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Factors Associated with the Highway Mortality of Mule Deer at Jordanelle Reservoir, Utah

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FACTORS ASSOCIATED WITH THE HIGHWAY MORTALITY OF MULE DEER AT JORDANELLE RESERVOIR, UTAH

by

Laura A. Romin

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ABSTRACT

Factors Associated with the Highway Mortality of Mule Deer at Jordanelle Reservoir, Utah

by

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Utah State University, 1994

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Department: Fisheries and Wildlife

Highway mortality of deer (*Odocoileus* sp.) is a nationwide concern. In 1991, 538,000 deer-vehicle collisions occurred nationwide. Property damage to vehicles, human injuries and fatalities, and potential impacts to local deer populations occur from deer-vehicle collisions. Techniques have been evaluated to reduce highway mortality of deer; however, an effective, cost-efficient solution does not exist for widespread use. If mitigative technologies are to be successful, we need to understand deer behavior and movement patterns associated with highway relationships. Most research about highway deer kills has focused on white-tailed deer (*Odocoileus virginianus*) in mixed hardwood habitat types. The following study pertains to mule deer (*Odocoileus hemionus*) in a mountain brush and sagebrush-grass zone.

The study area was located at the site of the newly constructed Jordanelle Reservoir near Park City, Utah. Area roads were relocated due to inundation of existing highways. Preconstruction road-kill was documented to be 0.29 kills/km. Annual road-kill levels of 278 (5.9 kills/km) and 119 (2.5 kills/km) deer occurred along the new roads from October 1991 to October 1993. Even though there was a 64.2% reduction in observed deer density, second year mortality was still 9 times the pre-project kill.

A study design of road-kill data collection and repetitive spotlight censuses was used to compare levels and composition of deer road-kills to that of the living population. Deer-vehicle collision levels tracked large population fluctuations. Deer behavior predisposed deer to mortality. Numbers of road-killed deer peaked in the fall of both years, coincident with breeding and hunting periods. Road-kill peaks also occurred in July and April of each year, respectively.

Traffic characteristics, road alignment, and vegetative and topographic features were described relative to mule deer kill locations (recorded to the .10 mile). Traffic volume and percent vegetative cover were higher along US40 than either state route; road-kills were correspondingly higher along US40. Roads adjacent to agricultural areas along all routes sustained the fewest highway mortalities of deer. Deer approached roads along drainages; large drainages intersected highways in 79% of designated kill areas. Right-of-way vegetation and slope influenced kill locations.

(83 pages)

CHAPTER I

INTRODUCTION

Highway mortality of deer (*Odocoileus* sp.) is a nationwide concern and was documented as early as 1925 (Stoner 1925). The problem persists; annual nationwide deer-vehicle collisions were estimated at 200,000 by 1980 (Williamson 1980). I reviewed the scientific literature pertaining to highway mortality of deer to understand the level of current knowledge and directions for further study. I identified 14 studies (Table I-1) that described ecological relationships associated with deer road-kill distributions. These studies also documented the seasonal distributions of sex and age classes involved in automobile collisions. Another three studies (Arnold 1978, Jahn 1959, O'Gara and Harris 1988) focused on population characteristics of road-kills.

Only four states, California, Michigan, Pennsylvania, and Wyoming, are represented in the 14 studies on deer-highway relationships. Eleven studies addressed white-tailed deer (*O. virginianus*); 10 were conducted in predominantly mixed hardwood forests with interspersed agricultural areas. Mule and black-tailed deer (*O. hemionus*) were represented in three studies. However, the identification and descriptions of deer kill sites in two of these studies (Mansfield and Miller 1975, Reeve 1988) were general.

Published literature indicated that the temporal and spatial distributions of deer road-kills were nonrandom. Bimodal seasonal road-kill peaks were evident in white-tailed deer research (Allen and McCullough 1976, Bellis and Graves 1971, Carbaugh et al. 1975, Puglisi et al. 1974) and were attributed to seasonal behavioral patterns.

Table I-1. Ecological research about the highway mortality of deer.

Author	Species	State	Habitat Type
Allen/McCullough 1976	*O. virginianus*	Mich.	Mixed hardwood
Bashore et al. 1985	*O. virginianus*	Pa.	Mixed hardwood
Bellis/Graves 1971	*O. virginianus*	Pa.	Mixed hardwood
Carbaugh et al. 1975	*O. virginianus*	Pa.	Mixed hardwood
Goodwin/Ward 1976	*O. hemionus*	Wyo.	Prairie
Kasul 1976	*O. virginianus*	Mich.	Mixed Hardwood
Kress 1980	*O. virginianus*	Pa.	Mixed Hardwood
Mansfield/Miller 1975	*O. hemionus*	Calif.	Varied[a]
Peek/Bellis 1969	*O. virginianus*	Pa.	Mixed Hardwood
Puglisi et al. 1974	*O. virginianus*	Pa.	Mixed Hardwood
Reeve 1988	*O. hemionus*	Wyo.	Sagebrush
Reilly/Green 1974	*O. virginianus*	Mich.	Mixed Hardwood
Sicuranza 1979	*O. virginianus*	Mich.	Mixed Hardwood
Vaughan 1970	*O. virginianus*	Pa.	Mixed Hardwood

a. Habitat types included mixed conifer, foothill woodland, sagebrush, riparian.

In Pennsylvania, research along I-80 (Bellis and Graves 1971, Puglisi et al. 1974) indicated fall peaks in highway mortality. In two southern Michigan studies (Allen and McCullough 1976, Sicuranza 1979), peak road mortality occurred between October and December. In northern Michigan, Reilly and Green (1974) found most road-kills occurred during spring. From 1968 to 1970, Michigan's statewide mortality indicated a small peak in May and a large peak in November (Hawkins et al. 1971). Mule deer research studies identified a fall peak in highway deer kills (Goodwin and Ward 1976, Myers 1969) associated with migration. Mansfield and Miller (1975) observed that peaks in road-kill varied with seasonal distributions and migratory patterns of mule and black-tailed deer.

Literature on white-tailed deer focused on the orientation of wooded, agricultural, and right-of-way areas relative to high deer kill sites. Carbaugh et al. (1975) found high kill in forested zones and low kill in agricultural areas with abundant forage. Deer were killed more frequently where right-of-way areas or woodland-field edges encouraged deer movement to roads for foraging (Puglisi et al. 1974, Sicuranza 1979, Bashore et al. 1985). Deer kills in wooded areas occurred in a random pattern on both 2-lane (Bashore et al. 1985) and 4-lane (Bellis and Graves 1971) roads in Pennsylvania. The juxtaposition of roads and fields at high kill areas was not consistent between studies; Puglisi (1974) evaluated statewide deer-vehicle collisions from 1968 to 1970 and found 58% of deer-vehicle accidents occurred where fields were present on both sides of the road. Along a 500-km section of I-80, Puglisi et al. (1974) documented high kill where one side of the highway was wooded and the other a field. Right-of-way slope and vegetation also encouraged deer movement along or across roadways (Bellis and Graves 1971, Goodwin and Ward 1976, Kasul 1976, Carbaugh et al. 1975). However, Bellis and Graves (1971) documented high kill where both sides of the road were flat and provided grazing, or where inclined right-of ways and elevated median strips formed troughs that funneled deer along roads. Carbaugh et al. (1975) observed the highest number of living deer where the right-of-way inclined or declined relative to the road. In Michigan, Kasul (1976) described high kill areas with at least one side of the road and the median wooded. Mule deer mortality locations were associated primarily with the location of drainages (Goodwin and Ward 1976) and highway cuts.

The literature on highway mortality of deer is limited at a nationwide level. Site-specific and species-specific differences in deer road-kill distributions exist. Habitat may influence the number and location of deer-vehicle accidents. Deer utilize the array of habitat types across North America (Wallmo 1981). Within habitat types, deer utilize different habitat components for various activities, i.e. bedding, foraging, migrating (Geist 1981). White-tailed deer are considered to be more cover-dependent than mule deer. In areas of sympatric association, white-tailed deer seek cover or move to valley bottoms during the winter, whereas mule deer occupy slopes, broken terrain, and forest edges (Kramer 1971, 1973). Within subspecies there is some evidence of sexual segregation and resource partitioning (McCullough 1979, Bowyer 1984). The following chapters are intended to address mule deer road-kill relationships in a predominantly sagebrush-grass and mountainbrush zone in northeastern Utah. The study area provides yearlong range for deer which migrate to local seasonal use areas depending on weather conditions. Chapters II through IV address the habitat and behavioral relationships of mule deer adjacent to three highways. Chapter II, *Road Relocation at Jordanelle Reservoir, Utah, and the Subsequent Increase in the Highway Mortality of Deer*, is intended as a summary of the deer road-kill problem at the study area that was related to the relocation of roads into migratory and daily use areas. Chapter III, *Temporal Distribution of Mule Deer Highway Mortality Levels and Composition*, evaluates the potential impacts to a local deer population from highway mortality and describes seasonal sex and age ratios of the road-kill population and living population. Chapter IV, *Factors Associated with the Spatial Distribution of Mule Deer-Vehicle Collisions*, describes traffic characteristics, road alignment, vegetative and topographic features associated with the location of deer kills. Chapter V, *Deer-Vehicle Collisions: Nationwide Status and Technologies to Reduce Their Occurrence*, summarizes a survey distributed nationwide to state natural resource agencies. The purpose of the survey was to identify current annual nationwide deer road-kill levels as well as evaluate the status of efforts to provide mitigative techniques to reduce highway mortality. Development of mitigative technologies for highway mortality of deer must be based on an understanding of ecological relationships. Broadly, the following chapters are intended to increase the knowledge of mule deer-highway relationships and to compare the findings of this research to those in other areas with different deer species. Locally, the information derived from the following chapters will be used to determine locations for the installation of fencing and experimental big game crossing structures. Successful analysis of the experimental highway crossing structures depends on preliminary research of the level and composition of deer road-kills at the study area.

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CHAPTER II

ROAD RELOCATION AT JORDANELLE RESERVOIR, UTAH AND THE SUBSEQUENT INCREASE IN THE HIGHWAY MORTALITY OF DEER[1]

Williamson (1980) estimated at least 200,000 deer-vehicle collisions occurred per year nationwide. By 1991, recorded nationwide deer road-kills reached a level of at least 538,000 animals (L. A. Romin and J. A. Bissonette, Utah St. Univ., unpubl. data). Interstate highways (Puglisi et al. 1974), large deer populations (Bashore et al. 1985), and changes in deer distribution (Arnold 1978) were responsible for increased deer-vehicle collisions in many areas. Deer behavior and use of roadside habitats were important factors in understanding deer-highway relationships (Peek and Bellis 1969, Carbaugh 1970, Bellis and Graves 1971, Puglisi et al. 1974, Goodwin and Ward 1976), and can provide important information when new highway systems are planned (Goodwin and Ward 1976) and mitigative strategies (Puglisi et al. 1974) are selected.

