Wildlife Society Bulletin; DOI: 10.1002/wsb.679

Original Article

Foraging at the Wildland–Urban Interface Decouples Weather as a Driver of Recruitment for Desert Bighorn Sheep

KATHLEEN LONGSHORE,[1] *U.S. Geological Survey, Western Ecological Research Center, 160 N Stephanie Street, Henderson, NV 89074, USA*
CHRISTOPHER LOWREY, *U.S. Geological Survey, Western Ecological Research Center, 160 N Stephanie Street, Henderson, NV 89074, USA*
PATRICK CUMMINGS, *Nevada Department of Wildlife, 4747 Vegas Drive, Las Vegas, NV 89108, USA*

ABSTRACT A growing number of ungulate populations are living within or near the wildland–urban interface. When resources at the interface are of greater quality than that of adjacent natural habitat, wildlife can be attracted to these developed areas. Little is known about how use of the wildland–urban interface by wildlife may affect vital rates. Under natural conditions, recruitment by desert bighorn sheep (*Ovis canadensis nelsoni*) correlates with variation in the timing and amount of rainfall that initiates and enhances growth of annual plant species. However, for populations that forage in developed areas, this relationship may become decoupled. In the River Mountains of Nevada, USA, desert bighorn sheep have been feeding in a municipal park at the wildland–urban interface since its establishment in 1985. Approximately one-third of the population now uses the park during summer months when nutritional content of natural forage is low. We hypothesized that use of this municipal area, with its abundant vegetation and water resources, may have decoupled the previous relationship between precipitation and lamb recruitment. We assessed variables known to affect lamb recruitment before (1971–1986) and after (1987–2006) establishment of the park using linear regression models. Our top candidate model for the pre-park period indicated that total November precipitation was the greatest driver of lamb recruitment in this population. After park establishment, this relationship became decoupled because lamb recruitment was no longer driven by weather variables. These results raise questions about the effects of decoupling drivers of population growth and maintaining natural populations near urban areas. Published 2016. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS bighorn sheep, disturbance, ecological decoupling, *Ovis canadensis nelsoni*, recruitment, wildland–urban interface.

As urbanization increases throughout the world, a growing number of wildlife populations are living within or near the wildland–urban interface, where urban and suburban development borders undeveloped wildland vegetation (Theobald et al. 1997, Radeloff et al. 2005). Urban and suburban development can have important consequences for wildlife, and it is thus becoming increasingly important to expand our understanding of how this development effects vertebrate populations (Theobald et al. 1997, Lubow et al. 2002, Rubin et al. 2002). Behavioral responses of animals at the wildlife–urban interface can be generally classified as avoidance, attraction, tolerance, and habituation (Knight and Cole 1995). Many species avoid urban areas by altering their movement patterns, which can result in habitat loss and fragmentation (Rubin et al. 2002). However, when resources (e.g., food, water, refuge from predators) at the wildland–urban interface are perceived by animals to be of greater quality than that of the adjacent wildland, wildlife can be attracted to developed areas, including golf courses, house lawns and gardens, and municipal parks (Gill et al. 2001). Wildlife can then become tolerant to disturbance at these sites (Thompson and Henderson 1998, Rubin et al. 2002). Use of developed areas, where productivity is stable (Shochat et al. 2006), can then cause changes in vital rates (Etter et al. 2002, Hebblewhite et al. 2005, Harveson et al. 2007, Polfus and Krausman 2012). Vital rate changes may indicate that fundamental ecological patterns and demographic processes have become decoupled. Understanding how anthropogenic activities affect ecological processes and ungulate demographics is an important conservation and management concern.

There is evidence that in some populations of ungulates, individuals who forage at the urban–wildlife interface may have increased fitness as a result of better nutrition (e.g., white-tailed deer [*Odocoilous virginianus;* Butfiloski et al. 1997], desert bighorn sheep [*Ovis canadensis nelsoni;* Rubin et al. 2002], and North American elk [*Cervus elaphus;*

Received: 4 September 2015; Accepted: 20 May 2016

[1]*E-mail: longshore@usgs.gov*

Thompson and Henderson 1998, Lubow et al. 2002]). However, these animals may also display changes in foraging behavior and habitat selection that can have negative effects on the long-term viability of the population, including increased parasite loads (Rubin et al. 2002) and rates of disease transmission (Sherrill et al. 2012). Many studies have described how use of urban areas affects behavior, ecology, and demographics of ungulates at the wildland–urban interface (e.g., Rubin et al. 2002, Harveson et al. 2007, Polfus and Krausman 2012), but to our knowledge, no studies have described the decoupling of ecological patterns and demographic processes of ungulates using urban resources in arid environments.

