HABITAT FACTORS ASSOCIATED WITH MORTALITY OF SOUTHERN MICHIGAN WILDLIFE ON AN INTERSTATE HIGHWAY

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

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1976

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By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1976

ABSTRACT

HABITAT FACTORS ASSOCIATED WITH MORTALITY OF SOUTHERN MICHIGAN WILDLIFE ON AN INTERSTATE HIGHWAY

By

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There were 372 individuals from 25 mammalian species and 142 individuals from 14 avian species known to be killed by vehicles from August 20, 1975 to March 15, 1976 on a 15.5 mile (25 Km) length of Michigan Interstate 96 in a rural-agricultural area of Ingham County. An estimated 40% of the mammals which were mink size (0 68 Kg and 60.9 cm overall body length) or larger, and birds which were screech owl size (55.5 cm wingspan) or larger, and at least 80% of smaller mammals and birds were not recovered.

The group of larger mammals and birds included 379 individuals of the 19 species in the general size range of those normally removed daily from the highway by the Michigan Department of State Highways and Transportation. They were large enough to be easily visible to motorists, and as such, were considered to be potential direct or indirect threats to motorist safety. Among this group, the most commonly observed were; cottontail rabbit (67), raccoon (64), opossum (50), muskrat (46), and ring-necked pheasant (38). Larger mammals and birds were killed in the greatest numbers (59) from August 20 to 31, 1975, and the kill continually declined through the next February 15

(none during January 1 - 16), when it again increased after the snowpack melted.

Analysis of variance on the number of large and medium sized animals killed per mile indicated that the three habitat factors on which this variable was measured, roadside vegetation, median vegetation, and median width, all affected the distribution of vehicle-killed animals on the highway. In general, the largest number of animals killed per mile occurred where the roadsides were wooded, and especially where woods also occurred in the median. This was probably because the kill was composed largely of animals which use wooded habitats for food and/or cover.

An average kill of 33.4 individuals per mile occurred where there were woods on at least one roadside. This was significantly greater than a mean animal kill of 17.8 per mile on highway sections where only old field and/or cropland occurred along both roadsides. The mean animal kill of 29.4 per mile on highway sections with a mowed median less than 100 feet (30.5 m) wide was significantly greater than the mean animal kill of 20.8 per mile found on highway sections with an unmowed median less than 100 feet wide. The largest number of animals killed per mile (76.6) occurred where there were woods in the median in addition to at least one roadside. There did not appear to be any seasonal change in the percentage of animals killed in relation to wooded and non-wooded highway segments during the study period.

These results suggest that movement of animals, in particular the movement of medium-sized forest mammals, may be affected by the interstate highway. Progressively wider medians result in an overall wider right-of-way, which reduced the incidence of vehicle-caused wildlife mortality possibly by inhibiting movement in some species. Wooded medians appear to facilitate animal movements, either by 1) reducing the size of the highway as a barrier to movement, or 2) by attracting animals which would normally cross the highway at other locations. Some management implications of this study are also discussed.

ACKNOWLEDGEMENTS

I wish to express my sincere graditude to the Michigan Department of State Highways and Transportation. In particular I am indebted to Mr. Bud Bekaert for cooperation given in the field, and Mr. Jan Raad and Mr. John Baker for helping to initiate the study.

I am especially grateful to my major professor, Dr. Leslie Gysel, and the members of my guidance committee, Drs. Donald Beaver and Walter Conley, for suggestions concerning experimental design, for encouragement throughout the study, and for helpful criticism of the thesis manuscript.

Appreciation is extended to Mr. Joel Young of the USDA Agricultural Stabilization and Conservation Service for the loan of aerial photographs which were essential during several phases of the study. Additionally, I wish to acknowledge Dr. John Gill for statistical advice, and Mr. Glenn Dudderar for suggestions concerning the interpretation of my results. Use of the Michigan State University computer facilities was made possible through support, in part, from the National Science Foundation.

I am particularly indebted to Arlene Wong Hestbeck, for critically reviewing and typing the thesis manuscript.

Finally, I wish to thank fellow graduate students, Jay B. Hestbeck, J. Edward Gates, Philip B Davis, Gary P. Friday, and Thomas M. Butynski, for their continual advice and encouragement.

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INTRODUCTION

The U.S. interstate highway system is ultimately expected to consist of 41,000 miles of divided 4- or 6- lane highways encompassing over 1 million acres of land. In following the principles of the complete highway concept (Anon. 1966), the modern interstate highway system often includes large acreages in median and roadside vegetation that may be suitable for development as wildlife habitats. Continued declines in the amount of native wildlife habitat has brought recommendations to manage highway rights-of-way for wildlife (Egler, 1953, 1954, 1957). Such developments may supplement local native habitat or may serve as refuges for plants and animals. Additionally, they may be aesthetically desirable to motorists. The possibilities for management of roadside wildlife cover have been explored in relation to nesting cover for waterfowl in North Dakota (Oetting and Cassel, 1971) and ring-necked pheasant (*Phasianus colchicus*) in Illinois (Joselyn *et al*., 1968).

Highway officials concerned for motorist safety have been reluctant to allow wildlife habitat development along highway rights-of-way because they believe that development of roadside cover to attract wildlife may result in a greater number of vehicle-animal collisions (Joselyn, 1969). While this argument may be valid, present highway design and maintenance practices, including the planting of trees and other cover and the use of vegetation for screening, may unwittingly encourage the high rates of animal mortality that highway officials would like to avoid. Unfortunately, there is little data available to relate wildlife mortality to the vegetative and natural features along highways.

In eastern and mid-western states, the most serious wildlife-motorist problems are caused by white-tailed deer (Odocoileus virginianus). Accident reports from toll roads and turnpikes for years 1964 through 1966 indicated that deer caused an average of 5.7% of all reported vehicle accidents (Joselyn, 1969). An additional 0.8% of accidents were caused by animals other than deer; these included ring-necked pheasant, raccoon (Procyon lotor), and striped skunk (Mephitis mephitis).