Reilly and Green (1974) documented road-kills before and after highway construction at a deer wintering area in northern Michigan. They reported 6 deer/year killed in vehicular collisions before highway construction and 41 deer/year after construction. Deer-vehicle collisions declined through 1967 but remained approximately twice that of pre-interstate mortality. Reilly and Green (1974) recommended that highway construction proposals address impacts on deer movement

[1]Coauthored by Laura A. Romin and John A. Bissonette

patterns and population levels.

Three new roads were constructed as part of the Jordanelle Reservoir project (JRP) nearby to Park City in northeastern Utah. Jordanelle Reservoir is a part of the Municipal and Industrial System in the Bonneville Unit of the Central Utah Project (CUP). The CUP was authorized for funding in 1956 under the Colorado River Storage Project. Its aim was to provide abundant water to cities and towns along Utah's heavily populated Wasatch Front (Hinchman 1991). When filled, Jordanelle Reservoir will have an average surface area of 840 acres.

Based on Utah Division of Wildlife Resources (UDWR) highway mortality records of deer between 1971 and 1975, an interagency biological assessment team determined annual pre-project deer loss at 12 deer per year (0.29 kills/km). Road realignment would increase annual deer loss to a predicted 24 (0.41 kills/km) deer per year (L. B. Dalton, UDWR, pers. commun.). The team expected mortality to be highest across the relocated highway 189 (now state route [SR] 32) because this area had the most active deer movement route (U.S. Department of Interior 1979).

Subsequent to road construction, it was apparent that deer-vehicle collisions exceeded the predicted loss (L. B. Dalton, UDWR, pers. commun.). A cooperative effort between the Bureau of Reclamation (BOR), Utah Department of Transportation (UDOT), UDWR, United States Fish and Wildlife Service (USFWS), and Utah Cooperative Fish and Wildlife Research Unit resulted in a two-phase study to understand mule deer-highway relationships and evaluate an experimental big game-highway crossing structure. In this chapter we report deer-vehicle collision levels before and after highway relocation at the JRP.

STUDY AREA

Prior to construction of Jordanelle Reservoir, two roads totaling 42 km (routes 40 and 189) accessed the local communities of Heber, Kamas, and Francis on the eastern slope of the Wasatch range in northeastern Utah (Fig. II-1). The roads were located in a valley bottom where dominant vegetative communities included mesic meadow, riparian, pastureland, and sagebrush-grass habitats. Reservoir construction necessitated inundation of area roads. Three new highways (US40, SR248, and SR32) totaling 47.3 km were constructed further up drainage slopes to provide continued access to local communities. Mountain brush and sagebrush-grass communities characterized the drainage slopes (6,000 to 7,000 ft elevation). Limited stands of cottonwood (*Populus* sp.) and aspen (*Populus tremuloides)* occurred, particularly along drainage bottoms.

METHODS

UDWR personnel provided reports of highway deer kill for the first year of new road operation, from December 1989 to December 1990. We conducted weekly surveys of area roads from 15 October 1991 to 14 October 1993, to document locations, sex, and age of deer road-kills; UDOT and UDWR personnel assisted with collection efforts during their daily activities.

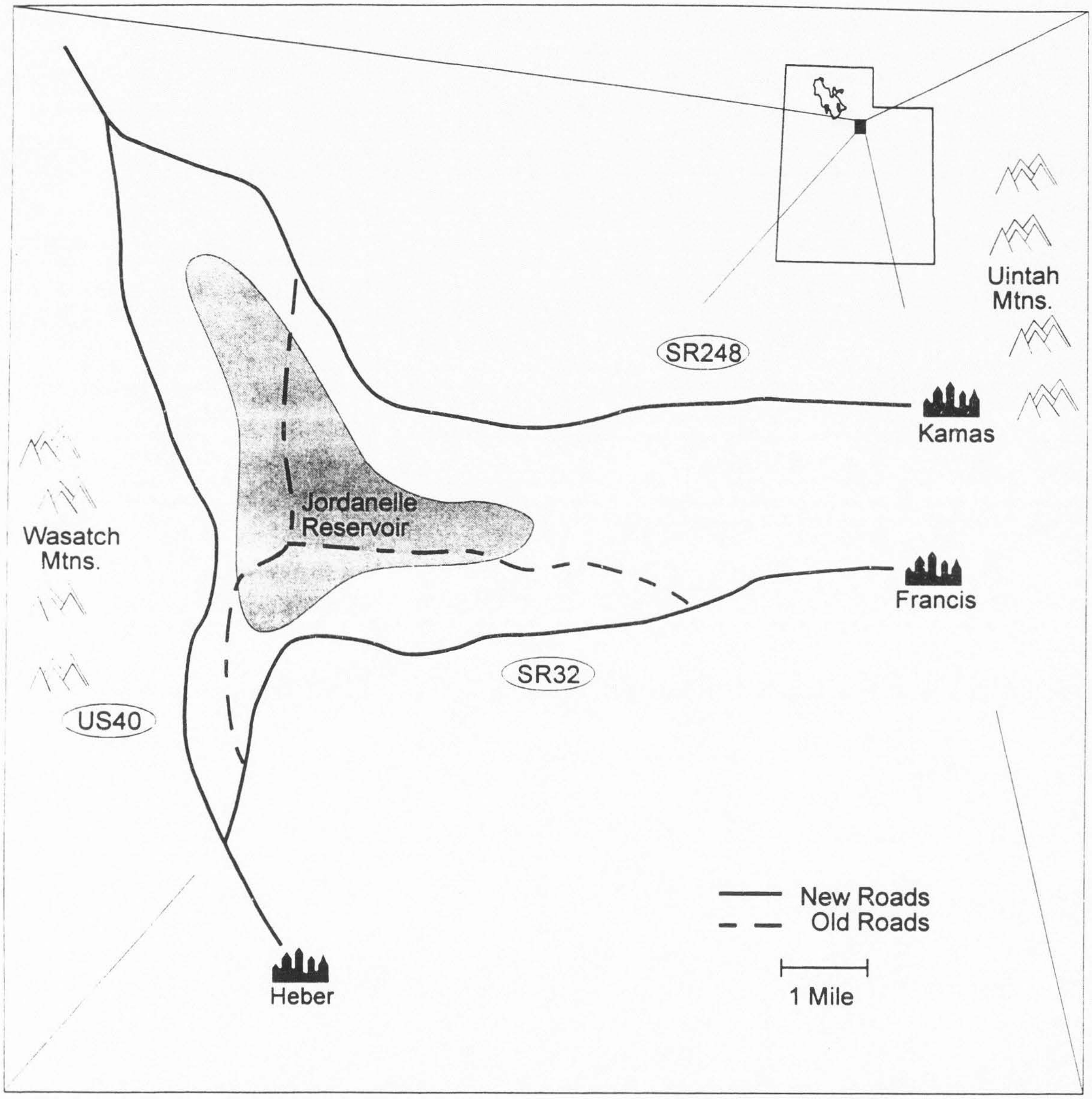

Figure II-1. Road alignment at Jordanelle Reservoir, Utah highway relocation project, 1991 - 93.

RESULTS

Personnel from UDWR documented 87 deer-vehicle collisions during the first year of new road operation (Dec 1989 to Dec 1990); UDOT personnel removed an equivalent number during the same period (L. B. Dalton, UDWR, pers. commun.) for a realized kill of 174 deer (3.3 kills/km) on area roads. Road-kills exceeded the preconstruction kill by 14.5 times. Similarly, high deer road-kill levels (Fig. II-2) of 278 (5.9 kills/km) and 120 (2.5 kills/km) deer occurred during each year of the study, respectively. Even though there was a 64.2% decrease in the observed deer density during the study (Romin and Bissonette, Utah St. Univ., unpubl. data), second year road-kill mortality (120 deer) was still > 9 times the pre-project kill. Reed (Colorado Div. Wildl. Res., pers. commun.) estimated that only 50% of deer-vehicle collisions in Colorado were documented; we expect a similar rate holds for Utah.

The largest percentage of deer-vehicle collisions occurred along US40 during both years: 68% in the first year and 55% in the second. During the first year of study, 14% of the total mortality occurred on SR32 while 18% of documented mortalities occurred on SR248. Twenty-five percent and 19% of the total deer road-kills occurred on SR248 and SR32, respectively, during the second year of study.

DISCUSSION

Deer apparently did not initiate frequent road crossings prior to road relocation at Jordanelle Reservoir (L.B. Dalton, T.L. Parkin; UDWR, pers. commun.); few

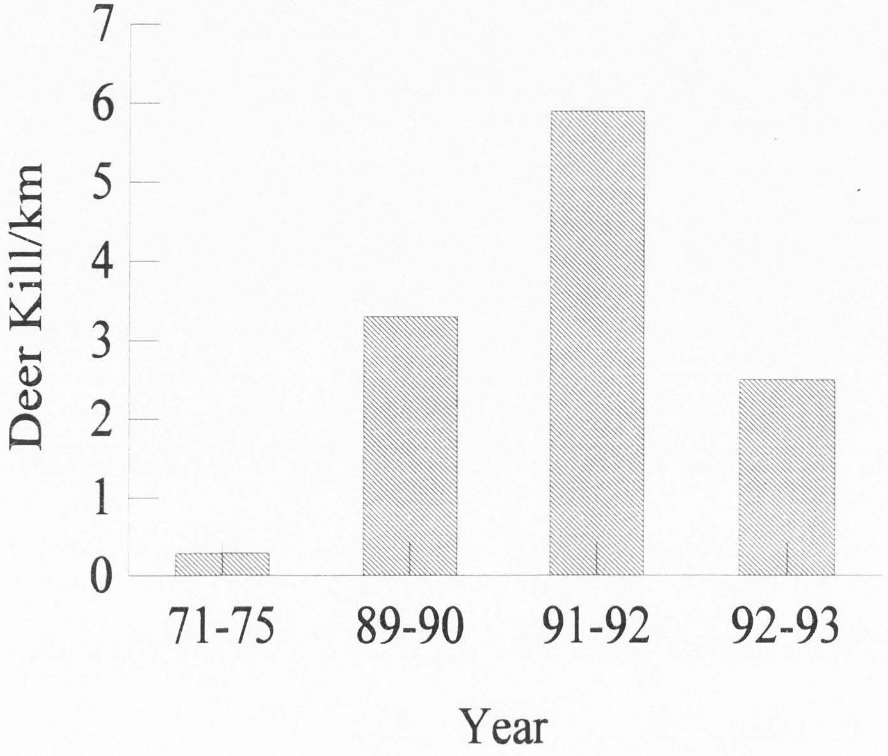

Figure II-2. Annual deer kill/km at Jordanelle Reservoir, Utah, on old (1971 - 75) and new (1988 - 93) roads.

deer were killed by vehicles. New roads bisected deer use areas further up drainage slopes, and deer crossed both daily and during seasonal migrations. Road relocation was followed immediately by a substantial increase in highway deer kills over the next 4 years, from 1990 to 1993.

