D. and M.S. degrees in wildlife from Michigan State University and his B.S. degree in wildlife from the University of Montana. His research and management programs emphasize ungulate and large carnivore populations and habitat, integrated wildlife and livestock habitat management, and wildlife enterprises in the Southwest and Mexico.

JON C. BOREN earned his bachelor's and master's degrees in wildlife ecology and his doctoral degree in range science from Oklahoma State University before coming to New Mexico State University in 1996 as an assistant professor and extension wildlife specialist. He was selected as associate dean and director of the New Mexico Cooperative Extension Service in 2009. He has investigated wildlife and livestock interactions through scientific studies on rangelands and forests in New Mexico, developed innovative and cost effective methods to cope with problems from wildlife damage, and developed teaching materials to use in natural resource educational curricula. He conducts educational programs for youth in 4-H, FFA, and the public school system.

HEATHER HALBRITTER is a terrestrial biologist in the northeast region for the Colorado Division of Wildlife. She has a B.S. degree in biology from State University of New York–Brockport and received an M.S. degree in wildlife biology from New Mexico State University. She has spent most of her career working on various ungulate research and management projects and has a strong interest in livestock–wildlife conflicts.

SHAD COX is the superintendent of New Mexico State University's Corona Range and Livestock Research Center (CRLRC). He graduated from New Mexico State University in 1994 with a B.S. degree in animal science and an M.S. degree in reproductive physiology and toxicology in 2000. He has lived and worked on the CRLRC for 17 years. He spends his leisure time insuring extracurricular opportunities for youth in agriculture.