Because deer have caused a significant number of vehicle accidents, several studies have examined the behavior of deer in relation to highways and the nature of deer-vehicle collisions in relation to natural features associated with highways (Carbaugh et al., 1975; Puglisi et al., 1974; Vaughn, 1970; Bellis and Graves, 1968). Similar data have not been obtained for animal species other than deer. The large numbers of these mostly medium sized mammals and birds has been well documented. These animals account for far more vehicle-wildlife collisions than deer, may cause vehicle accidents, and in Michigan, are regularly removed from highways at considerable expense in response to the wishes of the motoring public.

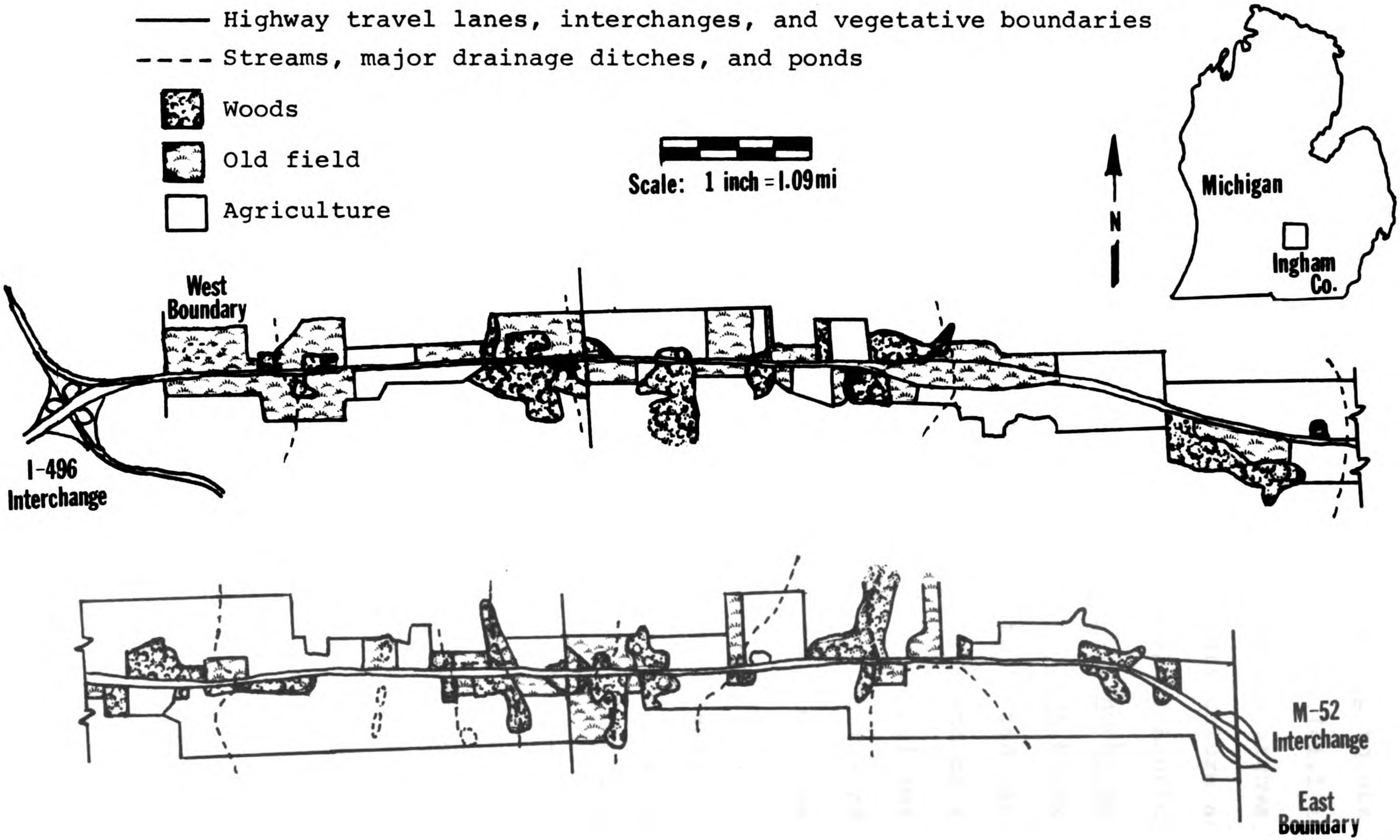
This study was conducted to examine the distribution of highway mortality of medium- and large-sized animals in relation to vegetation adjacent to the highway right-of-way, vegetation of the highway median, and width of the highway median. My intent was to provide data to aid decision making processes regarding the manipulation of major vegetation patterns in the design, maintenance, and use of highway rights-of-way to benefit wildlife, and motorist safety and aesthetics.

STUDY AREA

The study area was a 15.5 mile (25 Km) segment of Interstate 96 that traverses rural-agricultural landscape in Ingham County, Michigan, between the Interstate 496 interchange and the M-52 interchange (Figure 1). The study area was constructed during 1960-61 and opened to traffic in summer, 1962, and includes a 2-lane eastbound travelway and a 2-lane westbound travelway separated by a vegetated median strip which varies from 10 to 200 yards (9.1 to 182.9 m) in width. The right-of-way extends an average of 26.7 yards (24.5 m) from the outside edge of each travelway to a 4.5 foot (1.38 m) vertical fence.

