Temporal and spatial distribution of highway mortality of mule deer on newly constructed roads at Jordanelle Reservoir, Utah

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TEMPORAL AND SPATIAL DISTRIBUTION OF HIGHWAY MORTALITY OF MULE DEER ON NEWLY CONSTRUCTED ROADS AT JORDANELLE RESERVOIR, UTAH

Laura A. Romin and John A. Bissonette

ABSTRACT—In this paper we evaluated traffic characteristics and vegetative and topographic features associated with mule deer kills on 3 highways (US 40, SR 32, SR 248) in northeastern Utah. We also compared number, and sex and age composition of roadkills to that of the living population observed during spotlight counts. From 15 October 1991 to 14 October 1993 we documented 397 deer roadkills: 51.6% were does, 18.9% bucks, 21.7% fawns, and 7.8% could not be classified. Sixty-seven percent of adult kills were ≤2.5 yr of age. Kill composition compared closely to spotlight counts. Of 1515 spotlighted deer, 65.2% were does, 8.9% bucks, and 25.9% fawns. Spotlight density and deer mortality were strongly correlated from summer 1992 through summer 1993 ($r = 0.94$).

Traffic conditions, topographic features, and vegetative characteristics contributed to mortality levels. Roadkills were highest along US 40 (68% year 1, 55% year 2) where traffic volume and speed were significantly higher than along either state route. Large drainages intersected highways in 78% of designated kill zones. Roads adjacent to agricultural areas along all routes sustained the fewest highway mortalities. Percent cover was higher (40%) in kill zones than in other areas (29%).

Key words: deer, habitat, highway mortality, Odocoileus hemionus, roadkill.

In Utah a mean 3115 mule deer (Odocoileus hemionus) were killed annually by vehicles during the period 1981–1991 (Utah Division Wildlife Resources 1992). At least 538,000 deer–vehicle collisions occurred nationwide in 1991 (Romin and Bissonette in press). Annual economic loss amounted to $7.8 million, based on average values for each deer killed and vehicle damaged.

Many techniques (e.g., fencing with overpasses and underpasses, swareflex warning reflectors, and highway lighting) have been evaluated in an effort to reduce deer-highway mortality; however, none have provided an effective, cost-efficient solution for widespread use (Reed 1993, Romin and Bissonette in press). Development of successful mitigative technologies relies on an understanding of deer movements onto or across highways.

Topographic and vegetative features, road characteristics, and deer behavior may contribute to deer movement patterns with respect to roads. Published research pertaining to highway mortality of deer has been focused largely...
on white-tailed deer populations in mixed-hardwood habitat types of Pennsylvania (Peek and Bellis 1969, Vaughan 1970, Bellis and Graves 1971, Puglisi et al. 1974, Carbaugh et al. 1975, Kress 1980, Bashore et al. 1985) and Michigan (Reilly and Green 1974, Allen and McCullough 1976, Kasul 1976, Sicuranza 1979). In general, high concentrations of kill occurred in nonwooded areas and were related to deer foraging patterns. The juxtaposition of crops and fields to wooded areas influenced deer roadkill locations but varied between studies. In Pennsylvania 58% of white-tailed deer–vehicle accidents occurred in areas where both sides of the road were bordered by fields (Puglisi et al. 1974). In southern Michigan higher accident rates occurred where old fields bordered woods or crops than where cover type was continuous (Sicuranza 1979). Accident locations were not consistent between years (Puglisi et al. 1974). At the roadside, right-of-way topography and vegetation attracted deer, particularly in wooded areas (Carbaugh et al. 1975), and affected deer movements, channeling deer parallel to the road as they foraged (Bellis and Graves 1971).