Density-dependent mechanisms and density-independent climate fluctuations often interact to regulate demography of wild ungulate populations (Douglas and Leslie 1986, Wehausen et al. 1987, Portier et al. 1998, Koons et al. 2012). However, in arid regions, density-independent variables that affect availability of primary growth appear to have a greater effect on demographic processes than does density dependence (Davis et al. 2002). In ungulate species such as desert bighorn sheep, adult survival is generally greater and less variable than that of young because juveniles are more sensitive to changes in weather and resource availability (Douglas and Leslie 1986, Clutton-Brock et al. 1987, Wehausen et al. 1987, Wehausen 2005). Desert bighorn sheep inhabit mountainous terrain in arid and semiarid regions of western North America where the timing and amount of precipitation, and therefore forage productivity, is highly variable (Beatley 1969, Noy-Meir 1973). Desert bighorn sheep populations are greatly affected by rainfall patterns because annual plant species are a critical food source during late winter and spring, when most lambs are born and nursing (Wehausen 2005). Accordingly, lamb recruitment and overall population dynamics have been found to correlate with variation in rainfall (Douglas and Leslie 1986, Wehausen et al. 1987, Wehausen 2005).

The River Mountains of southern Nevada, USA, form a typical, low-elevation mountain range in the Mojave Desert. Located mostly within the Lake Mead National Recreation Area, the range is bounded on the southeast by the municipality of Boulder City and in the northwest by Henderson and Las Vegas metropolitan areas. The River Mountains are occupied by a population of bighorn sheep and the area has an estimated carrying capacity of approximately 250 animals (Leslie and Douglas 1979). These sheep have been the subject of a number of earlier studies (Papez and Tsukamoto 1970, McQuivey and Leslie 1976, Leslie and Douglas 1979, Kirkeeng 1985, Hass 1997), including a study of density–dependent and independent drivers of lamb survival by Douglas and Leslie (1986), who found autumn rainfall to be the strongest driver of lamb survival. This population has also been a source for translocations throughout the southwestern United States since 1969.

Over the past 3 decades, urban development has increased along the base of the River Mountains, particularly in the southeast where the mountain range interfaces with Boulder City. A municipal park was built in 1985 within the wildland–urban interface of Boulder City. Not long after the lawn was installed, bighorn sheep started feeding in the park. Their numbers have increased over the years until contemporary estimates of >80 animals can be found in the park on a single day. Based on observations of marked sheep during surveys, some animals are observed in the northern part of the mountain range but rarely in Hemenway Park, while others are observed in the park but rarely in the northern portion of the range. Bighorn sheep generally begin feeding in the park during late spring–early summer when native forage quality is at its lowest (Wehausen 2005) and depart with the onset of autumn rains. During years when precipitation is low and few winter annuals germinate, sheep can be found in the park the entire year. Residents living at the wildland–urban interface also provide water for sheep.

We hypothesized that use of this municipal area by bighorn sheep, with its abundant vegetation and water resources, may have decoupled the previous relationship between precipitation and lamb recruitment. To test this hypothesis, we constructed regression models to assess variables known to influence variation in recruitment and compared their relationship to lamb recruitment before and after the park was established. We also tested for differences in precipitation means prior to and after establishment of the park.

STUDY AREA

The River Mountains of southern Nevada occupy 90 km^2 of mountainous terrain, typical of low-elevation ranges in the Mojave Desert. The River Mountains were mostly situated in the Lake Mead National Recreation Area but were bounded on the southeast by Boulder City and in the northwest by the city of Henderson. Elevation ranged from 384 m to 1,155 m, with steep and rocky topography, consisting of rugged volcanic outcrops dissected by desert washes. Average annual rainfall was <15.0 cm/year (SE = 2.6) mostly occurring during winter and summer months. The mountain range supported 2 biotic communities: the creosote bush (*Larrea tridentata*) community and the desert wash community (Bradley and Deacon 1965). The desert wash community generally received more water available for growth from runoff. Dominant vegetation consisted of *Larrea tridentata–Ambrosia dumosa* associations and the more abundant species included *Atriplex* spp., *Encelia farinosa*, *Dalea* spp., *Ephedra nevadensis*, and *Krameria erecta* (Leslie and Douglas 1979). Although mesopredators, such as coyotes (*Canis latrans*) and bobcats (*Lynx rufus*), occurred in the range, the area was not inhabited by resident cougars (*Puma concolor*).