The surrounding area is characterized by flat to moderately hilly topography and a complex of well-drained to somewhat poorly drained loam soils of glacial origin. Approximately 50% of the land directly adjacent to the right-of-way (hereafter called roadside vegetation) was planted with crops; mainly alfalfa (Medicago sativa L.), corn (Zea mays L.), hay, (mostly Phleum prantense L.), and soy beans (Glycine max L.). A small portion of these and other fields were used as pasture. Remaining roadside vegetation consisted of woods and fallow or abandoned agricultural land. Abandoned fields varied in age from recently abandoned fields containing a

Figure 1. Location map of Inter tate 96 study area with generalized vegetative features



few early successional shrubs or sapling trees to more developed field communities containing extensive (up to 60%) development of shrubby cover. The 45 to 450 yard (41.1 to 411.9 m) long segments of woods occurred along the highway primarily on low-lying areas not suited for agriculture and consisted mainly of young stands (20-38 cm dbh) of American beech-sugar maple (Fagus grandifolia Ehrh.-Acer saccharum Marsh.) woods mixed with aspen (Populus tremuloides Michx.), and lesser amounts of hickory (Carya spp. Nutt.), red oak (Quercus rubra L.), white oak (Quercus alba L.), and on wetter sites, silver maple (Acer scharinum L.). Several small streams and drainage ditches crossed or paralleled the right-of-way at irregular intervals. A generalized map of these patterns is shown in Figure 1.

Control of vegetation on the right-of-way consisted of mowing and herbicide treatment to control vegetation around guard rails. A 5 yard (4.57 m) strip of vegetation adjacent to the driving surface was mowed each June and August by personnel from the Michigan Department of State Highways and Transportation. In addition, highway median which is less than 100 feet (30.5 m) wide was completely mowed. Approximately 40% of the median on the study area was completely mowed while the remainder was unmowed except for the 5 yard strips adjacent to the driving surface.

Vegetative cover on unmowed portions of the right-of-way consisted of smooth brome (Bromus inermus Leyss.) interspersed with scattered patches of less common herbaceous cover including alfalfa, red clover (*Trifolia pratense* L.), and other locally cultivated crops. Roadside ditches contained common cattail (*Typha latifolia* L.) and scattered patches of reed (Phragmites australis (Cav.) Steudel). Except for 11 small woodlots found in the median and scattered ornamental trees planted on approximately 2 miles (2.51 Km) of the highway, little woody vegetation occured on the right-of-way.

METHODS

Wild and domestic animals killed by vehicles on the study area were collected 4-5 days each week from August 20, 1975 through March 15, 1976, except for the one week period from December 20 through 27. Vehicle-killed animals were observed while driving the right lane of the highway at the minimum 45 mph (72.4 Km/hr) legal speed. Each individual which I observed was buried or removed from the right-of-way so that it would not be counted again on subsequent days. Approximately once each week I made observations while driving along the emergency shoulder to detect animals lying among the roadside vegetation. A yellow flashing caution light mounted on top of my vehicle was operated while driving the emergency shoulder or stopping to remove vehicle-killed animals from the highway. In addition, a fluorescent orange vest was worn at all times to ensure maximum safety for myself and other motorists. Observations were generally made during the morning hours at off-peak traffic times.

Permission to stop a vehicle and trap animals within the highway right-of-way of the study area was given in writing by the Michigan Department of State Highways and Transportation. The permit was valid only during daylight hours and off-peak traffic times. For the duration of the study, the Highway Department suspended daily collection and disposal of vehicle-killed animals on the study area so they would not bias my observations. The Ingham County Animal Control Department and the Michigan State Police were notified of this study, and they agreed to refer motorist complaints regarding vehicle-killed animals to me.

Data recorded on prepared field sheets for each individual were species, location, distance to nearest permanent water, distance to nearest woodlot and, where possible, sex and age. The location of each observation was recorded in relation to type of roadside vegetation, type of median vegetation, and width of median. These features were surveyed using vehicle reconnaissance and aerial photographs, classified and mapped for use on field sheets, prior to initial collection of vehicle-killed animals. Several areas were later reclassified as errors in the initial classification were encountered.

Roadside vegetation was classified as: 1) both sides wooded; 2) one side wooded, one side old field; 3) one side wooded, one side agricultural; 4) both sides old field; 5) one side old field, one side agricultural; and 6) both sides agricultural. All roadside classified as wooded was composed of closed stands of aspen or beech-maple woods as previously defined. Old fields consisted of abandoned agricultural land dominated by naturally occurring herbaceous vegetation. Many segments of roadside classified as old field also contained varying percentages of early successional woody cover which was visually estimated. Naturally vegetated fields subject to light grazing pressure were generally classified as old field while heavily used pastures and land supporting all crop types were classified as agricultural.

Vegetative composition of the median was described as herbaceous or wooded. Width of the median was described as less than 100 feet or greater than 100 feet. Herbaceous median less than 100 feet was completely mowed each June and August. Herbaceous median greater than 100 feet was unmowed. Altogether, there were 84 variable-sized sampling units described relative to 6 types of roadside vegetation, 2 types of median vegetation, and 2 types of median width. Sampling units were delineated by natural boundaries between roadside vegetation, boundaries between mowed and unmowed median, and woodlots found on the median. The shortest sampling unit extended 89 yards (81.4 m) along the right-of-way. Shorter segments of vegetation were not classified or mapped.

In order to detect animals not observable from the vehicle and to examine the distribution of animals missed from the vehicle in relation to roadside vegetation, median vegetation and median width, 14 segments of right-of-way totaling 1.76 miles (11.3%) of the study area were searched on foot. A systematic ground search of both roadsides and median was conducted 5 times for each area.

The distribution of vehicle-killed mammals and birds observed from the vehicle were analyzed relative to roadside vegetation, median vegetation, and median width (Table 1). The total number of animals killed for selected species was used to compute the variable animal kill per mile for each sampling unit as

$$\frac{\text{(number of animals killed)(1760 yards/mile)}}{\text{length of sampling unit in yards}}$$

where the length of each sampling unit was measured from aerial photographs to the nearest 10 yards. Analyses of variance were used to test null hypotheses of no difference between animal kill per mile in relation to roadside vegetation, median vegetation, and median width.

Table 1. Experimental design and distribution of sampling units among roadside vegetation, median vegetation, and median width.