Limited studies of mule deer–highway relationships indicated that deer moved along drainages and riparian areas when approaching a road. These routes corresponded with migratory routes of deer (Mansfield and Miller 1975, Reeve 1988). Highway mortality of both white-tailed and mule deer generally peaked during fall in conjunction with breeding and hunting seasons, with a 2nd, smaller peak occurring in spring, when deer foraged along right-of-ways during goremup (Bellis and Graves 1971, Reilly and Green 1974, Goodwin and Ward 1976, Sicuranza 1979, Dusek et al. 1989). Different patterns of highway mortality are due, in part, to differences in seasonal distribution and migratory patterns of deer (Mansfield and Miller 1975). In studies conducted on deer winter concentration areas in Colorado, virtually all mortality was observed during early spring (Myers 1969).

Relatively few studies compared sex composition of roadkills with that of the living population; yet such comparisons may reveal behavioral traits influencing location and timing of roadkills. The sex ratio of observed roadkills along I-80 in Wyoming was similar to the reported herd composition of 23 male:100 female (Goodwin and Ward 1976). The sex ratio of road-killed adult deer in Wisconsin (Jahn 1959) was not representative of the living population. During fall a higher proportion of bucks were involved in deer-vehicle accidents although the living population showed a higher proportion of does. Similarly, from December through May, yearling males in the Yellowstone area were involved in vehicle accidents in greater proportion than their abundance in the living population (Dusek et al. 1989). Many calculations of live herd composition and number have been based on few spotlight censuses, and reported results may not adequately reflect live population characteristics. Behavioral and habitat use patterns differ among and within species (Kramer 1971, 1973, Geist 1981), and implementation and success of mitigation strategies intended to reduce deer roadkill may be site- or species-specific.

We designed this study (1) to determine whether mule deer roadkills on newly relocated highways would increase and (2) to evaluate the influence of topographic features and vegetation characteristics on the kill pattern. We documented roadkill locations and assessed traffic speed and volume, road alignment, and vegetative and topographic features at areas of high and low kill. We compared live deer-use patterns and roadkill locations to determine the influence of roadside features to deer–vehicle accident locations. Deer–highway mortality levels and composition were compared to that of the living population over a 2-yr period with an extensive data collection study using weekly roadkill collections and repetitive spotlight censuses.

Information obtained through this research effort complements existing research and further our understanding of deer–highway relationships. There is limited information that broadly characterizes mule deer use and kill distributions on and near highway systems, or that has investigated the influence of physical landscape features.

**Study Area**

The study area is located in the valley between the Wasatch and Uintah mountain ranges of northeastern Utah; the Provo River originates in the Uintah mountains and bisects the valley floor. Segments of three highways—
US 40, state routes (SR) 32 and 248, totaling 47.3 km on the eastern slope of the Wasatch mountains in northeastern Utah—were chosen for study. Construction of the roadways was completed in 1989 and was necessitated by inundation of existing roads following construction of Jordanelle Reservoir. Filling commenced in spring 1993.

Dominant valley habitats consist of mesic meadow, riparian areas, and pasture lands. Surrounding drainage slopes are predominantly within a mountain brush and sagebrush-grass zone (6000-7000 ft elevation), with scattered pinyon pine and juniper. Limited stands of aspen, cottonwood, and willow occur. Mule deer utilize the area as year-long range but usually are forced into the valley bottom during winters with heavy snowfall.

METHODS

Deer roadkill data were collected at least once per week by research personnel from 15 October 1991 to 14 October 1993. UDOT and UDWR personnel assisted with collection efforts during their daily activities. Date, highway identification, and location of each kill were recorded to the nearest 0.10 mile. Deer initially were classified as adult or fawn; incisors were removed from adult deer for age determination by cementum annuli procedures (Low and Cowan 1963).

Deer kill zones and nonkill zones were designated based on 1991-1993 deer-highway mortality locations. A minimum of 5 kills per mile had to have occurred for a segment of roadway to be considered a kill zone. A kill zone ended when a section of road did not contain a kill for more than 0.10 mile. Deer initially were classified as adult or fawn; incisors were removed from adult deer for age determination by cementum annuli procedures (Low and Cowan 1963).