Heavy winter mortality contributed to lower deer densities and lower road-kills during the second year of the study. UDWR estimated a 70% reduction in the deer population during the harsh winter of 1992 - 1993 (M. Welch, UDWR, pers. commun.). We attributed the decrease in deer-vehicle collisions that we observed from October 1991 to October 1993 to a population decline, partially caused by the harsh winter 1992 - 1993, and perhaps because deer population numbers were decreasing over the study as a result of the heavy road-kill; the observed live deer density proximal to area roads decreased 64.2% between the first and second years of our study (L. A. Romin and J. A. Bissonette, Utah St. Univ., unpubl. data).

Our study incorporated 2 years of data collection. Area roads have been operational since 1989. Over the short term, absolute number of kills decreased, but the proportion of road-kills to the observed population size remained similar. Long-term impacts of highway mortality on the local deer population are difficult to ascertain, but trends indicate road-kills have a negative impact.

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CHAPTER III

TEMPORAL DISTRIBUTION OF MULE DEER HIGHWAY MORTALITY LEVELS AND COMPOSITION[1]

Abstract: We studied highway mortality of mule deer (*Odocoileus hemionus*) in northeastern Utah from October 1991 to October 1993. We compared number, and sex and age composition of the road-kills to that of the living population observed during spotlight counts. Deer-vehicle collision levels tracked large population fluctuations. Deer behavior, i.e. breeding, fawning, and migration, also predisposed deer to mortality. Numbers of road-killed deer peaked in the fall of both years, coincident with breeding and hunting periods. The road-kill buck:doe ratio (23:100) was higher than that observed in the living population during the fall (5:100). Road-kill peaks also occurred in July and April of both years. Fawn mortality was highest during fall of both years. Patterns of road-kills relative to the living population suggested that highway mortality of deer is some combination of compensatory and additive mortality.

During 1980, annual nationwide highway mortality of deer was estimated to be at least 200,000 animals (Williamson 1980). Since then, many states have indicated increases in deer-vehicle collisions. At least 538,000 deer road-kills occurred during 1991 (L. A. Romin and J. A. Bissonette. Utah St. Univ., unpubl. data).

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[1]Co-authored by Laura A. Romin and John A. Bissonette

Research on the mortality of deer on highways frequently addressed seasonal road-kill patterns, sex and age composition of the kill, and potential reasons for high and low kill periods. Highway mortality of white-tailed (*Odocoileus virginianus*) and mule deer generally peaked during the fall, with another smaller peak occurring in spring (Bellis and Graves 1971, Reilly and Green 1974, Goodwin and Ward 1976, Sicuranza 1979, Dusek et al. 1989). However, in studies conducted in deer winter concentration areas in Colorado, virtually all mortality was observed during the early spring (Myers 1969). Mansfield and Miller (1975) observed seasonal peaks in deer highway kill levels and found they reflected the seasonal distributions and migratory tendencies of deer.

Breeding behavior, in conjunction with movement associated with hunting seasons, was used to explain the fall peak in deer road-kill levels (Puglisi et al. 1974, Arnold 1978). The spring peak was attributed to the green-up of right-of-way vegetation and subsequent foraging by deer (Reilly and Green 1974, Carbaugh et al. 1975). Goodwin and Ward (1976) documented a road-kill sex ratio on I-80 in Wyoming of 27 males:100 females from January 1967 to March 1973. An increase in male mortality occurred during fall, and was associated with the breeding season. Jahn (1959) found over a 10-year study that the percent of male fawns involved in automobile collisions (48.7%) was lower than the national natural mortality average. The national average of male:female natural fawn mortalities was 51.5:48.5 (Severinghaus and Cheatum 1956) and did not include highway mortality. Goodwin and Ward (1976) found lower highway mortality of male mule deer fawns in

Wyoming. Bellis and Graves (1971) found similar male:female road-kill ratios in fawn and yearling white-tailed deer, but adult mortality was skewed towards females (37.8:100). They reported little or no fawn road mortality during the summer months, and speculated that monthly differences in sex and age of road-killed deer reflected both the herd composition and differential vulnerability of deer sex and age classes. O'Gara and Harris (1988) compared highway mortality of deer to predator mortality of deer in Montana. Eighty-eight percent of deer involved in vehicular collisions were fawns or deer $\geq$ 7 years of age while predators killed more deer (86%) between 1 and 6 years of age. Only 10% of road-killed deer were in good condition. Proportionally more male deer were taken by predators than were involved in deer-vehicle collisions.

Few studies compared deer road-kill composition with that of the living population. Goodwin and Ward (1976) reported herd composition consisted of 23 male:100 female, similar to their observed road-kill population. 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). 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 was involved in deer-vehicle accidents although the living population showed a higher proportion of does. In Nugget Canyon (Lincoln County) Wyoming, road-kills in November and December corresponded to low numbers of live deer seen during spotlight counts (Reeve 1988). The sex and age composition of the Nugget Canyon deer herd was not reported. Jahn (1959) and Dusek et al. (1989) warned that numbers of deer road-kills should not be used as a representation of annual population changes. However, 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.

There is a need for further study focusing on the composition of deer road-kills compared to that of the living population. Deer-vehicle collisions may be related to population densities and activities related to deer life histories, i.e. breeding, fawning, migration. In this chapter we compare deer road-kill levels and composition to that of the living population over a 2-year period with an extensive study design using weekly highway deer kill collections and repetitive spotlight censuses.

STUDY AREA

The study area was located in the valley between the Wasatch and Uintah mountain ranges of northeastern Utah; the Provo River originated from the Uintah mountains and bisected the valley floor. The Jordanelle Reservoir feature of the Central Utah Project was intended to capture Provo River water for municipal and industrial use in Utah and Salt Lake counties. Prior to construction of Jordanelle Reservoir, 2 roads, totaling 42 km, bisected the valley floor; the roads were inundated due to reservoir construction. Three new roads totaling 59 km were constructed partway up the drainage slopes. Segments of the new roadways (totaling 47.3 km) were chosen for study: state route (SR) 248 from its western junction with US40 east to Kamas, SR32 from its western junction with Francis east to US40, and US40 from the SR32 junction north to SR248. Valley vegetation was predominantly mesic meadow, riparian, and pasture land. Surrounding drainage slopes were situated within a mountain brush and sagebrush-grass setting with scattered juniper (*Juniperus* sp.) and pinyon pine (*Pinus edulis*). Limited stands of aspen (*Populus tremuloides*), cottonwood (*Populus* sp.), and willow (*Salix* sp.) occurred, particularly along drainages. Mule deer utilized various parts of the study area as winter range, summer range, and year-long range depending on seasonal weather conditions. Migration corridors accessed local seasonal use areas.

METHODS

Highway mortality of deer was documented over a 2-year period, from 15 October 1991 to 14 October 1993. Area roads were surveyed for deer kills at least once a week. UDOT and UDWR personnel assisted with collection. Recorded data for each mortality included date, highway identification, kill location to the nearest 0.1 mile, sex, and age for all deer. Initially, we recorded age as adult or fawn, then removed incisors from adult deer for age determination by cementum annuli procedures (Low and Cowan 1963).

Twice-monthly spotlight counts were conducted (Reed 1969) to document live deer numbers and location along the three study area roads. The counts were conducted at dark and averaged 3.2 hours (S.D. = 21 min.) in length. Each night we began the spotlight run on a different route. We drove along both sides of each road at a speed of 40-50 kph and used a hand-held 400,000 candlepower spotlight to locate deer. Sex and age (adult, fawn) classes of deer were recorded. Fawns were distinguished by size and morphological facial characteristics. We took rangefinder readings at each 0.1-mile interval to provide an estimate of observable area along each road (Fafarman and DeYoung 1986). Mountain brush habitats decreased deer visibility, and some areas along the roads were not visible from a vehicle due to roadside rock cuts or steep declines bordered by concrete barriers. We calculated from numerous spotlight runs that the mean maximum distance we were able to see with the spotlight was 500 m.

Identification of road-kill and live deer populations was to the mile or 0.1 mile, consistent with highway mile marker delineation. We converted to metric units for analysis in our results where appropriate.

RESULTS

During winter 1991 - 1992, mean monthly snowfall totaled 7.7 cm; mean monthly winter snowfall for 1992 - 1993 was 46.9 cm. We documented 397 deer road-kills during the study from 15 October 1991 to 14 October 1993; 205 (51.6%) does, 75 (18.9%) bucks, 86 (21.7%) fawns, and 31 (7.8%) unclassified. Sixty-four fawns (16.1%) were female and 22 (5.5%) were male. There was a 57% decrease from 278 (5.9 deer/km) deer-highway mortalities during the first year to 119 (2.5 deer/km) road-kills during the second year. We determined the age of 198 (70.7%) adult deer by cementum annuli techniques (Fig. III-1). Sixty-seven percent (n = 133)