Vegetation on opposite sides of right-of-way	Number of sampling units (% of study area)		
	Herbaceous median		Wooded median
	<100 ft. wide	≥100 ft. wide	≥100 ft. wide
Woods - woods	6 (6.1)	4 (2.0)	4 (2.8)
Woods - field	7 (4.0)	8 (6.0)	2 (0.9)
Woods - agric	5 (2.7)	8 (6.8)	3 (4.5)
Field - field	7 (10.6)	4 (4.2)	
Field - agric	8 (13.9)	5 (10.4)	
Agric - agric	6 (12.9)	7 (12.7)	

[solid box] Design for ANOVA of animal kill per mile in relation to roadside vegetation x median size.

[dashed box] Design for ANOVA of animal kill per mile in relation to roadside vegetation x median vegetation.

RESULTS

There were 364 vehicle-killed individuals from 23 mammalian species and 133 individuals from 13 avian species that were observed during the daily surveys of the study area. Combined, a minimum of 0.20 animals per mile per day were killed during the 7 month study period. Of these, 379 (76.0%) were used in the analysis of animal mortality in relation to roadside vegetation and median characteristics. These consisted of 14 species of mammals having overall body sizes averaging larger than 24 inches (60.9 cm) overall length and 1 1/2 lb. (0.68 Kg) in weight and 5 species of birds with wingspans of 22 inches (55.5 cm) or larger (Table 2). These species were within the general size range of those animals normally removed daily from the highway by Highway Department personnel. They were large enough to be easily visible to motorists, and, as such, were considered to be potential direct or indirect threats to motorists' safety. They were also the animals for which the most accurate data was obtained. Field observation suggested that smaller animals, particularly small rodents and passerine birds, were not readily observable from the vehicle; they were quickly obliterated by vehicle traffic.

There were 17 vehicle-killed individuals observed in

Table 2. Numbers of vehicle-killed mammals and birds observed during each two-week peroid from August 20, 1975 to March 15, 1976 along 15.5 miles of Interstate 96 between the Interstate 496 and M-52 interchanges.

Mammals		Birds	
Common name(Scientific name)	Nos. killed	Common name(Scientific name)	Nos. killed
Order Artiodactyla		Order Anseriformes	
White-tailed deer		Mallard(*Anas platyrhynchos*)[2]	4
(*Odocoileus virginianus*)[1]	7	Wood duck(*Aix sponsa*)[2]	1
Order Carnivora		Order Columbiformes	
Domestic dog(*Canis domesticus*)[1]	10	Rock dove(*Columba livia*)[2]	13
Gray fox(*Urocyon cinereoargenteus*)[1]	1		
Red fox(*Vulpes fulva*)[1]	1	Order Coraciiformes	
Domestic cat(*Felis catus*)[1]	5	Belted kingfisher(*Mega cerlyealcyon*)	1
Badger(*Taxidea taxis*)[1]	1	Order Galliformes	
Least weasel(*Mustela rixosa*)	2	Ring-necked pheasant	
Longtail weasel(*Mustela frenata*)	2	(*Phasianus colchicus*)[2]	38
Mink(*Mustela vison*)[1]	6		
Striped skunk(*Mephitis mephitis*)[1]	11	Order Passeriformes	
Raccoon(*Procyon lotor*)[1]	64	Common grackle(*Quiscalus quiscula*)	2
		Eastern meadowlark(*Sturnella magna*)	9
Order Chiroptera		Northern oriole(*Icterus galbula*)	1
Red bat(*Lasiurus borealis*)	1	Cardinal(*Cardinalis cardinalis*)	1
		American robin(*Turdus migratoris*)	2
Order Insectivora		House sparrow(*Passer domesticus*)	3
Eastern mole(*Scalopus aquaticus*)	18	Starling(*Sturnus vulgaris*)	2
Starnose mole(*Condylura cristata*)	1		
		Order Sterigiformes	
		Screech owl(*Otus asio*)[2]	17

Table 2 (con't).

Order Lagomorpha	
Cottontail rabbit (*Sylvilagus floridanus*)[1]	67
Order Marsupialia	
Opossum (*Didelphis marsupialis*)[1]	50
Order Rodentia	
Eastern chipmunk (*Tamias striatus*)	1
Eastern fox squirrel (*Sciurus niger*)[1]	30
Muskrat (*Ondatra zibethica*)[1]	46
Norway rat (*Rattus norvegicus*)	8
Red squirrel (*Tamiasciurus striatus*)	1
White-footed mouse (*Peromyscus* spp.)	24
Woodchuck (*Marmota monax*)[1]	4

[1] Large and medium-sized mammals used in the analysis of animal kill per mile in relation to roadside vegetation and median characteristics. The smallest was the mink, which averages 0.68 Kg in weight and 60.9 cm overall length.