Hemenway Park was located on the southeastern border of the mountain range in the municipality of Boulder City. The park was approximately 4 ha in area and constructed during 1985; it consisted of a large lawn, playground equipment, gazebos, basketball courts, horseshoe pits, and 2 lighted tennis courts. The park was visited regularly by local residents and by tourists who came to view bighorn sheep. Sheep use occurred primarily in the warmer months (mean daily no. of animals counted from Jun through Sep = 51.8, SD = 18.8).

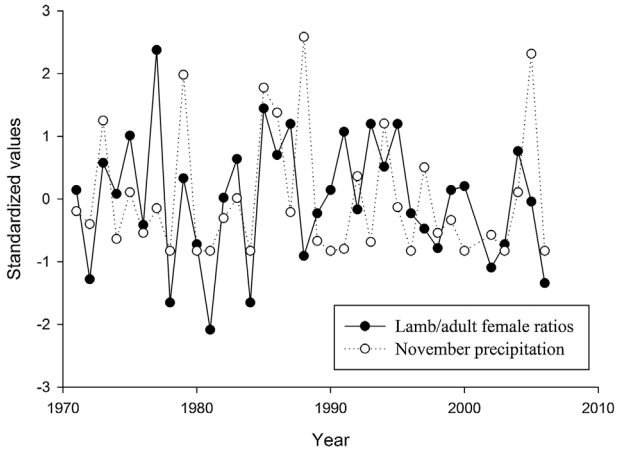

Figure 1. November precipitation and lamb/adult female ratios of bighorn sheep estimated from helicopter overflights during 1971–2006, River Mountains, Nevada, USA. No survey was conducted during 2001. Hemenway Park was constructed in 1986.

METHODS

We estimated desert bighorn sheep population sizes and lamb/adult female ratios (no. of lambs/F) from helicopter overflights conducted each year during October, by the Nevada Department of Wildlife (Fig. 1). We assembled precipitation data from the Remote Automated Weather Station adjacent to the River Mountains from 1971 through 2004 and the Community Environmental Monitoring Program station (<1 km from the Remote Automated Weather Station) from 2005 to 2006. We chose our candidate lamb recruitment models *a priori*, based on the hypothesis described above. Specifically, our models addressed how timing and duration of precipitation might affect lamb/adult female ratios, and whether those effects changed as a result of the creation of a municipal park. We included the variables of total seasonal precipitation during different time periods: early (Sep–Nov) and late (Dec–Feb) winter; different durations (single month, 2-, 3-, and 4-month totals); and bighorn population size at 1 year (Pop1) and 2 years (Pop2) prior to measurement of lamb/adult female ratios (Douglas and Leslie 1986, Wehausen et al. 1987, Portier et al. 1998; Table 1). Summations of 2-, 3-, and 4-month precipitation totals were based on combining either early or late winter months. We adjusted population sizes for previous year(s) by removing the number of animals translocated from the study site during that year. We did not adjust lamb/adult female ratios by animals removed.

We square-root–transformed precipitation values to meet the distribution requirements of general linear regression (Sokal and Rohlf 1998). We categorized our data set into 2 time periods (Time): the 16 years before (1971–1986) and 19 years after the municipal park was established (1987–2006; early time period coded as 0, late period as 1). We used a logit transformation for our dependent variable (Sokal and Rohlf 1998). We created 31 models: 15 models that hypothesized that precipitation and previous population size remained constant across the entire time series (no time period interaction) and 15 models that hypothesized significant interaction between the time periods and precipitation and previous population size. We additionally included a null model using only the intercept. We used an analysis of variance to compare mean rainfall for each month between time periods and assess whether the difference between recruitment models may have been the result of differences in rainfall amounts before and after establishment of the park.

We ranked and evaluated the support for each model given the data using Akaike Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002). An interaction model(s) that prevailed over the non-interaction model(s) is evidence that the relationship between lamb/adult female ratios and precipitation and previous population size changed over time (Burnham and Anderson 2002). If our non-interaction model(s) prevailed, no further analyses would be needed. If a Time × Variable interaction model ranked higher, however, we would further explore the

Table 1. The 10 top-ranked models for desert bighorn sheep lamb/adult female ratios and respective attributes for time period 1971 through 2006 (excluding 2001) in the River Mountains, Nevada, USA, based on Akaike Information Criterion (AIC_c) and model weight (w_i).