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We recorded the distribution of kills over the entire study area, average traffic volume and speed for each highway, percent vegetative cover, and topography proximal to area roads. Kills were recorded to the nearest 0.01 mile. Twice monthly spotlight counts were conducted to document deer use and density adjacent to study area roads. Counts were initiated at dark; each count averaged 3.2 h (± 21 min). We began the spotlight run on a different route each night. We drove along both sides of each road at a speed of 45–50 kph and used a handheld 400,000 candlepower spotlight to locate deer. Deer were located to the nearest 0.10 mile. We stopped when deer were spotted to identify sex and age class, distinguishing fawns by size. The activity of deer spotted in the right-of-way was classified as feeding, bedding, walking, or standing. We used statistical correlations to compare deer roadkill locations between years and with locations of live deer.

Rangefinder readings were recorded at each 0.1-mi interval to provide an estimate of observable area along each road (Fafarman and DeYoung 1986). Mountainbrush habitats decreased deer visibility, and some areas along roads were not visible from a vehicle due to roadside rock cuts or steep declines bordered by concrete barriers. From numerous spotlight runs, we calculated the mean maximum visible distance to be 500 m.

Deer snow track counts were recorded along the right-of-way once each during the winters 1991–92 and 1992–93 to evaluate deer approaches to the roads. We counted the number of trails within each 0.10 mile interval and described them as either parallel or perpendicular to the road. A parallel trail continued its direction for at least 30 m.

Road alignment, right-of-way width and slope, right-of-way vegetation, and vegetation composition were characterized to a perpendicular distance 100 m beyond the right-of-way fence. Each highway was classified as either 4-lane or 2-lane with passing lanes. UDOT recorded traffic speed and volumes for each road during 2 periods: 11 March to 15 March 1992 and 29 June to 5 July 1992. Road alignments at each selected kill and nonkill transect location were described as curve, hill, or straight section. A curve or hill was considered part of the road alignment if it was within 100 m of the transect. Deer further than 100 m from the road are unlikely to be involved in an immediate collision (Romin and Dalton 1992); thus, beyond this distance, a hill or curve that would have reduced driver visibility had less significance.

We analyzed habitat features during September 1993. Stereoscopic aerial photography (1:24,000) was used to describe habitat features. We placed a transparent grid over photographs to determine percent cover (mountain brush
and riparian areas) and topographical features at deer–highway mortality locations beginning at the road and extending 1.2 km distant. At each paired kill and nonkill location we established 3 habitat transect lines aligned perpendicular to the road. The transects were spaced 100 m apart and extended through the right-of-way zone 100 m past the right-of-way fence. We measured the length of each habitat along each transect line. Habitats included right-of-way revegetation, mountain brush, sagebrush-grass, grass-forb, aspen, cottonwood, willow, agricultural pastureland, riparian, and river. We calculated the proportion of each habitat present along the combined transect lines for each kill and nonkill location.

We identified roadkill and live deer locations, as well as descriptive roadside features to 0.1 mile, consistent with highway mile marker delineation. We converted to metric units for analysis where appropriate.

**RESULTS**

**Deer locations**

We documented 397 deer roadkills during the study from 15 October 1991 to 14 October 1993; 278 (5.9 kills/km) kills occurred during
the 1st year of study (15 October 1991 to 14 October 1992), and 119 (2.5 kills/km) were documented during the 2nd year (15 October 1992 to 14 October 1993). Highway US 40 sustained the highest kill levels: 68% during the 1st year and 55% during the 2nd year. State routes 248 and 32 sustained similar kill levels; during the 1st year we recorded 18% and 14% of the total deer-highway mortality on SR 248 and SR 32, respectively. During the 2nd year we recorded 25% of the total annual kill on SR 248 and 19% on SR 32. Deer kills averaged <20 before the roads were relocated.