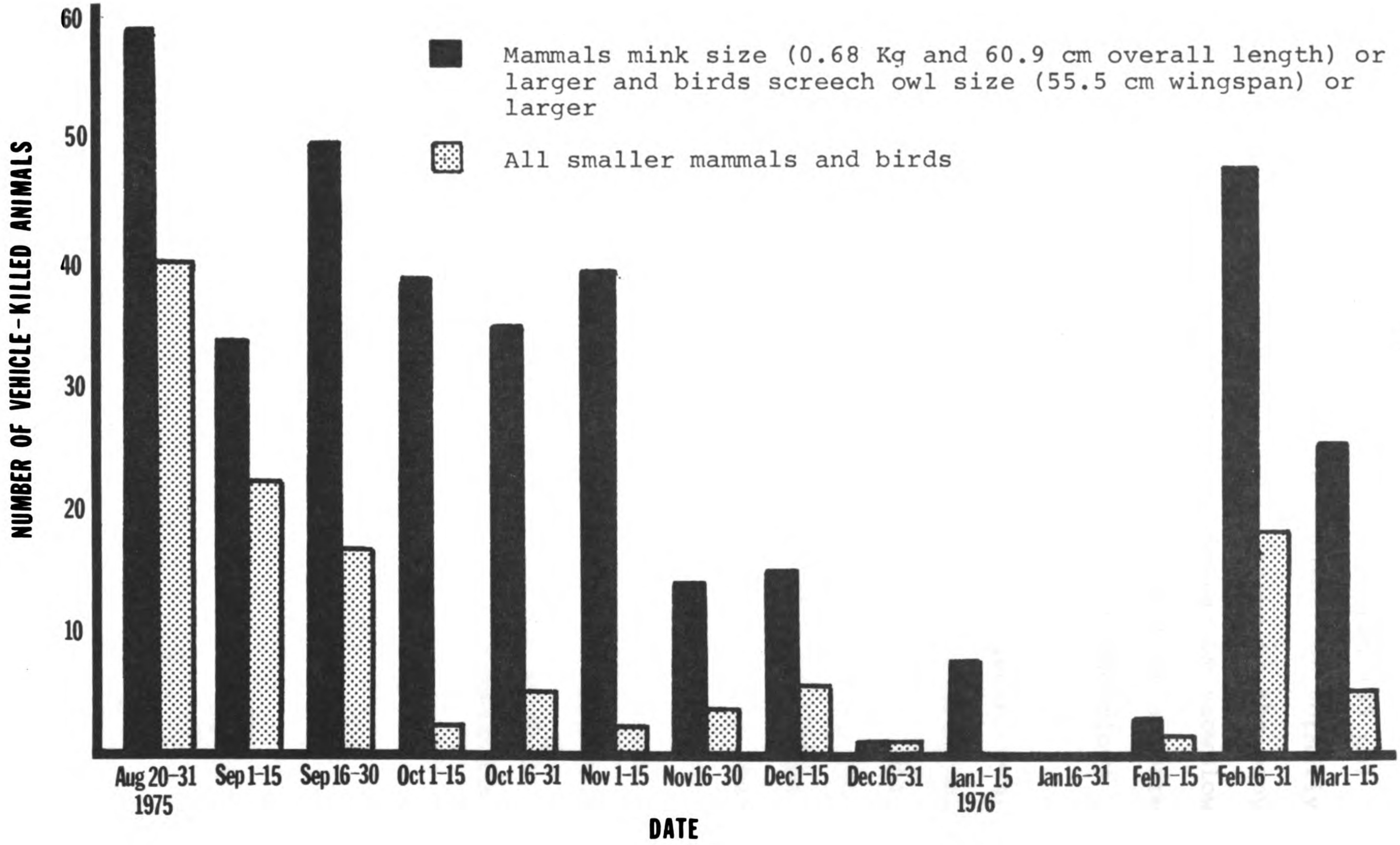
[2] Avian species used in analysis of animal kill per mile in relation to roadside vegetation and median characteristics. The smallest was the screech owl, which has an average wing span of 55.5 cm.

median and roadside vegetation during the 5 ground searches of 1.76 miles of highway, conducted to provide a check on the accuracy of the visual counts from the vehicle. These included 3 species which were not observed from the vehicle: 1 meadow vole (*Microtus pennsylvanicus*), 1 house mouse (*Mus musculus*), and 2 common crows (*Corvus brachyrhynochos*). Only 7 were medium-sized mammals or birds of concern to motorist aesthetics or safety. The ratio of the number of animals counted during the ground searches to the total number of animals counted (during ground searches and from the vehicle) suggests that approximately 40% of large and medium-sized mammals and birds and at least 80% of small mammals and birds were not recovered during the surveys from the vehicle. Because only 7 large- and medium-sized mammals and birds were counted during the ground surveys, the distribution of these animals in relation to roadside vegetation, median vegetation and median width could not be evaluated.

Seasonal Variation

For the 7 month period during which observations were made, vehicle-caused mortality of animals was highest during fall and early spring (Figure 2). Most of the spring observations were the result of an apparent pre-breeding muskrat dispersal. Mortality was lowest during the winter months. Only 9.8% of all observations occurred from November 16 through February 15 when the ground was snow covered. A

Figure 2. Numbers of vehicle-killed mammals and birds observed during each two-week peroid from August 20, 1975 to March 15, 1976, along 15.5 miles of Interstate 96 between the Interstate 496 and M-52 interchanges.



deep snowpack, which reached a depth of 14 inches (35 cm) in mid-January, probably inhibited the movement of normally active animals. Animals killed during or prior to the many winter snowstorms were removed from the highway by snowplows and lost to observation. Because inclement weather appeared to inhibit movement of most animals, removal by snowplows was considered insignificant.

Movement of animals from old fields to the dense cover of wooded areas was hypothesized to occur as the season changed from fall to winter, and a concomitant shift in animal mortality was expected to occur. However, when the total number of animals killed per mile was divided into two groups, those occurring adjacent to wooded roadsides and those that did not, the percentage of animals killed adjacent to woods was nearly constant (approximately 70%) in each two week period. Although there was no data for the summer months, there appeared to be no seasonal shift in overall animal activity with respect to wooded versus non-wooded sections of highway.

Roadside Vegetation and Median Width

Animal kill per mile was calculated for each sampling unit using the total number of vehicle-killed individuals from the 19 largest species of mammals and birds (Table 2). Analysis of variance on animal kill per mile in relation to roadside vegetation and median width was conducted on the

77 sampling units having an herbaceous median (Table 1). The distribution of residuals for animal kill per mile was not normally distributed (Kolmogorov-Smirov $Z_{n=75} = 1.46$, $P_{\alpha/2} < 0.028$); thus, the square root of each value of animal kill per mile was computed to normalize the distribution of residuals (Kolmogorov-Smirov $Z_{n=75} = 0.79$, $P_{\alpha/2} > 0.560$) and produce a homogeneous variance. At the = 0.05 level of acceptance, there were significant effects due to roadside vegetation and median width and no significant interaction (Table 3).