Model variables	K[a]	ΔAIC_c	w_i
Time[b] + Nov[c] + (Time × Nov)[d]	5	0.00	0.78
Time + Pop1[e] + Nov + (Time × Pop1) + (Time × Nov)	7	5.25	0.05
Time + Pop2 + Nov + (Time × Pop2) + (Time × Nov)	7	5.42	0.05
Time + Nov	4	6.59	0.03
Time + (Nov + Dec)[f] + [Time × (Nov + Dec)]	5	7.75	0.02
Time + Pop1 + Nov	5	8.33	0.01
Time + Pop2 + Nov	5	8.62	0.01
Time + (Nov + Dec)	4	9.03	0.01
Time + Pop1 + (Nov + Dec)	5	10.26	0.005
Time + (Oct + Nov + Dec) + [Time × (Oct + Nov + Dec)]	5	10.46	0.005
Intercept only	2	25.96	<0.001

[a] K = number of of parameters in model + 2.
[b] Time = categorical time variable (0 = before park establishment, 1 = after park establishment).
[c] Month abbreviations indicate total precipitation for that month, measured in mm.
[d] "×" indicates interaction term.
[e] Pop1 and Pop2 = Total population size 1 year and 2 years, respectively, prior to the measurement year of lamb/adult female ratios.
[f] Months within parentheses with + signs were summed before analysis.

interaction using linear regression. We included a regression analysis to obtain both parameter direction and relative strength, which we believe gives us more interpretive ability than using AIC parameter weights alone (Steidl 2006). Although we could report the potential differences in the effect of precipitation within a single model by using a Time × Precipitation interaction term, we believe using 2 linear regression models resulted in a clear and concise comparison of how lamb/adult female ratios may be decoupled from precipitation between the 2 time periods.

RESULTS

Mean lamb/adult female ratios were variable across years ($\bar{x} = 0.42$ lambs/adult female, SD = 0.16, range = 0.08–0.80). Based on AIC model selection, November precipitation ($\beta = 0.005$, 95% CI = −0.051 to 0.061) and the Time period × November precipitation interaction term (early time period $\beta = 0.126$, 95% CI = 0.043–0.210: late time period $\beta = -0.149$, 95% CI = −0.279 to −0.019) were the only 2 important contributors to the top-ranked model. Average November precipitation over the study period was 13.2 mm (SD = 15.9, range = 0.0–54.6). The AIC variable weights for November precipitation and (Time × Nov) precipitation interaction were 0.94 and 0.89, respectively. Given our candidate model set was based on hypotheses concerning changes over time, the Time variable was in all of our models (except the intercept-only model), which necessarily gives it a weight of almost 1.0. The AIC weights for all other model variables were low (<0.08). The greater ranking of the model with the interaction term compared with those of the noninteraction model was evidence for the potential decoupling of the relationship between lamb recruitment and precipitation between the 2 time periods (Table 1). Additionally, the early Time × Precipitation interaction term was significant and positive ($F_{1,31} = 9.48$, $P = 0.004$), indicating the positive effect of rainfall diminished after the park was established. We found little evidence for an effect of previous population size on lamb/adult female ratios (Table 1; $\bar{x}$ population size = 224, SD = 35, range = 165–298). We found lamb/adult female ratios responded directly and positively to November precipitation before the establishment of the municipal park ($\beta = 0.131$, SE = 0.034, 95% CI = 0.059–0.204, $P = 0.002$, adjusted $r^2 = 0.49$). After park establishment, however, we found no association between lamb/adult female ratios and any measured variables (Nov precipitation $\beta = 0.005$, SE = 0.025, CI = −0.047 to 0.057, $P = 0.85$, adjusted $r^2 = 0.002$; Fig. 2). We found no difference in rainfall amounts (Aug–Feb) measured before and after establishment of the park ($F_{1,33} = 0.04$, $P = 0.84$; Table 2).