Nineteen deer kill zones were identified based on the spatial distribution of deer road-kills during both years (Figs. 1, 2). The mean length of kill zones was 1.0 km ($s = 0.62$). Deer-vehicle collisions along US 40 occurred most frequently between mile markers 6.0 and 9.0 during both the 1st (56%) and 2nd (48%) years of the study. Twenty-eight percent of deer roadkills along US 40 occurred from mile marker 7.0 to 7.9 during the 1st year. Roadkill locations were correlated between years along US 40 at both the 1.0-mile ($r = 0.69, P = 0.03$) and 0.10-mile ($r = 0.56, P < 0.001$) interval. Deer kill locations were not significantly correlated between 1st and 2nd years along SR 32 at either the 1.0-mile ($r = -0.14, P = 0.70$) or 0.10-mile ($r = 0.004, P = 0.968$)
scale. Deer kill locations along SR 248 were significantly correlated at the 1.0-mile interval \((r = 0.72, P = 0.02)\) but not at the 0.10-mile interval \((r = 0.18, P = 0.07)\).

Deer spotlight counts were not significantly correlated to kill locations at the 1.0-mile interval for any road during either year: SR 248 year 1 \((r = 0.43, P = 0.19)\), year 2 \((r = 0.17, P = 0.61)\); SR 32 year 1 \((r = 0.42, P = 0.23)\), year 2 \((r = 0.12, P = 0.73)\); US 40 year 1 \((r = 0.51, P = 0.14)\), year 2 \((r = 0.15, P = 0.68)\). However, positive correlations were stronger during the first year.

Forty percent of spotlighted deer were seen on the right-of-way. We identified the behavior of 968 (55%) of the deer along the right-of-way. Thirty-three percent were standing when first observed, 32% were feeding, 12% were bedded, and 23% were walking along the right-of-way or crossing the road.

Perpendicular snow tracks were not correlated with deer-highway mortality locations \((r = 0.29, P = 0.42)\). Parallel tracks constituted 48% and 32% of all deer trails counted during the 1st and 2nd years, respectively.

**Traffic Characteristics**

Traffic characteristics contributed to deer-highway mortality levels (Table 1). Highway US 40 had the highest (3.7-9.9 times) mean 24-hr traffic totals of the 3 study area roads. Mean traffic speed was highest along US 40 (69.3 mph) from 11 March to 15 March 1992; however, over the 4 July weekend (29 June-5 July 1992), average speed along SR 248 (59.1 mph) was slightly higher than along US 40 (58.9 mph). Volume and speed were somewhat higher along SR 248 than along SR 32 for both test dates.

Highway US 40 is a 4-lane road and SR 248 and SR 32 are 2-lane roads with occasional passing zones. Road alignment (Table 2) was similar for transect kill and nonkill zone locations \((\chi^2 = 1.2, df = 2, P = 0.70)\).

**Habitat**

From aerial photographs (1:24,000) we determined that percent cover was greater along US 40 (63%) than along SR 248 (28%) or SR 32 (31%). Designated kill zones had higher mean percent cover (40%) than nonkill zones (29%). Highway deer kill along US 40 was highest in an area (mile markers 6.0–9.0) of 88% vegetative cover during both the 1st (56%) and 2nd (48%) years of study. Low mortality occurred in predominantly sagebrush-grass/wet meadow (mile markers 4.0–5.0) or agricultural zones (mile markers 12.3–12.9) with <20% cover. Along SR 248, agricultural zones sustained 1 deer (1%) mortality during the 2-yr period. State route 32 sustained 25% of its total deer road-kill in agricultural areas. However, 50% of this kill occurred at mile marker 9.0, located in a riparian area at an agricultural pasture and cliff interface. During spotlight censuses we observed a larger proportion of deer along right-of-ways associated with mountain brush habitat than along agricultural areas (Table 3). Paired \(t\) tests of microhabitat features showed no significant difference in proportion of cover 100 m beyond the fence between kill and nonkill locations \((t = 0.13, df = 13, P = 0.90)\). Proportion of cover on the right-of-way never was higher than 29% for any transect.