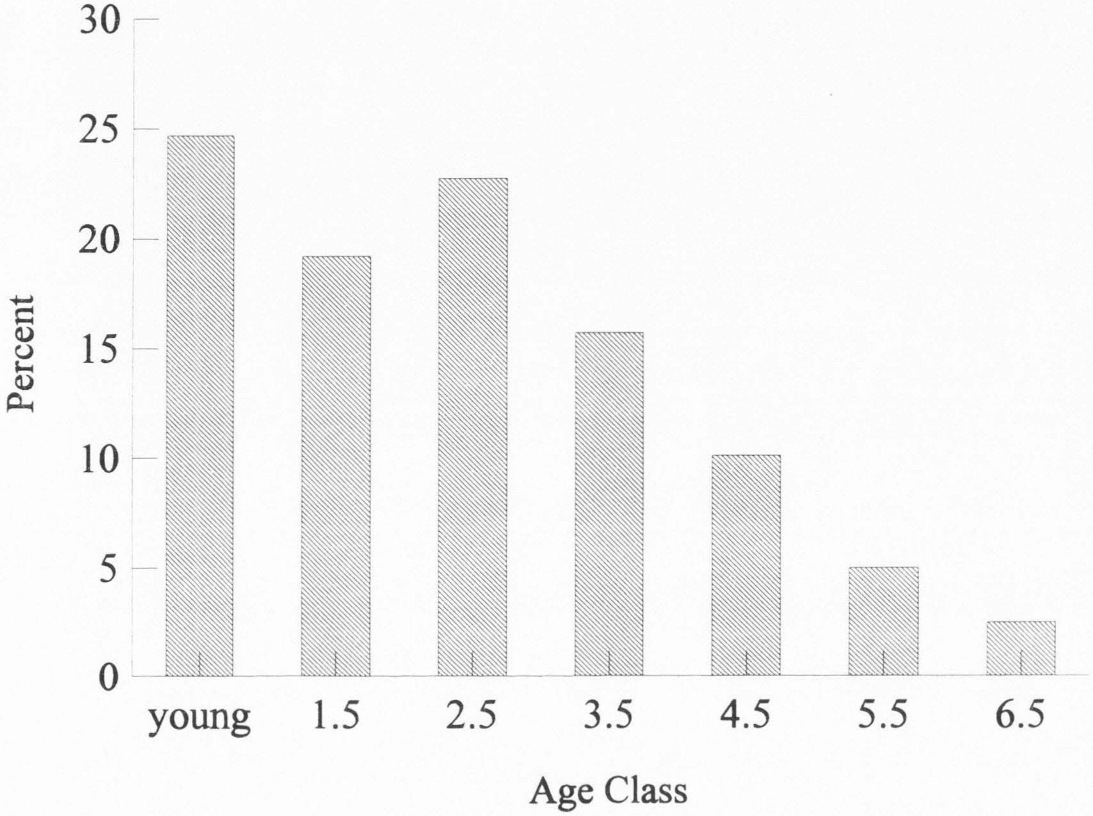

Figure III-1. Adult age classes of highway-killed deer (n = 198), Jordanelle Reservoir, Utah, 1991 - 93.

adult kills were $\leq$ 2.5 years old. The oldest recorded deer road-kills (2.5%) were 6.5 years old. The 1992 hunter buck harvest from the Kamas District, east of the study area, also indicated a young population (n = 85); 55% were yearlings, 15% were 2.5 years old, and 30% were $\geq$ 3.5 years old (M. Welch, UDWR, pers. commun.).

We located 4,378 deer on 39 spotlight trips driving a total of 1,845 km. There was a 64.2% decrease from an average 14.6 deer/km^2 in the first year of the study to 5.23 deer/km^2 during the second year. UDWR estimated a similar 70% reduction in the deer population on the Kamas District, attributed to the harsh 1992 - 1993 winter (M. Welch, UDWR, pers. commun.). We identified the sex and age of 1,515 (34.6%) deer during spotlight counts: 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 km^2 for the study area. Monthly and seasonal peaks in highway deer kills (Fig. III-2) were identified. Seasons were: fall (Sep - Nov), winter (Dec - Feb), spring (Mar - May), and summer (Jun - Aug). The following analyses treat the study period as year 1 (15 Oct 1991 - 30 Aug 1992) and year 2 (1 Sep 1992 - 14 Oct 1993), to allow interpretation of seasonal deer distributions and road-kill patterns. The highest road-kill 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

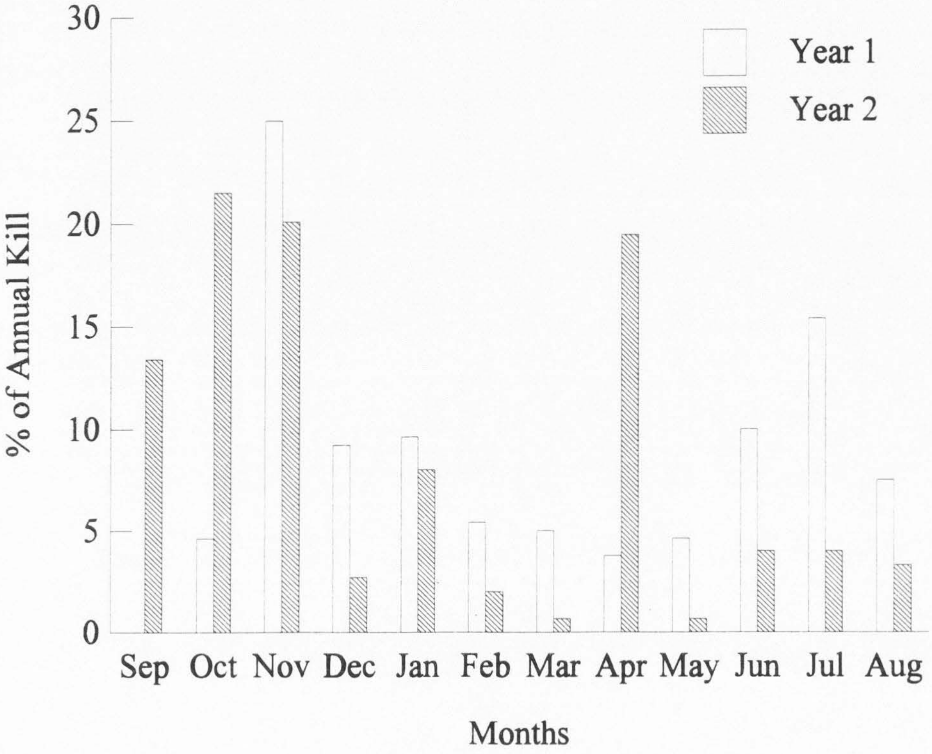

Figure III-2. Monthly deer road-kill (%) at Jordanelle Reservoir, Utah, 1991 - 93.

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 III-1). 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.

We compared seasonal distributions of deer road-kills to observed deer densities during the same periods. Correlation coefficients did not show a significant relationship ($r = 0.54$, $\underline{P} = 0.14$) between seasonal deer densities and highway mortalities over the entire two year period (Fig. III-3). However, deer road-kill levels and deer population density were strongly correlated from summer 1992 through summer 1993 ($r = 0.94$, $\underline{P} < 0.01$), suggesting a density dependent relationship. A negative correlation existed between deer densities and kill/density ($r = -0.68$, $\underline{P} = 0.06$). 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 second winter. Following the winter 1992 - 1993 season, deer density adjacent to study area roads increased slightly during spring (3.3 deer/km^2) and summer (3.8 deer/km^2). However, observed density never reached pre-winter levels. Highway mortality of deer also increased ($n = 31$) in the 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 - 1993.

The road-kill buck:doe ratio during the fall (22.9:100) and early winter

Table III-1. Seasonal road-kill distributions (%) for each deer class at Jordanelle Reservoir, Utah, 1991 - 93.

YEAR 1	Fall	Winter	Spring	Summer
Doe	30.0	16.0	10.2	44.0
Buck	14.5	27.3	16.4	41.8
F Fawn	57.4	28.6	11.4	2.9
M Fawn	47.0	40.0	13.0	0.0
YEAR 2				
Doe	65.4	6.2	13.6	14.8
Buck	52.6	10.5	26.3	10.5
F Fawn	50.0	21.4	28.6	0.0
M Fawn	40.0	40.0	0.0	20.0

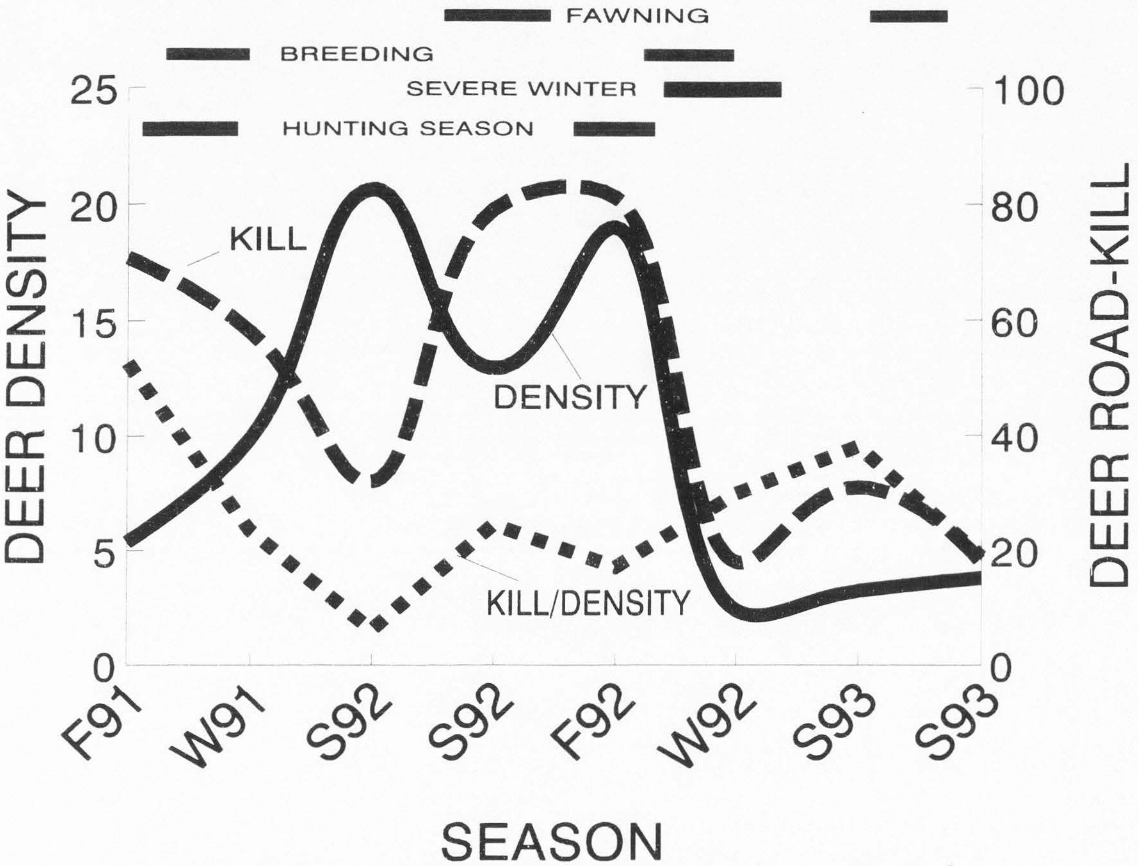

Figure III-3. Seasonal deer-highway mortality (No.) and density (deer/km^2) at Jordanelle Reservoir, Utah, 1991 - 93.