DISCUSSION

Our results suggest that bighorn sheep use of anthropogenic resources at the wildland–urban interface in the River Mountains has decoupled the relationship between lamb recruitment and precipitation of the previous years. Prior to when bighorn sheep started feeding in Hemenway Park in 1987, the variable best explaining variation in lamb recruitment was total November rainfall. This relationship changed after the establishment of the park. Furthermore, after 1987, we found no relationship between lamb/adult female ratios and precipitation. What is unknown about this population is whether recruitment of animals in the northern portion of the mountain range, characterized by more natural conditions, is still coupled to weather. Approximately one-third of the female bighorn sheep in the River Mountains forage in Hemenway Park. The influence of the park may be strong enough to influence recruitment for the whole population. However, at this time, we do not have enough information on vital rates of individuals to determine whether this is true or not.

Parameters affecting variation in lamb recruitment in our pre-park model differed from that of the earlier lamb-survival model of Douglas and Leslie (1986). In our model, only precipitation during November of the previous year affected lamb recruitment. Douglas and Leslie (1986) found variation in lamb survivorship to be explained by total September through December precipitation (52% of variation) and a density-dependent component that accounted for 35%. In an analysis of later years when estimates of density were unavailable, they included total wind speed in the model

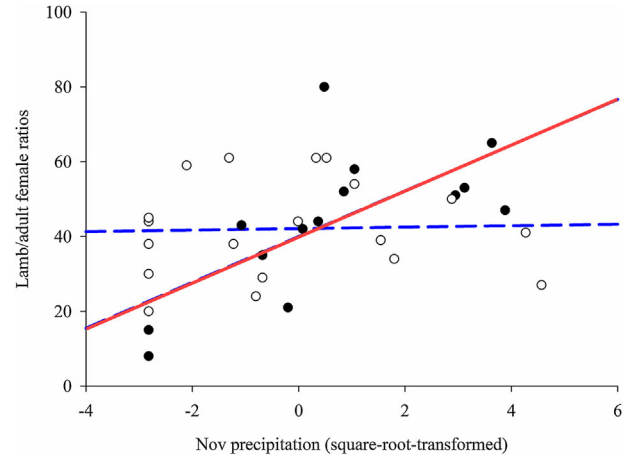

Figure 2. Lamb/adult female ratios of bighorn sheep regressed on November precipitation from 1971 through 1986 (solid points, adjusted $r^2 = 0.50$; solid red line) and from 1987 through 2006 (open points, adjusted $r^2 = 0.001$; dashed blue line) in the River Mountains, Nevada, USA.

Table 2. Mean, standard deviation, and range values of precipitation (mm) in the River Mountains, Nevada, USA, within time periods prior (1971–1986) and after (1987–2006) construction of Hemenway Park, Boulder City.

	Historical period			Present-day period				
Month	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	$F_{1,33}$	P
Aug	18.1	15.3	0.1–45.2	12.1	12.7	0.1–41.7	0.10	0.21
Sep	9.7	8.4	0.1–26.6	12.5	2.8	0.1–46.4	1.62	0.48
Oct	8.1	14.5	0.0–40.3	8.0	12.9	0.0–56.6	0.51	0.99
Nov	14.2	15.5	0.0–44.9	12.4	16.7	0.0–54.6	0.001	0.74
Dec	14.7	15.7	0.0–62.4	10.9	14.3	0.0–52.0	0.57	0.46
Jan	17.2	17.8	0.0–56.6	18.8	22.1	0.0–72.8	0.05	0.82
Feb	14.9	14.9	0.0–59.6	26.1	25.3	0.0–79.7	2.44	0.13

and found it to be negatively correlated (22% of variation) with lamb/adult female ratios (Douglas and Leslie 1986). Our finding was more consistent with that of Wehausen et al. (1987), who found precipitation during November, January, and February to be major predictors of lamb recruitment in the Santa Rosa Mountains of southern California, USA. Their results suggest that rainfall patterns and their interaction with temperature may differ regionally.

These differences may have been influenced by Douglas and Leslie (1986) using survey data from 1970 through 1982 to construct their model, whereas we used data from 1971 through 1987. Although we found no difference in mean monthly rainfall before and after park establishment, differences in temperature regimes and the timing of major storms during the years of 1983 to 1987 may also account for differences between our models. Phenological events in the Mojave Desert are triggered by rain storms with >25 mm of precipitation (Beatley 1974). However, the timing and quantity of precipitation delivered by individual storms are more important for annual plant germination than is total rainfall during that period (Beatley 1974). Late September rains are only effective for germination if autumn temperature regimes have replaced summer air and soil regimes; December rainfall is only effective for germination if autumn temperature regimes are still present (Beatley 1974).