We examined 19 kill zones and 19 nonkill zones in the study area for associations with drainages (Fig. 2). Since deer-vehicle collisions occurred along nearly all of US 40, we evaluated the 8 highest kill locations along this road. Major drainages intersected the roads in 16 (79%) kill zones. Along US 40, large drainages intersected the highway at 6 (75%) of the kill locations. Two kill zone locations along US 40 were at highway overpasses (mile markers 4.0 and 8.0); drainages were located within 0.2 miles. Two other kill zones extended past highway underpasses (mile markers 8.2 and 11.4) Seven (37%) nonkill zones had drainages intersecting the roads. However, in 4 of the nonkill zones, drainages were within 0.2 miles of a kill zone.

Kill and nonkill locations did not differ in right-of-way widths \((t = 1.1, df = 13, P = 0.30)\). Deer kill per km was greatest when right-of-way areas were inclined rather than declined or level (Table 4).
Table 2. Road alignment at paired (n = 42) kill and nonkill locations along study areas routes at Jordanelle Reservoir, Utah.

<table>
<thead>
<tr>
<th></th>
<th>Curve</th>
<th>Straight</th>
<th>Hill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kill</td>
<td>15</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>Nonkill</td>
<td>18</td>
<td>21</td>
<td>2</td>
</tr>
</tbody>
</table>

\[ x^2 = 1.2, df = 2, P = 0.70. \]

Table 3. Deer observed (% of total deer) along right-of-ways associated with agricultural or mountain brush habitat types.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>US 40</th>
<th>SR 248</th>
<th>SR 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>22</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>Mountain brush</td>
<td>49</td>
<td>40</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 4. Deer kill per km relative to right-of-way slope relief along both sides of study area roads at Jordanelle Reservoir, Utah, 1991–1993.

<table>
<thead>
<tr>
<th>Road</th>
<th>US 40</th>
<th>SR 248</th>
<th>SR 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>No incline</td>
<td>6.7</td>
<td>0.9</td>
<td>2.6</td>
</tr>
<tr>
<td>Incline 1 side</td>
<td>22.3</td>
<td>6.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Incline 2 sides</td>
<td>17.1</td>
<td>9.3</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Temporal Deer Roadkill Distributions

During winter 1991–92, mean monthly snowfall totaled 7.7 cm; mean monthly winter snowfall for 1992–93 was 46.9 cm. Of 397 deer mortalities documented during the study from 15 October 1991 to 14 October 1993, we classified 205 (51.6%) does, 75 (18.9%) bucks, 86 (21.7%) fawns, and 31 (7.8%) unknown. Sixty-four fawns (16.1%) were female and 22 (5.5%) were male (Fig. 3). There was a 57% decrease from 278 (5.9 deer/km²) deer roadkills during the 1st year to 119 (2.5 deer/km²) roadkills during the 2nd year. We determined the age of 198 (70.7%) adult deer by cementum annuli techniques. Sixty-seven percent (n = 133) adult kills were ≤ 2.5 yr old. The oldest recorded deer roadkills (2.5%) were 6.5 yr old. The 1992 hunter buck harvest from the Kamas district, east of the study area, also indicated a young population (n = 85); 55% yearlings, 15% 2.5 yr old, and 30% ≥ 3.5 yr old (M. Welch, UDWR, personal communication).

We located 4378 deer on 39 spotlight trips driving a total of 1845 km. There was a 64.2% decrease from an average 14.6 deer/km² in the 1st year of the study to 5.23 deer/km² during the 2nd year. UDWR estimated a similar 70% reduction in the deer population on the Kamas District, attributed to the harsh 1992–93 winter (M. Welch, UDWR, personal communication). We identified sex and age of 1515 (34.6%) spotlighted deer: 987 (65.2%) does, 136 (8.9%) bucks, and 392 (25.9%) fawns. We calculated an observable area unobstructed by roadside barriers or dense vegetation of 10.98 km² for the study area.