(fall = 6.7:100, winter = 4.4:100) during the same periods (Table III-2). Likewise, the road-kill 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 the road-kill and living populations during both years. From June to November 1992, the correlation coefficient between the number of fawns involved in vehicular collisions and the number of fawns observed on spotlight runs was significant; r = 0.84 ($\underline{P}$ = 0.04). The summer fawn:doe ratio of road-killed animals was low during both years, 1.9:100 and 8.3:100, respectively. Similarly low fawn:doe ratios were observed in the living populations for both the first (1.4:100) and second (15.4:100) summers. During the fall 1992, the fawn:doe ratio of road-killed deer (30:100) and the living population (50.6:100) was higher than the summer count.

DISCUSSION

Population density, and age and sex composition of area mule deer were evaluated using spotlight census techniques over a 2-year period. Seasonal biases in buck:doe and fawn:doe ratios may occur; however, population trends can be detected using repetitive spotlight counts (Progulske and Duerre 1964, McCullough 1982, Fafarman and DeYoung 1986). Jahn (1959) and Arnold (1978) found that deer-vehicle collisions were related to deer activity patterns. Arnold (1978) also found local deer population levels to vary proportionately with road-kill levels at constant traffic volumes. We compared spotlight counts and road-kill data to track population trends and evaluate deer behavior and movement patterns which affected deer-vehicle

Table III-2. Seasonal buck:doe ratios obtained from deer killed on highways or seen during spotlight counts.

Counts[a]	Seasons[b]							
	F91	W91	Sp92	Su92	F92	W92	Sp93	Su93
Kill	22.9	78.9	75	44.2	18.9	40.0	45	16.7
Spotlight	6.7	4.4	2.9	31.3	5.6	0.0	13.3	12.5

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

b. Winter counts only include Dec and early Jan; spring counts only include Apr and May. Bucks are probably underrepresented in these spotlight counts due to antler loss.

collision incidences.

Our results indicated that while seasonal highway mortality distributions of deer tracked large fluctuations in population levels, behavior associated with life history activities of deer, e.g. fawning, breeding, and migration, also influenced year-round road-kill levels and composition. During the 2-year study period, both road-kill and observed deer density levels decreased. When harsh winter conditions (1992 - 1993) reduced population levels, deer road-kill levels correspondingly were lower.

Relationships between live deer density and road-kill numbers can be attributed in part to deer use patterns. Between the fall and spring seasons 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 it is evident from highway mortalities that 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 the highway mortality of deer appeared related to activities associated with hunting and breeding during this time (Fig. III-3). Deer were moving around the study area more than usual. 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 generally occurred from late August through October (T. L. Parkin, UDWR, pers. commun.); the most intense deer hunting occurred in late October.

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 between 11 - 20 June, and declines through 15 August (Robinette and Gashwiler 1950). Fawns are seen infrequently during their first 6 to 8 weeks since predator defense relies on a "hider" strategy (Geist 1981). Fawns were absent in the observed population during the summer, and appeared during the fall. We therefore expected the seasonal pattern of fawn road-kills that occurred.

Females were involved in collisions and observed more frequently than males during both years. Sixty-eight percent of adult deer road-kills 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.

Knowledge of the compensatory or additive nature of deer road-kills is important in understanding long-term impacts of road construction on a local deer population. We did not determine mortality other than that attributable to road-kills; however, it is likely that road-kill mortality was in some measure additive. Kill/density was low when observed deer density was relatively high; suggesting highway mortality was compensatory. Following the decline during the winter 1992 - 1993, kill as a function of density increased, suggesting additive mortality. Whether road mortality is compensatory or additive, or some measure of both, will depend in part upon deer densities, level of road kill, and other mortality agents.

MANAGEMENT RECOMMENDATIONS

Highway planning teams need to account for deer use patterns and population trends in an area. Our study suggested that the highway mortality of deer was additive when deer densities were low. One strategy to reduce deer-vehicle collisions is to reduce local deer herds by increasing hunting (Sicuranza 1979, Reed 1993, L. A. Romin and J. A. Bissonette, Utah St. Univ., unpubl. data). Yet, if deer densities are reduced significantly by hunting, highway mortality will cause even further declines. Management designed to reduce local deer herds by hunting needs to consider the additive and compensatory nature of other forms of deer mortality.

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CHAPTER IV

FACTORS ASSOCIATED WITH THE SPATIAL DISTRIBUTION OF MULE DEER-VEHICLE COLLISIONS[1]

Abstract: We evaluated traffic characteristics, road alignment, and vegetative and topographic features associated with mule deer (*Odocoileus hemionus*) kills on three highways (US40, SR32, SR248) in northeastern Utah to determine whether kill locations could be predicted. Traffic volume and percent vegetative cover were higher along US40 than either state route; road-kills were correspondingly higher along US40. Roads adjacent to agricultural areas along all routes sustained the fewest highway mortalities. Large drainages intersected highways in 79% of designated kill zones.

In Utah 3,115 mule deer were killed annually by vehicles during the period 1982 - 1991 (Utah Div. Wildl. Resour. 1992). Annual economic loss amounted to $7.8 million, based on average values for each deer killed and vehicle damaged (Romin and Bissonette, Utah St. Univ., unpubl. data). At least 538,000 deer-vehicle collisions occurred nationwide in 1991 (L. A. Romin and J. A. Bissonette, Utah St. Univ., unpubl. data). Many techniques have been evaluated in an effort to reduce deer-vehicle collisions; however, none have provided an effective, cost-efficient solution for widespread use (Reed 1993, L. A. Romin and J. A Bissonette, Utah St.

[1]Co-authored by Laura A. Romin and John A. Bissonette

Univ., unpubl. data). An understanding of deer movements nearby and across highways is necessary if mitigative technologies are to be successful.

Road-kill locations of white-tailed deer (*Odocoileus virginianus*) on an interstate highway (Bellis and Graves 1971) and 2-lane roads (Bashore et al. 1985) in Pennsylvania were analyzed. Deer road-kill was concentrated in non-wooded areas. Random kill patterns occurred in longer, wooded sections. Kress (1980) found a positive relationship between deer numbers and field size. Sicuranza (1979) found that deer-vehicle accident rates were higher in areas where old fields bordered crops or woods than where cover type was continuous. Puglisi (1974) documented that 58% of white-tailed deer-vehicle accidents along Interstate 80 in Pennsylvania were in areas where both sides of the road were bordered by fields. Puglisi et al. (1974) found high kill to occur where one side of the road was wooded and the other side a field. He found that accident locations were not consistent within any year. Kasul (1976) reported that deer road-kills were greatest where the median and at least one side of the road were wooded. Carbaugh et al. (1975) observed white-tailed deer most frequently on inclines and declines adjacent to highways rather than on level areas. They observed that planted right-of-ways adjacent to wooded areas were used more highly by foraging deer than were cultivated areas. Peek and Bellis (1969) and Bellis and Graves (1971) obtained similar results in the same area. Topography also affected deer movements at highways, channeling deer parallel to the road as they foraged (Bellis and Graves 1971). Areas of concentrated mule deer mortality along Interstate 80 in southeastern Wyoming were related to deer migratory movement patterns and physiographic features, and were associated particularly with riparian areas (Goodwin and Ward 1976, Ward et al. 1976)). Highway mortality of deer was concentrated along a migratory route between summer and winter ranges in Nugget Canyon, Wyoming (Reeve 1988). Mansfield and Miller (1975) found high correlations between Columbia black-tailed deer winter ranges and kill locations. In general, there is limited information that broadly characterizes highway mortality of mule deer. Few papers addressed whether mule deer road-kill locations were predictable, or at what scale. We designed this study to understand mule deer-highway relationships. We documented road-kill locations and assessed traffic characteristics, road alignment, and vegetative and topographic features at areas of high and low kill. We compared live deer-use patterns and road-kill locations to determine the influence of roadside features to deer-vehicle accident locations. Our primary objective was to determine if road-kill locations could be predicted.

STUDY AREA

Segments of three highways, US40, state route (SR) 32, and SR248, 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 the inundation of existing roads following construction of Jordanelle Reservoir; filling commenced in spring 1993. Nearby communities include Heber, Kamas, and Francis, Utah.

Dominant valley vegetation consisted of mesic meadow, riparian, and pasture land habitats. Surrounding drainage slopes were predominantly within a mountain brush and sagebrush-grass zone (6,000-7,000 ft. elevation), with scattered pinyon pine (*Pinus edulis*) and juniper (*Juniperus* sp.). Limited stands of aspen (*Populus tremuloides*), cottonwood (*Populus* sp.), and willow (*Salix* sp.) occurred. Mule deer utilized the area as year-long range, but usually were forced into the valley bottom during winters with heavy snowfall.

METHODS

Deer road-kill data were collected at least once a week from 15 October 1991 to 14 October 1993. UDOT and UDWR personnel assisted with collection efforts. We recorded date, highway identification, and location of each kill to the nearest 0.10 mile. Deer kill zones and non-kill zones were designated based on 1991 - 1993 deer road-kill locations. At least five kills per mile were required 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 greater than 0.10 miles. Four kill zone and four non-kill zone paired locations of 0.10 mile length were randomly selected along each highway and established transects perpendicular to the road to evaluate associated habitat features.

Twice monthly spotlight counts were conducted to document deer use adjacent to study area roads. We drove along both sides of each road at a speed of 40 - 50 kph and used a hand-held 400,000 candlepower spotlight to locate deer. Deer were located to the nearest 0.10 mile. The truck was stopped when deer were spotted to allow for identification of sex and age class. Activity of deer spotted in the right-of-way was recorded as: feeding, bedding, walking, or standing.

Deer snow trails were recorded along the right-of-way once each during the winters of 1991 - 1992 and 1992 - 1993 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 in that direction for at least 30 m.

Deer road-kill locations were analyzed at both large and small scales. We recorded the distribution of kills over the entire study area, average traffic volume and speed for each highway, percent vegetative cover, and topography. Features proximal to the road at kill and non-kill locations were described: road alignment, right-of-way width and slope, right-of-way vegetation, and vegetation composition 100 m beyond the right-of-way fence.

Each highway was characterized as 4-lane or 2-lane with passing lanes. UDOT recorded traffic speed and volumes for each road during two periods; 11 March to 15 March 1992 and 29 June to 5 July 1992. Road alignment at each selected kill and non-kill transect location was described as a curve, hill, or straight section.

We completed the analysis of habitat features during September 1993. Stereoscopic aerial photography (1:24,000) was used to describe habitat features. A transparent grid was placed over the photographs to determine percent cover (mountain brush and riparian areas) and topographical features at kill and non-kill zones from the road to 1.2 km distant. At each selected kill and non-kill zone location we established three habitat transect lines aligned perpendicular to the road. The transects were spaced 100 m apart and traversed the right-of-way zone to a distance 100 m past the right-of-way fence. The length of each habitat type was measured along the transect lines. Habitat types included revegetation, mountain brush, sagebrush-grass, grass/forb, aspen, cottonwood, willow, agricultural pasture land, riparian, and river. We pooled the six perpendicular transect lines at each kill and non-kill zone location to derive a proportion of cover for the whole transect.