The mean animal kill of 29.4 per mile on highway with a median width less than 100 feet was significantly larger than the mean animal kill of 20.8 per mile found on highway with a median width greater than 100 feet. The mean animal kill per mile for each combination of roadside vegetation and median width is given in Table 4. Pairwise comparisons among means for classes of roadside vegetation were not significantly different at the $\alpha = 0.10$ level of acceptance using the conservative Scheffe's multiple comparison test for group means. This does not necessarily indicate that there were no actual pairwise differences. Small sample sizes and wide structural heterogeneity among sampling units may have contributed to large within class variation which masked actual pairwise differences in animal kill per mile among classes of roadside vegetation. Scheffe's multiple comparison test indicated that a mean animal kill of 33.4 per mile on segments of highway with woods occurring on at

Table 3. Analysis of variance of animal kill per mile in relation to roadside vegetation and median width.

Source of Variation	df	Sums of Squares	Mean Square	F	Probability of a larger F
Roadside vegetation	5	59.47	11.89	2.73	$.05 \geq P \geq .025$
Median vegetation	1	17.96	17.96	4.13	$.05 > P > .025$
Roadside x median interaction	5	33.95	6.79	1.56	$.25 > P > .10$
Residual	63	274.14	4.35		
Total	75	381.90			

Table 4. Mean animal kill per mile in relation to roadside vegetation, median width, and median vegetation.

Vegetation on opposite sides of right-of-way	Number of sampling units (% of study area)		
	Herbaceous median		Wooded median
	100 ft. wide	100 ft. wide	100 ft. wide
Woods - woods	39.5	24.6	96.0
Woods - field	37.6	31.8	68.4
Woods - agric	52.0	19.5	56.3
Field - field	24.6	11.5	
Field - agric	21.2	17.8	
Agric - agric	11.9	15.0	

least one side of the right-of-way was significantly greater ($P < 0.05$) than a mean animal kill of 17.8 per mile on highway segments where there were no woods.

A large portion of the total animal kill associated with wooded roadside was composed of raccoon, opposum, fox squirrel, and cottontail rabbit (Table 5). These were among the species killed in the largest numbers (Table 2), and, except for the cottontail rabbit, they are generally associated with wooded habitats.

Sampling units, on which animal kill per mile was calculated, varied in length from 89 - 1489 yards (81.4 - 1361.5 m). Wooded areas had the shortest average sampling units (186.5 m) and the largest mean killrate (33.4 animals per mile) while agricultural areas had the longest average sampling units (491 m) and the lowest killrate (13.6 animals per mile). Since type of roadside vegetation and size of sampling unit varied together, the significant effect due to roadside vegetation indicated in the analysis of variance may have been due, at least in part, to variation in size of the sampling units. Smaller sampling units would indicate greater interspersion of vegetative types along the highway. Greater interspersion of habitats may result in greater animal abundance (Leopold, 1933; Allen, 1962; Dasmann, 1964), and concomitantly, greater mortality on those sections of highway. However, regression analysis conducted for each class of roadside vegetation did not show any significant variation in killrate over the range of sampling

Table 5. Mean kill per mile for the more important species of mammals and birds in relation to roadside vegetation, median vegetation, and median width.

Species	Mean kill per mile: Roadside vegetation having mowed median <100 ft. wide						Roadside vegetation with unmowed median ≥100 ft. wide		
	1[1]	2	3	4	5	6	1	2	3
Badger	0	0	0	0	0	0.3	0	0	0
Cottontail rabbit	6.3	4.5	5.2	3.1	4.4	2.0	16.3	13.8	5.7
Fox squirrel	7.9	1.9	2.6	0	0.3	0.3	11.7	0	8.6
Gray fox	0	0	0	0	0.3	0	0	0	0
Mallard	2.4	0	0.6	0	0	0	0	0	0
Mink	0.8	0	0	0.4	0.8	0	0	0	0
Muskrat	2.4	7.9	3.9	1.7	3.0	0.8	0	0	0
Opossum	5.5	3.2	1.9	0.4	0.8	2.3	32.6	0	0
Raccoon	7.9	2.6	6.5	1.7	1.6	2.3	14.0	6.9	17.2
Ring-necked pheasant	0.8	2.6	2.6	0.8	4.3	2.8	0	0	0
Rock dove	1.6	0.6	0	1.7	0.8	0.8	0	0	0
Screech owl	1.6	1.9	0	0.8	0.3	0.3	7.0	0	7.1
Striped skunk	0	1.2	0.6	0.8	0.8	0.8	2.3	0	0
White-tailed deer	0.8	0	0.6	0	0.3	0.3	2.3	0	0
Woodchuck	0.8	0	0	0	0.8	0	0	0	0
Wood duck	0	0	0	0	0.8	0	0	0	0

[1] Codes for roadside vegetation: 1 = woods-woods, 2 = woods-field, 3 = woods-agriculture, 4 = field-field, 5 = field-agriculture, 6 = agriculture-agriculture.

unit sizes present on the study area. This suggests that the significant variation in killrate per mile in relation to the different types of road side vegetation was not influenced by size of the sampling units.

Roadside and Median Vegetation

Where the highway was routed through a wooded area, the woods were either left in the median or the median was completely cleared of trees and maintained in herbaceous growth. Only where woods occurred on at least one side of the right-of-way was there a possibility of woods on the median. Analysis of variance was used to test the hypothesis of no difference between animal kill per mile in relation to wooded roadsides and median vegetation using the 29 sampling units having woods on at least one side of the right-of-way and a median greater than 100 feet wide (Table 1). Data from sampling units with a median less than 100 feet wide were not used because of the significant effect of median width on animal kill per mile found previously.

The distribution of residuals for animal kill per mile was not normally distributed (Kolmogorov-Smirov $Z_{n=29} = 1.31$, $P_{\alpha/2} < 0.064$); thus the square root of each value of animal kill per mile was computed to normalize the distribution of residuals (Kolmogorov-Smirov $Z_{n=29} = 0.52$, $P_{\alpha/2} > 0.950$) and produce a homogeneous variance. A significant effect ($P < 0.05$) due to median vegetation was detected (Table 6).