We identified monthly and seasonal peaks in deer mortality (Table 5) by phenological period: fall (September–November), winter (December–February), spring (March–May), and summer (June–August). The following analyses treat the study period as year 1 (15 October 1991–30 August 1992) and year 2 (1 September 1992–14 October 1993), to allow interpretation of seasonal deer distributions and roadkill patterns. The highest roadkill peak (25%) occurred during November 1991. Thirty percent of the mortality in year 1 occurred during the fall even though data collection did not begin until 15 October 1991. Another peak (33%) was evident during the summer of year 1; 15% of the mortality for the year occurred in July. A similar fall peak (52%) occurred during year 2; 20% of the mortality occurred in October and 19% in November. A relatively large peak (18%) occurred in April. Eleven percent of the mortality occurred during the summer. During year 1, 41.8% of the annual
buck mortality and 44.8% of doe mortality occurred during summer (Table 5). Fawn mortality peaked for both males (47%) and females (57.4%) in the fall. During year 2, the highest mortality among all sex and age classes occurred during fall.

Seasonal distributions of deer-highway mortality were compared to observed deer densities during the same periods. Seasonal deer densities and highway mortalities were not significantly correlated ($r = 0.54, P = 0.14$) over the 2-year period (Fig. 4). For the period of summer 1992 to summer 1993, deer-highway mortality and deer population density were strongly correlated ($r = 0.94, P < 0.01$), suggesting a density-dependent relationship. A negative correlation existed between deer densities and kill/density ($r = -0.65, P = 0.06$). During year 1, observed deer density was low during fall (5.4 deer/km$^2$) and winter (9.9 deer/km$^2$) while highway mortality was high (fall = 71 deer, winter = 58 deer). Deer density (2.41 deer/km$^2$) and highway mortality (18 deer) were low during the 2nd winter. Following winter 1992–93 deer density adjacent to study area roads increased slightly during spring (3.3 deer/km$^2$) and summer (3.8 deer/km$^2$). Observed density never reached pre-winter levels. Highway mortality levels of deer also increased ($n = 31$) in spring 1993 but did not return to pre-winter levels. Kill as a function of density was lower than observed deer density from winter 1992 to winter 1993 but exceeded density following the harsh winter of 1992–93 (Fig. 4).

The roadkill buck:doe ratio during fall (22.9:100) and early winter (78.9:100) of year 1 was greater than that observed in the living population (fall = 6.7:100, winter = 4.4:100) during the same periods (Table 6). Likewise,
the roadkill buck:doe ratio during the fall of year 2 (18.9:100) was larger than the ratio of the living population (5.6:100). The summer buck:doe ratio was similar for roadkill and living populations during both years. For the months June–November 1992, the correlation coefficient between number of fawns involved in vehicular collisions and number observed on spotlight runs was significant: \( r = 0.84 \) (\( P = 0.04 \)). For both summers the fawn:doe ratio of road-killed animals was 8.3:100, higher than the observed fawn:doe ratio (1.4:100) of the living population.

**DISCUSSION**

We distinguished aspects of deer mortality based on traffic volume, habitat, topography, and seasonal distribution. Traffic volume significantly influenced overall deer mortality levels. Though total kill in the study area decreased by 57% from the 1st to the 2nd year, roadkills remained higher along US 40 than either SR 248 or SR 32. The 4-lane alignment of US 40 contributed to higher deer kills. Traffic volume was higher and deer-vehicle collisions occurred more frequently along SR 248 than along SR 32 during both years.

Vegetative cover along the length of US 40 was greater than along state routes 248 or 32. Likewise, percent cover was higher for designated kill zones compared to nonkill zones. High percent cover appears to attract deer to right-of-ways for foraging. Agricultural areas provide abundant forage away from roadsides and were associated with low deer–vehicle collision levels. Deer usually approached roads along drainages, and higher kill levels occurred near large drainages.

The ability to predict kill locations requires that kill locations remain similar over time. Kill location correlations at the 0.10-mile interval were low for SR 248 and SR 32 between the 2 yr. The kill locations along US 40 were significantly correlated; however, most of US 40 was considered a continuous kill zone, which would lead to a correlation simply by coincidence.