Identification of road-kill and live deer locations was to the mile or 0.10 mile, consistent with highway mile marker delineation. We converted to metric units for analysis in our results where appropriate.

RESULTS

Deer Locations

We recorded 278 (5.9 kills/km) deer road-kills during the first year of study (15 Oct 1991 to 14 Oct 1992) and 119 (2.5 kills/km) deer during the second year (15 Oct 1992 to 14 Oct 1993). Highway US40 sustained the highest kill levels: 68% during the first year and 55% during the second year. State routes 248 and 32 sustained similar road-kill levels; during the first year we recorded 17% and 14% of the total deer road mortality on SR248 and SR32, respectively. During the second year we recorded 25% of the total annual kill on SR248 and 19% on SR32.

Nineteen deer kill zones were identified based on the spatial distribution of deer road-kills during both years. The mean length of kill zones was 1.0 km (S.D. = .62). Deer-vehicle collisions along US40 occurred most frequently between mile markers 6.0 and 9.0 (Fig. IV-1) during both the first (56%) and second (48%) years of the study. Twenty-eight percent of the deer road-kills along US40 occurred from mile marker 7.0 to 7.9 during the first year. Road-kill locations were correlated between years along US40 at both the 1.0 mile ($r = 0.69$, $P = 0.03$) and 0.10 mile ($r = 0.56$, $P < 0.001$) scale. Deer kill locations were not significantly correlated between the first and second years along SR32 at either the 1.0 mile ($r = -0.14$, $P = 0.70$) or 0.10 mile ($r = 0.004$, $P = 0.97$) scale. Deer kill locations along SR248 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: SR248 year 1 ($r = 0.43$, $P = 0.19$), year 2 ($r = 0.17$, $P = 0.61$); SR32 year 1 ($r = 0.42$, $P = 0.23$), year 2 ($r = 0.12$, $P = 0.73$); US40 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 ($n = 1751$) of deer spotlighted were seen on the right-of-way. We identified the behavior of 968 (56%) deer. Thirty-three percent were standing when we first observed them, 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 road-kill locations ($r = 0.29$, $P = 0.42$). Parallel tracks consisted of 48% and 32% of all tracks counted in the snow during the first and second years, respectively.

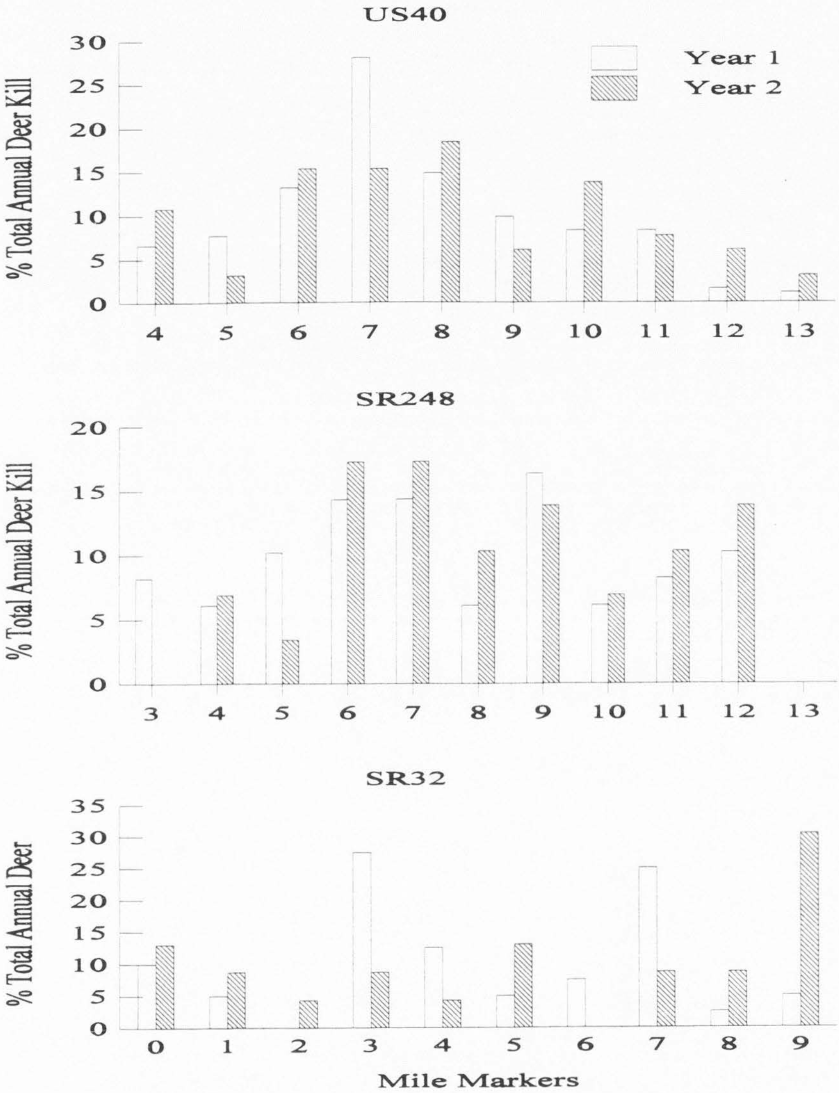

Figure IV-1. Distribution of deer kill (%) by mile marker on 3 newly built highways (US40, SR248, SR32) at Jordanelle Reservoir, Utah, 1991 - 93.

Traffic Characteristics

Traffic characteristics contributed to highway mortality levels of deer (Table IV-1). Highway US40 had the highest (3.7 to 9.9 times) mean 24-hour traffic totalsof the three study area roads. Mean traffic speed was highest along US40 (112.9 kph) from 11 - 15 March 1992; however, over the 4 July weekend (29 Jun to 5 Jul) average speed along SR248 (96.3 kph) was slightly higher than along US40 (96.0 kph). Volume and speed were higher along SR248 than along SR32 for both test dates. Highway US40 was a 4-lane road and SR248 and SR32 were 2-lane roads with occasional passing zones. Road alignment (Table IV-2) was similar for transect kill and non-kill zone locations ($\chi^2 = 1.2$, df = 2, $\underline{P} = .70$).

Habitat

From aerial photographs (1:24,000) we determined that percent vegetative cover was greater along US40 (63%) than along SR248 (28%) or SR32 (31%). Designated kill zones had higher mean percent vegetative cover (40%) than non-kill zones (29%). Highway deer kill along US40 was highest in an area (mile markers 6.0 - 9.0) of 87.6% vegetative cover during both the first (56%) and second (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 SR248, the agricultural zones sustained one deer (1.3%) kill during the 2-year period. SR32 sustained 28% of its total deer road-kill in agricultural areas; however, 50% of the kill occurred at mile marker 9.0, which

Table IV-1. Traffic speed (km/hr) and volume along new roads at Jordanelle Reservoir, Utah, 1992.

Date	Highway	Mean speed	Maximum speed	Mean Vehicles
11-15 March	US40	112.9	123.8	172.2
	SR248	92.7	117.3	37.9
	SR32	88.0	110.8	17.3
June 29-5 July	US40	96.0	110.8	264.6
	SR248	96.3	104.0	71.4
	SR32	89.6	110.8	37.8

Table IV-2. Road alignment at paired (n = 42) kill and non-kill locations at Jordanelle Reservoir, Utah.

	Curve	Straight	Hill
Kill	15	23	4
Non-kill	19	21	2

$\chi^2 = 1.2$, df = 2, $\underline{P} = 0.70$

was 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 right-of-ways in agricultural areas (Table IV-3). Paired sample t-tests showed no significant difference in the proportion of cover 100 m beyond the fence between kill and non-kill locations ($t = 0.13$, $df = 13$, $\underline{P} = 0.90$).

We examined 19 kill zones and 19 non-kill zones in the study area for associations with drainages (Fig. IV-2). Because deer road-kills occurred along nearly all of US40, we examined the 0.10 mile location in each kill zone that sustained the highest mortality. Major drainages intersected the roads in 16 (79%) kill zones. Along US40, large drainages intersected the highway at 6 (75%) of the kill zone locations. Two kill zone locations along US40 were at highway overpasses (mile markers 4.0 and 8.0); two other kill zones extended past highway underpasses (mile marker 8.2, mile marker 11.4)). Seven (37%) non-kill zones had drainages intersecting the roads. However, in four of the non-kill zones, the drainages were within 0.2 miles of a kill zone.

Kill and non-kill locations did not differ in right-of-way widths ($t = 1.10$, $df = 13$, $p = 0.30$). Deer kill per km was greatest when right-of-way areas were inclined rather than declined or level ($\pm$ 4°) relative to the road (Table IV-4). The proportion of cover on the right-of-way was never > 29% for any transect.