Table 6. Analysis of variance of animal kill per mile in relation to roadside and median vegetation.

Source of Variation	df	Sums of Squares	Mean Square	F	Probability of a larger F
Roadside vegetation	2	17.85	8.93	1.82	$.25 \geq P \geq .10$
Median vegetation	1	80.08	80.08	16.32	$< .001$
Roadside x median interaction	2	2.86	1.43	0.29	$> .999$
Residual	23	112.83	4.91		
Total	29	222.19			

There were an average of 76.6 animals killed per mile where the median was wooded, and an average of 25.4 animals killed per mile where the median was herbaceous. The average kill per mile for each combination of roadside and median vegetation is given in Table 4. Although segments of highway with a wooded median composed only 8.2% of the study area, 22.25% of the observed animal mortality occurred in those portions.

Average Daily Probabilities

Average daily probabilities of finding at least one vehicle-killed animal on a sampling unit were calculated on highway sections for every combination of roadside and median characteristics during two time periods, August 20 through November 30, 1975, and December 1, 1975 through March 15, 1976. The calculations utilized data only from those days where a survey was conducted on the immediately preceding day. These probabilities are based on the formula

$$P = \frac{\sum_{i=1}^{S} N}{(S)(D)}$$

where:

P = the average probability of finding at least one vehicle-killed animal each day on a single sampling unit;

N = total number of days for which at least one vehicle-killed animal was observed on each sampling unit;

S = # of sampling units;

D = total observation days, 65 for the period August 20 through November 30, 1975, and 62 for the period December 1, 1975 through March 15, 1976.

For the fall months, the probability of finding at least one vehicle-killed animal on any day was lowest (P = .012) on sampling units having a wide, herbaceous median, and both roadsides wooded or one wooded and the other in agriculture. It was highest (P = .108) on sampling units having a wooded median and one wooded roadside with the other in agriculture (Table 7). For the winter months, the probability of finding at least one vehicle-killed animal was much lower than for fall months in all cases except where the median was wooded and the roadside consisted of wooded areas and field (P = .032 in winter vs. P = .023 in fall). The highest probability value (P = .048) occurred when the sampling unit contained a wooded median and one wooded roadside with the other in agriculture (Table 8).

These probabilities were calculated using sampling units of different lengths, and thus the values do not have a common distance denominator. As previously indicated, sampling units averaged the shortest for wooded areas, intermediate for old field areas, and longest for agricultural areas. As expressed relative to a standard length for a sampling unit according to the formula

Table 7. Average probabilities of finding at least one large and/or medium-sized mammal or bird per sampling unit per day from August 20 through November 30, 1975.

Vegetation on opposite sides of right-of-way	Probability (Factor increase in probability over lowest probability after adjustment for size of sampling unit)		
	Herbaceous median		Wooded median
	<100 ft. wide	≥100 ft. wide	≥100 ft. wide
Woods - woods	.051(7.27)	.021(9.13)	.021(6.25)
Woods - field	.017(3.70)	.023(3.30)	.023(22.17)
Woods - agric	.031(9.90)	.012(1.53)	.108(20.87)
Field - field	.020(1.63)	.012(2.33)	
Field - agric	.016(1.00)	.056(4.63)	
Agric - agric	.028(1.89)	.042(2.88)	

Table 8. Average probabilities of finding at least one large and/or medium-sized mammal or bird per sampling unit per day from December 1, 1975 through March 15, 1976.

Vegetation on opposite sides of right-of-way	Probability (Factor increase in probability over lowest probability after adjustment for size of sampling unit)		
	Herbaceous median		Wooded median
	<100 ft. wide	≥100 ft. wide	≥100 ft. wide
Woods - woods	.019(5.56)	.004(3.64)	.016(9.4)
Woods - field	.012(5.45)	.010(3.04)	.032(64.65)
Woods - agric	.008(5.38)	.006(1.60)	.048(19.4)
Field - field	.012(2.05)	0.00 (——)	
Field - agric	.012(1.56)	.032(5.60)	
Agric - agric	.013(1.84)	.007(1.00)	

$$\frac{\left[\dfrac{P}{\text{average length of sampling unit}}\right]}{\left[\dfrac{P}{\text{average length of sampling unit}}\right]_{\text{lowest non-zero value}}}$$

the factor increases in probability over the lowest non-zero probability after adjustment for sampling unit length differences show that, per mile of highway, the highest probability of finding at least one vehicle-killed animal occurred where the roadside was wooded; it was particularly high where the median was also wooded.

DISCUSSION

The higher overall mortality of mostly medium-sized mammals and birds that occurred on highway sections with wooded roadsides is related to several factors: the species which composed the bulk of the observed mortality, the habitat preferences of these species, and their movement patterns and home range characteristics. Wooded areas adjacent to the highway often occurred along small streams or on wet soils where temporary or permanent sources of water were available nearby. These areas provided the major source of habitat for raccoons, opossums, fox squirrels, screech owls, and the other medium-sized woodland animals which composed the bulk of the observed wildlife mortality. It appeared that these animals were killed in numbers directly related to their abundance along the highway; the overall observed kill being highest where the local habitat allowed the highway population densities. In addition to habitat specificity, home range and movement characteristics of these animals also appears to be an important factor which influences the higher rate of vehicle-c sed mortality on wooded sections of highway.

In similar studies involving white-tailed deer (Allen and McCullough, 1976; Puglisi et. al., 1974), there were no differences in mean deer kill per mile among the same three types of roadside ocver difined in this study, which were woods, old field and agriculture. Michigan deer have a home range averaging 3.5 square miles (Dahlgerg and Gottinger, 1956); and because they are highly adaptable browsers and grazers, deer utilize the food and cover provided by the habitats which are typical of mixed-agricultural areas in southern Michigan. Due to their more general habitat requirements, vehicle-caused deer mortality could not be related to any specific habitat characteristics. In contrast, species observed in this study general ly have much smaller home ranges associtated with more specific habitat requirements. For example, raccoons and opossums, which are predominantly woodlot or forest animals, have home ranges averaging 100 - 200 acres (Ellis, 1964) and 10 - 40 acres (Lay, 1942) respectively. Because these and other medium-sized species are mainly found in wooded areas and have similarly small home ranges, vehicle-caused mortality was highwst where woods occurred adjacent to the highway.