Although drainages provide highway approaches, it is not possible to predict with exactness where deer-car collisions will occur based on habitat (% cover) and topography proximal to the roads. Deer often move parallel along the right-of-way after approaching a road. However, inclined right-of-ways funneled deer along the highway and were associated with higher kills. Low correlations between spotlight and kill locations further suggest that deer did not immediately cross the roads where they entered right-of-way areas. Snow trail counts also indicated parallel movement of deer.

While seasonal deer–highway mortality distributions tracked large fluctuations in population levels, behavior associated with life history activities of deer, e.g. fawning, breeding, and migration, also influenced year-round roadkill levels and composition. During the 2-yr study period, both roadkill and observed deer density levels decreased. When harsh winter conditions (1992–93) reduced population levels, deer-highway mortality was proportionally lower.

Variability in the association between live deer density and roadkill numbers can be attributed in part to deer-use patterns. Between fall and spring of year 1, highway mortality decreased and spotlight counts recorded increased deer density. The mild winter that year allowed deer access to large areas and they maintained residence higher on drainage slopes. Weather conditions did not force deer to remain near area roads, although they frequently approached and crossed roads. We attributed the initial increase in deer density during spring 1992 to the approach and congregation of deer along right-of-ways for foraging.

Fall peaks in deer-highway mortality appeared related to activities associated with

<table>
<thead>
<tr>
<th>Seasons</th>
<th>F91</th>
<th>W91</th>
<th>Sp92</th>
<th>Su92</th>
<th>F92</th>
<th>W92</th>
<th>Sp93</th>
<th>Su93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kill</td>
<td>22.9</td>
<td>78.9</td>
<td>75</td>
<td>44.2</td>
<td>18.9</td>
<td>40.0</td>
<td>45</td>
<td>16.7</td>
</tr>
<tr>
<td>Spotlight</td>
<td>6.7</td>
<td>4.4</td>
<td>2.9</td>
<td>31.3</td>
<td>5.6</td>
<td>0.0</td>
<td>13.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*Kill and spotlight counts are recorded as bucks:100 does.

*Winter counts include only December and early January, spring counts include only April and May. Bucks are probably underrepresented.
hunting and breeding during this time (Fig. 5). Deer were moving around the study area more frequently than during other seasons. Proportionally more bucks were involved in vehicular collisions during the fall than were observed in the population. The breeding season of mule deer in Utah begins the last few days of October, peaks between 20 November and 2 December, and declines through January (Robinette and Gashwiler 1950). During the study, Utah deer and elk hunting seasons occurred from late August through October (T. L. Parkin, UDWR, personal communication).

Fawns were involved in deer-vehicle collisions most often during the fall and least often during the summer of both years. The fawning period for mule deer in Utah begins approximately 5 June, reaches and maintains a peak 11–20 June, and declines through 15 August (Robinette and Gashwiler 1950). Fawns are seen infrequently during their first 6–8 wk because their predator defense is based on a "hider" strategy (Geist 1981). Fawns were absent in the observed population during the summer but appeared during the fall.

Does were involved in collisions and observed more frequently than males during both years. Sixty-eight percent of adult deer roadkill were does, while 70% of fawns were female during year 1. Similarly, 81% of adult deer killed were does and 87.5% of fawns were female during year 2. Does have heavy energy demands associated with gestation, parturition, and lactation, which may explain their association with high-quality roadside vegetation and subsequent high mortality rates.

**Management Recommendations**

Certain topographic features and vegetation characteristics associated with roads, coupled with deer movement dynamics, predispose mule deer to highway mortality. Highway alignment and right-of-way topography often function to funnel deer to the right-of-way and encourage movement of deer along the highway corridor, creating the potential for collisions at numerous locations. Roads planned in high deer-use areas that will sustain high traffic volumes should be prioritized for mitigative procedures during planning. Mitigative technologies, particularly fencing with crossing structures, should focus on the initial approach of deer to the highway along large drainages and take into account deer spatial dynamics and population trends.

Continuing studies designed for species-specific and habitat-specific conditions may further an understanding of why deer-vehicle collisions occur on a spatial and temporal basis, and promote development of appropriate pre-construction designs and mitigation strategies.

**ACKNOWLEDGMENTS**

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