Douglas and Leslie (1986) also found density dependence negatively affected lamb survival in the River Mountains; however, in our models, recruitment was not influenced by population size. Although other studies have demonstrated density dependence in lamb recruitment (Portier et al. 1998), these results were not unexpected for the River Mountains because population size during our study was intensively managed by the Nevada Department of Wildlife and, during most years, a number of animals were removed from the population as source stock for translocations.

However, the consequences of transplanting habituated animals that are accustomed to feeding in urban areas into new habitat are unknown. For wildlife populations whose numbers are not controlled through management (e.g., translocation or hunting) ecological decoupling may lead to problems associated with overpopulation. Under these circumstances, density dependence may become more important as a regulator of population size.

Use of the urban–wildland interface may also contribute to lower survivorship as a result of vehicle collisions, consumption of poisonous plants, and disease transmission. In the River Mountains, the use of Hemenway Park by bighorn sheep has coincided with reports of property damage and sheep mortality due to vehicle collisions. An increase in internal parasites has not been observed for sheep using the park. However, the River Mountain population experienced a pneumonia outbreak in August 2013 and has tested positive for *Mycoplasma ovipneumoniae*, a disease with potentially serious population-level consequences for desert bighorn. Translocation of animals to other mountain ranges for the purpose of population augmentation, and population regulation in the River Mountains, have ceased. How this will affect population demographics is unknown. Also unknown is how availability of greater quality forage may affect survivorship of animals with pneumonia.

As urban and suburban development increases across the southwestern United States, it is likely that conditions favoring attraction and tolerance of desert bighorn sheep to urban sites and the subsequent ecological decoupling of demographic processes may increase. Further understanding of how decoupling may affect populations on the wildland–urban interface is important for conservation and management of ungulates, particularly in arid regions.

ACKNOWLEDGMENTS

Financial support for this project was provided by the National Park Service, through a Southern Nevada Public Lands Management Act Grant, and by the U.S. Geological Survey, Western Ecological Research Center. We thank the Nevada Department of Wildlife, A. Curtis, and S. Kimble for providing population survey data. We thank E. Boydston for her valuable comments on an earlier version of the manuscript. We thank M. Hewison and 2 anonymous reviewers for comments that improved the manuscript. We also thank J. Yee of the U.S. Geological Survey for statistical advice. The use of trade, product, or firm names in this product is for descriptive purposes only and does not imply endorsement by the U.S. Government.

LITERATURE CITED

Beatley, J. C. 1969. Biomass of desert winter annual plant populations in southern Nevada. Oikos 20:261–273.

Beatley, J. C. 1974. Phenological events and their environmental triggers in Mojave Desert ecosystems. Ecology 55:856–861.

Bradley, W. G., and J. Deacon. 1965. The biotic communities of southern Nevada. Desert Research Institute No 9, Reno, Nevada, USA.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information theoretic approach. Springer Press, New York, New York, USA.

Butfiloski, J. W., D. I. Hall, D. M. Hoffman, and D. L. Forester. 1997. White-tailed deer management in a coastal Georgia residential community. Wildlife Society Bulletin 25:491–495.

Clutton-Brock, T. H., S. D. Albon, and F. E. Guinness. 1987. Interactions between population density and maternal characteristics affecting fecundity and juvenile survival in red deer. Journal of Animal Ecology 56:857–871.

Davis, S. A., R. P. Pech, and E. A. Catchpole. 2002. Populations in variable environments: the effect of variability in a species' primary resource. Philosophical Transactions of the Royal Society London B. 357:1249–1257.

Douglas, C. L., and D. M. Leslie. 1986. Influence of weather and density on lamb survival of desert mountain sheep. Journal of Wildlife Management 50:153–156.

Etter, D. R., K. M. Hollis, T. R. Van Deelen, D. R. Ludwig, J. E. Chelsvig, C. L. Anchor, and R. E. Warner. 2002. Survival and movements of white-tailed deer in suburban Chicago, Illinois. Journal of Wildlife Management 66:500–510.

Gill, J. A., K. Norris, and W. J. Sutherland. 2001. Why behavioral responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265–268.

Harveson, P. M., R. R. Lopez, B. A. Collier, and N. J. Silvy. 2007. Impacts of urbanization on Florida Key deer behavior. Biological Conservation 134:321–331.