While, in general, variation in animal kill per mile between types of roadside vegetation appears to have been a function of the abundance of medium-sized animals in these different habitats, the very high rate of animal mortality along highway sections with a wooded median was probably not entirely related to wildlife numbers, but to the movement patterns of amimals relative to wooded medians. The woods which occurred along highway roadsides in areas where the median was also wooded did not appear to provide better wildlife habitat than the woods which occurred along highway sections where there was an herbaceous median. Also, the wooded medians, which were approximately 25 yards (22.9 m) wide and 25 - 100 yards (22.9 - 91.4 m) long, could not provide sufficient additional habitat along the highway to increase animal numbers and produce the large number of dead animals observed along these sections of highway. My investigations of the wooded medians indicated heavy browsing on seedling trees by cottontail rabbits, light browsing by deer, and minimal use of oak acorns by fox squirrels. However, these areas did not appear to provide permanent ocver for any of these species. Thus, while wooded medians nay be utilized somewhat for food, I suggest that they are most important as travel cover for animals crossing the highway. Higher rates of animal mortality would be expected in these areas if animals were to concentrate along highway with wooded medians in order to use the median as travel cover to access food or cover on the other side of the highway. It may not necessarily be the tree canopy which provides attractive travel cover. The forest understory of wooded medians was usually dense, providing excellent cover while the forest floor was relaively open, providing ease of passage. Median vegetation, which can provide similar advantages such as an extensive development of shrubs without an overstory tree cover, may affect animal movement as wooded medians appeared to do in this study.

Wooded medians may affect animal movements in one of two ways. They may merely redistribute existing mortality by attracting animals which would normally cross the highway at some other point. Or, if the highway acts as an actual barrier to movement of these animals, the wooded median may facilitate the crossing of more animals than would cross the highway otherwise.

Oxley et. al. (1974) observed that progressively wider highway rights-of-way reduced the overall movement of small and medium-sized forest mammals across the highway. In this study, there was an average of 8.6 more animals killed per mile on highway with a narrow ($<$30.5 m), mowed median than the wider ($\geqslant$30.5 m), unmowed median. This may have been been due to reduced movement of animals along the highway wider medians, a result of either the home range characteristics of the animals involved or the highway acting as a barrier to movement. Clarification of this point could be obtained from trapping or telemetry observations of animal movement patterns in relation to highway of different widths and median characteristics.

The potential for control of vehicle-killed animals through highway siting, design, and maintenance practices is dependent on the presently unknown behavioral and movement patterns of animals in relation to the interstate highway. There is currently one mamagement practice that is beneficial and does not result in a large number of vehicle-killed animals. Where a highway is routed through a wooded area, particularly where near the edge of a large woodlot, the main body of the woods is left to one side of the right-of-way and a narrow strip of woods may be left on the other side. The parctice of leaving this narrow strip of woods is encouraged in present highway design and maintenance policies to screen against vehicle headlamps and to help maintain a natural setting in relation to the highway landscape (Anon., 1966; Noyes, 1969). My data indicate that wildlife mortality is no higher on areas where screening of this type is used than where the screening is not used and woods occurs only along one side of the right-of-way.

Disposal ov vehicle-killed animals may vary from one locality to another depending on the extent of the problem, and the policies determined by each maintenance garage responsible for care specific areas of highway. The Highway Department maintenance garage at Williamston, Michigan is responsible for 150 miles of roads, including my 15.5 mile study area. During 5 days each week the entire length of these roads is surveyed for damage to the road surface, highway signs, etc.; in addition to being surveyed for vehicle- killed animals. Although disposal of vehicle-killed animals is currently included with other duties, different management personnel have, in the past, commissioned twice weekly trips by a crew and truck specifically to dispose of vehicle-killed animals. My results indicate that the total effort given to disposal of these animals on interstate highways may be minimized in locatities where, because of voluminous complaints or the large number of animals killed, a special and regular effort is required to adequetely control an animal problem. Per mile of highway, the probability of finding at least one vehicle-killed animal per day is highest where the roadside is wooded, particularly where the median is also wooded. For fall and winter months, there is a 5 times greater probabilty of finding an animal on highway with wooded roadsides than of finding an animal on highway with non-wooded roadsides. In order to maintain the same degree of control over vehicle-killed animals, non-wooded sections ofhighway need to be checked only one-fifth as often as wooded sections. The savings in labor and equipment would result from minimizing the effort of animal disposal on sections of highway where, because of the small number of woodlots located near the highway, the probability of finding vehicle-killed animals is low.

Some caution must be exercised when interpreting these results. My data was collected for only a seven month period. Measurements were not made during the spring breeding season and summer season when many young are normally killed. It is possible that because of seasonal shifts in the activity of some animal species, mortality patterns may change seasonally between habitat types along the roadsides. Allen (1939) and Haugen (1942) suggested that cottontail rabbits may shift their activity from fields to wooded areas as winter approaches. In this study, most of the rabbits killed on the highway were accosicated with wooded areas. Similar movements may occur with pheasants in anticipation of severe winter storms (Madson, 1962), such as the ones that occurred during this study. Any shift in animal activity from one habitat to another would probably result in a similar shift in animal mortality patterns on highways. A large portion of my observations were made during the fall after a heavy mid-September frost had killed much of the herbaceous cover. Animal movements toward woody cover might be expected to occur at this time. Although there was no relative shift in animal kill per mile between wooded and non-wooded sections of highway during the study, late spring and summer data would be necessary to make certain that the seasons not included in this study did not affect the results.

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