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

Habitat	US40	SR248	SR32
Agricultural	22	19	23
Mountain brush	49	40	44

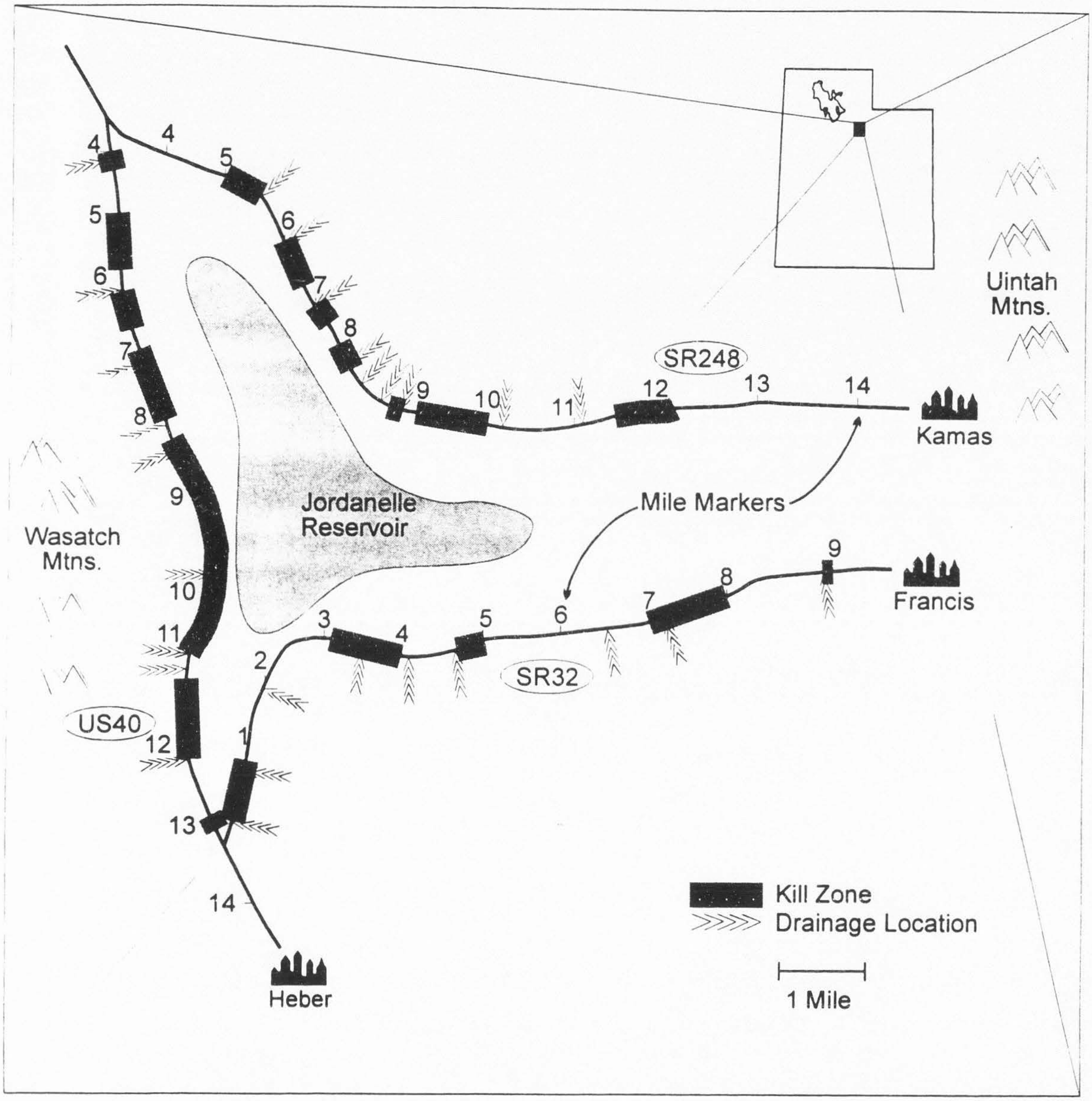

Figure IV-2. Deer kill zone and drainage locations along new roads at Jordanelle Reservoir, Utah, 1991 - 93.

Table IV-4. Deer kill per km relative to right-of-way slope relief along both sides of study area roads at Jordanelle Reservoir, Utah, 1991 - 93.

Right-of-way	Road		
	US40	SR248	SR32
No incline	6.7	0.9	2.6
Incline 1-side	22.3	6.8	7.1
Incline 2-sides	17.1	9.3	10.6

DISCUSSION

We distinguished patterns of deer road-kill distributions based on trafficvolume, habitat, and topography. Traffic volume influenced overall highway deer kill levels. Traffic volume was highest on US40. Though total kill in the study area decreased by 57% from the first to the second year, road-kills remained higher along US40 than either SR248 or SR32. Deer-vehicle collisions also occurred more frequently and traffic volume was higher along SR248 than along SR32 during both years. The 4-lane alignment of US40 may also have contributed to higher deer road-kill levels.

Road-kill locations at the 0.10 scale were not consistent between years, but they did seen consistent at the zone level (Fig. IV-1). Vegetative cover along the length of US40 was greater than along SR248 or SR32. Likewise, percent cover was higher for designated kill zones as compared to non-kill zones. Roadside cover appeared to encourage deer movement to right-of-ways for foraging. Agricultural areas provided abundant forage away from road sides and had low deer-vehicle collision levels. The initial approach of deer to road sides appeared closely related to drainage locations; higher kill levels occurred near large drainages.

Although drainages provided highway approaches for deer, right-of-way vegetation and slope influenced road-kill locations. Observed deer activity along the right-of-ways indicated deer moved parallel to roadways while utilizing the right-of-way for foraging and bedding. Sloped right-of-ways were characteristic of high kill areas, and may have funneled deer along the highway. Low spotlight-kill correlations further suggested that deer did not immediately cross the roads where they entered right-of-way areas. Snow track counts also indicated parallel movement of deer.

MANAGEMENT RECOMMENDATIONS

Our findings indicated that topographic and vegetative features associated with the highway mortality of deer were important when evaluating patterns of road-kills. Roads planned in high deer use areas that will sustain high traffic volumes should be identified 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 or in areas of heavy cover. Right-of-way vegetation and topography encouraged movement of deer along the highway corridor, creating a high potential for collisions.

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CHAPTER V

DEER-VEHICLE COLLISIONS: NATIONWIDE STATUS AND TECHNOLOGIES TO REDUCE THEIR OCCURRENCE[1]

Highway mortality of deer is a nationwide concern. In 1980 it was reported that 200,000 deer per year were killed on the nation's roadways each year (Williamson 1980). Property damage to vehicles, human injuries and fatalities, and potential reductions of local deer populations occur from deer-vehicle collisions. Economic losses can be substantial and will vary by state or province. Hunting expenditures and deer harvest rates can be used to calculate the economic value of deer; for example, in Utah in 1985, 64,333 deer were harvested (Utah Div. Wildl. Resour. 1992). Hunters spent a total of $79,887,400 while hunting big game. Deer accounted for 81% of the big game harvest, or $64,708,794 of total hunter expenditures. Each deer harvested, and subsequently, every deer in the state, can be valued at $64,708,794/64,333 deer = $1006. Using the consumer price index 30.5% adjustment to 1992, each deer today can be valued at $1313 (U.S. Fish and Wildlife Service 1989, L. A. Romin and J. A. Bissonette Utah St. Univ., unpubl. data). Utah auto insurance claims during 1992 indicated that an average $1200 damage per vehicle per accident results (Farmers Insurance Bureau, unpubl. data, 1992). In addition, the Federal Highway Administration places a monetary loss value of $1.5 million on each human fatality. It is estimated that 120 people per year are killed in animal-

[1]Co-authored by Laura A. Romin and John A. Bissonette

vehicle collisions nationwide (Nationwide Insurance 1993).

Some techniques have been evaluated to reduce deer-vehicle accidents. For example, the installation of animated deer crossing warning signs, either lighted or unlighted, did not result in significant reductions in accidents or vehicle speed (Pojar et al. 1975, Reed 1981). Likewise, accident rates and vehicle speed were not influenced by highway lighting (Reed 1981). Swareflex reflectors were shown to be ineffective at reducing mule deer-vehicle collisions (Reeve 1988, Ford and Villa 1993, L. B. Dalton and M. C. Stanger, Ut. Div. Wildl. Resour., unpubl. data). However, other studies have indicated success with swareflex reflectors (Schafer and Penland 1985). Mule deer did not exhibit behavioral responses that would indicate acknowledgement or avoidance of vehicles equipped with ultrasonic wildlife warning whistles (Romin and Dalton 1992). Wood and Wolfe (1988) showed intercept feeding to be effective at reducing deer-vehicle collisions, but only during certain time frames and where high concentrations of deer existed. Properly constructed and maintained big-game fencing restricted deer movement across highways and subsequently reduced deer-vehicle collision rates (Falk et al. 1978, Reed et al. 1979, Ludwig and Bremicker 1983, Feldhammer et al. 1986). Strategically located highway underpasses and overpasses have proven effective in allowing deer to cross roadways bisecting their use areas (Reed et al. 1979, Ward 1982).

Research of mitigative technologies to reduce deer-vehicle collisions is documented throughout the literature. Other work has been done internally within various agencies and is unpublished. Overall, it is evident that current technologies have not provided an effective, cost-efficient solution for widespread use. It is important, for continuing efforts to reduce highway mortality of deer, that we have knowledge of nationwide efforts so we can build upon those successes or failures. This study was designed to assess current deer highway mortality levels nationwide as well as to evaluate the current status of efforts to provide mitigative techniques to reduce their occurrence.

STUDY AREA AND METHODS

During October 1992, questionnaires were sent to state natural resource agencies nationwide requesting information on deer highway mortality within each state. We requested yearly estimates or actual counts of deer-vehicle collisions in each state for the past decade (1982 - 1991). In addition, we requested each state to identify methods they have employed in an effort to reduce deer-vehicle collisions. Each state also evaluated the success of the technique based on either scientific studies or field personnel reports.

RESULTS AND DISCUSSION

Forty-three states responded to our survey. Of these, 36 reported yearly totals of deer road-kills from 1981 to 1992 (Table V-1). In summary, the total reported deer road-kill for 1991 was 538,000 animals. Despite numerous states omitting these data, the 1991 total is at least double the reported deer kill from 1980 of 200,000 deer (Williamson 1980). Also, it is possible that only 50% of deer-highway mortality is

Table V-1. Percent change in deer road-kills by state during the period 1982-91.

	No. deer killed (year)			
State	Lowest year	Highest year	Actual count made?	Percent[a] change
Alabama	no data			
Alaska[b]	51-77/year		no	
Arizona	no data			
Arkansas	3,603(1990)	4,200(1989)	no	(0.14)
California	15,000/year		no	
Colorado	5,202(1983)	7,296(1991)	no	1.40
Connecticut	1,429(1982)	2,423(1986)	yes	1.70
Delaware	103(1982)	268(1991)	yes	2.60
Florida	no data			
Georgia	50,000/year		no	
Hawaii	no data			
Idaho	no data			
Illinois	2,797(1982)	15,560(1991)	yes	5.56
Indiana	2,858(1982)	12,671(1991)	yes	4.43
Iowa	4,805(1982)	9,248(1988)	yes	1.92
Kansas	2,492(1982)	3,536(1991)	yes	1.42
Kentucky	1,490(1982)	4,677(1990)	yes	3.14
Louisiana	1,500/year		no	
Maine	2,000(1980's)	3,500(1990's)	no	1.75
Maryland	no data			
Massachusetts	no data			

(table continues)

Michigan	18,045(1982)	44,374(1991)	no	2.46
Minnesota	11,471(1982)	16,280(1991)	yes	1.42
Mississippi	no data			
Missouri	4,779(1982)	9,519(1987)	yes	1.99
Montana	no data			
Nebraska	1,261(1982)	3,341(1991)	yes	2.65
Nevada	no data			
New Hampshire	455(1982)	1,000(1990)	yes	2.20
New Jersey[c]	455(1982)	10,494(1986)		23.06
New Mexico	no data			
New York	7,269(1984)	10,978(1991)	yes	1.51
No. Carolina	5,000-8,000/year		no	
North Dakota	2,500(1980's)	3,000(1990's)	no	1.20
Ohio	8,587(1982)	20,215(1991)	yes	2.35
Oklahoma[d]	450(1985)	495(1983)	yes	(0.09)
Oregon	no data			
Pennsylvania	24,648(1983)	43,002(1990)	yes	1.74
Rhode Island	no data			
So. Carolina	840(1982)	3689(1991)	yes	4.39
South Dakota	2,166(1982)	3,363(1991)	yes	1.55
Tennessee	no data			
Utah	1,826 (1980-81)	5,502 (1988-89)	yes	3.01
Vermont	1,105 (1982-83)	1,514 (1990-91)	yes	1.37

(table continues)

Virginia	1,446(1982)	3,427(1990)	yes	2.37
Washington	no data			
West Virginia	3,844(1985)	9,515(1991)	yes	2.48
Wisconsin	28,878 (1982-83)	76,626 (1989-90)		2.65
Wyoming	987(1988)	1756(1982)	yes	(0.44)

[a] % decrease

[b] Highest yearly estimate was used calculating total deer kill in 1991.