Hass, C. C. 1997. Seasonality of births in bighorn sheep. Journal of Mammalogy 78:1251–1260.

Hebblewhite, M., E. H. Merrill, and T. L. McDonald. 2005. Spatial decomposition of predation risk using resource selection functions: an example in a wolf-elk predator-prey system. Oikos 111:101–111.

Kirkeeng, K. I. 1985. Food habits and food resources of bighorn in the River Mountains, Nevada. University of Nevada, Cooperative National Park

Resources Studies Unit Contribution No. CPSU/UNLV 024-06, Las Vegas, USA.
Knight, R. L., and D. N. Cole. 1995. Wildlife responses to recreationists. Pages 51–70 *in* R. L. Knight and K. J. Gutzwiller, editors. Wildlife and recreationists: coexistence through management and research. Island Press, Washington, D.C., USA.
Koons, D. N., P. Terletzky, P. B. Adler, M. L. Wolfe, D. Ranglack, F. P. Howe, K. Hersey, W. Paskett, and J. T. du Toit. 2012. Climate and density dependent drivers in plains bison. Journal of Mammalogy 93:475–481.
Leslie, D. M., and C. L. Douglas. 1979. Desert bighorn sheep of the River Mountains, Nevada. Wildlife Monographs 66.
Lubow, B. C., F. J. Singer, T. L. Johnson, and D. C. Bowden. 2002. Dynamics of interacting elk populations within and adjacent to Rock Mountain National Park. Journal of Wildlife Management 66:757–775.
McQuivey, R. P., and D. M. Leslie. 1976. The status and trend of desert bighorn sheep in Nevada: River Mountains. Special Report 77-9, Federal Aid in Wildlife Restoration Project W-48-8, Study R-111, Job 1. Nevada Department of Fish and Game, USA.
Noy-Meir, I. 1973. Desert ecosystems: environment and producers. Annual Review of Ecology and Systematics 4:25–51.
Papez, N. J., and G. K. Tsukamoto. 1970. The 1969 trapping and transplant program in Nevada. Desert Bighorn Council Transactions 14:40–50.
Polfus, J. L., and P. R. Krausman. 2012. Impacts of residential development on ungulates in the Rocky Mountain West. Wildlife Society Bulletin 40:1–11.
Portier, C., M. Festa-Bianchet, J. M. Gaillard, J. T. Jorgenson, and N. G. Yuccoz. 1998. Effects of density and weather on survival of bighorn sheep lambs (*Ovis canadensis*). Journal of Zoology 245:271–278.
Radeloff, V. C., R. B. Hammer, W. I. Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. 2005. The wildland-urban interface in the United States. Ecological Applications 15:799–805.
Rubin, E. S., W. M. Boyce, C. J. Stermer, and S. G. Torres. 2002. Bighorn sheep habitat use and selection near an urban environment. Biological Conservation 104:251–263.
Sherrill, B. L., A. G. Snider, S. Kennedy-Stoskopf, and C. S. DePerno. 2012. Survey of zoonotic pathogens in white-tailed deer on Bald Head Island, North Carolina. Southeastern Naturalist 11:529–533.
Shochat, E., P. S. Warren, S. H. Faeth, N. E. McIntyre, and D. Hope. 2006. From patterns to emerging processes in mechanistic urban ecology. Trends in Ecology and Evolution 21:186–191.
Sokal, R. R., and F. J. Rohlf. 1998. Biometry. W. H. Freeman Press, New York, New York, USA.
Steidl, R. J. 2006. Model selection, hypothesis testing, and risks of condemning analytical tools. Journal of Wildlife Management 70:1497–1498.
Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and Urban Planning 39:25–36.
Thompson, M. J., and R. E. Henderson. 1998. Elk habituation as a credibility challenge for wildlife professionals. Wildlife Society Bulletin 26:477–483.
Wehausen, J. D. 2005. Nutrient predictability, birthing seasons, and lamb recruitment for desert bighorn sheep. Pages 37–50 *in* J. Goerrissen and J. M. Andre, editors. Sweeney Granite Mountains Desert Research Center 1978–2003: a quarter century of research and teaching. University of California Natural Reserve Program, Riverside, USA.
Wehausen, J. D., V. C. Bleich, B. Blong, and T. L. Russi. 1987. Recruitment dynamics in a southern California mountain sheep population. Journal of Wildlife Management 51:86–98.

Associate Editor: Hewison.