[c] Actual counts through 1988 - 89, estimated 10,000 deer/year from 1989 - 92.

[d] Discontinued record keeping after 1985 due to unreliable efforts.

actually documented (D. Reed, Colo. Div. Wildl. Resour., pers. commun.). Invariably, states considered their records to be considerably below the actual deer road-kill.

Due to wide variability and accuracy of deer road-kill reporting methods, most state records were too inconsistent for us to provide an average deer kill for the whole decade. More importantly, 61% of the states reported an increasing trend in deer road-kill levels between 1982 and 1991. Only one state, Wyoming, indicated a decrease in highway deer kill during those same years. Increasing deer populations and increasing traffic volumes in many states may be contributing to increasing deer-vehicle collisions.

Individually, New York (65,868 deer-vehicle collisions), Georgia (50,000 deer-vehicle collisions), Michigan (44,374 deer-vehicle collisions), Pennsylvania (41,513 deer-vehicle collisions), Wisconsin (34,000 deer-vehicle collisions), and Ohio (20,215 deer-vehicle collisions) reported the largest deer road-kill numbers for all states in 1991. Alaska reported the lowest kill, estimated between 51-77 deer. Moose-vehicle accidents were considered a more serious concern in Alaska; approximately 600 moose were killed in vehicular accidents each year. Another 150-750 moose were reported killed by trains each year.

If we assume that 538,000 deer is a nationwide estimate of deer-vehicle accidents, and we double the figure to allow for those animals that wander from the highway to die undetected or go unreported, total yearly monetary losses are substantial: $2.7 billion nationwide using the Utah estimates for deer value and vehicle damage. Without question, there is a need to provide methods to reduce the incidence of deer-vehicle collisions.

The second part of our survey was intended to provide a view of current work and knowledge in dealing with deer-vehicle collisions. All 43 states were able to provide a response in this area (Table V-2), although a few states have not addressed the deer road-kill problem at all.

The responses (Table V-3) we received were somewhat alarming and indicated that we are far from adequately solving the problem of deer-vehicle collisions. Deer crossing warning signs, swareflex reflectors, and public awareness programs have been utilized by a majority of states. At best, these methods have been evaluated as inconclusive regarding their effectiveness at reducing deer-vehicle collisions. Warning signs and swareflex reflectors were only rated as successful by 7% and 5% of the states using them, respectively. Public awareness programs, which can include varying news releases and classroom instruction, were deemed successful by 24% of the states implementing the programs.

Relatively few states have used fencing and overpasses/underpasses to deter deer from roadways. Yet, 91% of the states using fencing to keep deer off roads reported it as being effective. Of the states using overpasses/underpasses to route deer past highways, 63% have found the crossings to decrease deer-vehicle collisions. Illinois and Michigan also used hunting to reduce local deer populations in an effort to lower deer road-kill levels; Michigan indicated success with this management technique. In general, all mitigative techniques were ranked as inconclusive by a

Table V-2. Techniques used to reduce the highway mortality of deer in the United States, 1993.

	Mitigative Technique[a]										
State	FC	UO	CS	LS	MR	SR	HL	WW	HA	HZ	PR
Alabama			x[b]	x							x
Alaska			x						x		
Arizona					no data						
Arkansas						x					
California		x	x			x		x	x		
Colorado	x	x	x		x	x	x	x	x	x	
Connecticut			x								x
Delaware			x								
Florida					no data						
Georgia			x		x			x			
Hawaii					no data						
Idaho	x	x	x	x		x					
Illinois			x		x	x		x			x
Indiana			x					x			x
Iowa	x		x			x				x	x
Kansas			x								x
Kentucky			x			x		x			x

(table continues)

Louisiana			x	x							
Maine			x			x					
Maryland					no data						
Massachusetts			x	x							x
Michigan			x								x
Minnesota	x	x	x		x	x		x	x		
Mississippi			x								
Missouri			x		x	x		x			x
Montana						x		x			
Nebraska			x		x			x			x
Nevada					no data						
New Hampshire			x								
New Jersey		x	x			x		x			x
New Mexico			x			x					
New York		x	x		x	x		x			
North Carolina			x			x					x
North Dakota	x		x		x			x			x
Ohio			x		x			x			x
Oklahoma			x	x							
Oregon	x		x		x	x					

(table continues)

Pennsylvania	x		x					x			x
Rhode Island					no data						
South Carolina			x								x
South Dakota			x		x						
Tennessee					no data						
Texas			x								
Utah	x	x	x			x		x			x
Vermont			x			x					x
Virginia	x		x			x		x			x
Washington					no data						
West Virginia	x		x	x		x		x	x		
Wisconsin			x			x		x	x		x
Wyoming	x	x	x	x		x	x	x		x	x

[a] FC = fencing, UO = underpasses/overpasses, CS = deer crossing signs, LS = lower speed limit, MR = mirrors, SR = swareflex reflectors, HL = highway lighting, WW = ultrasonic warning whistles, HA = habitat alteration, HZ = hazing, PR = public awareness programs

[b] x indicates use by state

Table V-3. Evaluation of state (n=43) techniques for reducing highway mortality of deer.

Methods	%[a]	Successful (%)[b]			SS (%)[c]	
		yes	no	Incon-clusive	yes	no
Fencing (deer proof)	26	91	9	0	27	73
Underpasses/ Overpasses	19	63	12	25	25	75
Warning signs	93	7	23	70	25	75
Lower speed limit	16	0	0	100	0	100
Mirrors	26	9	36	55	27	73
Swareflex reflectors	51	5	36	59	36	64
Highway lighting	5	0	100	0	50	50
Ultrasonic warning whistles	39	0	53	47	6	94
Habitat alteration	14	17	17	66	17	83
Hazing	7	33	33	33	0	100
Public awareness programs	49	24	14	62	0	100

[a] % of states using method.

[b] % of respondents.

[c] based on scientific study conducted to address highway mortality of deer.

large proportion of the states utilizing them. There may be simple explanations for some of our findings. Deer crossing warning signs are often installed as part of highway construction designs. Their installation is relatively inexpensive and the signs tend to appease natural resource management agencies and the general public. However, their actual effectiveness appears minimal. The signs are so common and often used for such long stretches of road that drivers become complacent. Public awareness programs may be more worthwhile than our results indicate. It would be important to learn the precise tactics utilized by those states having success with their programs. Fencing and overpasses/underpasses, although rated as successful, are not frequently used due to typically high construction and maintenance costs.

Additionally, it appears from our survey that for the most part, the evaluation of the effectiveness of various techniques has often been based primarily on field personnel reports. Scientific evaluations are comparatively few. No states indicated scientific evaluation of the effects of reduced speed limits, hazing, or public awareness programs.

SUMMARY AND CONCLUSIONS

Our survey seems to indicate that there is still a need to evaluate highway mortality of deer and to provide techniques to reduce its occurrence. We hope that our results will help direct wildlife managers toward further studies evaluating the effectiveness of current technologies. New technologies may still be developed. Adaptations of existing technologies may provide more effective methods. In addition, many techniques may prove to be site-specific in effectiveness. Further studies of deer roadside behavior may lead to the development of effective techniques. In addition to human injuries and fatalities, the economic and biological losses attributed to deer-vehicle collisions are cause for concern. Based on our survey results, there appears to be a demand for the continued development and evaluation of techniques to reduce the highway mortality of deer.

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CHAPTER VI

SUMMARY

Road relocation at the Jordanelle Reservoir Project (JRP) in northeastern Utah was completed in December 1989. Annual highway mortality of deer subsequently increased from a pre-project kill of 12 deer per year (0.29 kills/km) to 174 deer (3.3 kills/km) in 1990, 278 deer (5.9 kills/km) from October 1991 to October 1992, and 120 deer from October 1992 to October 1993. The observed living population decreased by 64.2% following harsh winter conditions during 1992 - 1993.

Study efforts as described in the previous chapters identified temporal and spatial distributions of the deer road-kill in the JRP area. Locally, road-kill locations were identified to determine the placement of deer-proof fence and experimental big game highway crossing structures which will be installed during summer 1994. An understanding of pre-fence deer population and road-kill characteristics will help evaluate structure success. Broadly, research efforts added to the information already available concerning deer-highway relationships, which, to date, are disproportionate toward white-tailed deer in mixed hardwood habitat types.

Seasonal peaks in road-kills were identified. A fall peak occurred during both years. The post-winter peak varied between the summer (year 1) and spring (year 2). Seasonal sex and age class road-kill distributions were related to deer behavior patterns. The road-kill buck:doe ratio in the fall was higher than that evident in the living population. Fawns were infrequently seen and seldom involved in vehicular collisions during the summer. Seasonal peaks in mortality were similar to white-tailed deer, but the post-winter peak varied between years, indicating weather and subsequent behavioral responses affected kill distributions. Road-kill levels were additive at low deer density levels. Kill locations occurred near large drainages. This was not identified in white-tailed deer research, which focused on agricultural and woodland habitats. Road-kills occurred in areas of high percent cover; right-of-way vegetation encouraged deer to move toward roads to forage. Few kills occurred in agricultural areas. Steep right-of-way slopes encouraged deer to move along the highway corridor while foraging.

Similarities between white-tailed and mule deer-highway relationships indicated there are certain roadside features that may commonly contribute to mortality locations. Deer behavior patterns, i.e. breeding, fawning, and migratory movements, contribute to highway mortality on a site- and species-specific basis. Management teams need to assess the array of deer-highway research that exists and relate that to individual deer populations where appropriate. The accumulation of data allows highway planning teams to identify potentially critical areas and provide appropriate mitigative techniques. An understanding of local deer populations and area use patterns is necessary to identify construction impacts and mitigative techniques.