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Deer Accidents in Southern Michigan

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Leo Paul Sicuranza

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AN ECOLOGICAL STUDY OF MOTOR VEHICLE -
DEER ACCIDENTS IN SOUTHERN MICHIGAN

By

Leo Paul Sicuranza

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ABSTRACT

AN ECOLOGICAL STUDY OF MOTOR VEHICLE -
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Factors associated with motor vehicle-deer accidents on twelve historical accident areas were analyzed by use of multiple regression analysis, correlation, and a one-way analysis of variance. Regional deer populations, indicated by buck kills and deer densities on wintering areas, influenced accident rates more than did traffic volume. Old field communities on abandoned farmlands, corn, lowland vegetation, and roadside vegetation were other factors which increased accident rates.

Food plantings on state land strongly influenced deer winter concentrations, increasing local accident rates. State antlerless deer quotas were too low to effectively reduce local deer populations, and it was recommended that they be increased.

A state land classification system was modified for use in deer habitat analysis. Changes in the present accident data system kept by the Department of State Highways were also recommended.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Motor vehicle collisions with white-tailed deer (*Odocoileus virginianus*), hereafter referred to as motor vehicle - deer accidents or deer road kills, are the most serious forms of wildlife road kills that occur in the eastern and mid-western states and the southern Canadian provinces. Bashore (1978) reported that eighteen states (excluding Michigan) and four Canadian provinces listed substantial numbers of motor vehicle - deer accidents. Two reasons exist to explain the importance of deer road kills among wildlife highway mortalities. One, white-tailed deer are widespread, numerous, and well adapted to human activity, facts which often place them in contact with people and their automobiles. Two, high speed impacts with deer have severe effects on automobiles and their occupants, and often are tragic in nature (David Arnold personal communication).

Between 100,000 (Bashore 1978) and 130,000 (Puglisi *et al*. 1974) motor vehicle - deer accidents occur each year nationally causing an estimated $34.5 million in property damage, hundreds of human injuries, and even fatalities (Puglisi *et al*. 1974). Pennsylvania has had over 25,000 reported motor vehicle - deer accidents per year between 1971 and 1975 (Godshall 1977). Michigan reported close to 88,000 motor vehicle - deer accidents between 1971 and 1977, 96% of which resulted in property damage (Michigan Department of State Police 1972 to 1978). In these reported accidents, 24 people were killed, and 4,727 injured, 781 of whom required hospitalization (Michigan Department of State Police 1972 to 1978). These accidents increased 77% over this time.

Recorded accidents are actual counts, not samples, that must be regarded as underestimates of total accidents. Many deer struck on highways wander off and die undetected; no factor is added for these animals in recorded counts (Arnold 1978). Bashore (1978) surveyed a road section which had an official total of six reported deer road kills and found eight additional, uncounted deer road kills laying on the right-of-way.

The extent, number, and cost of motor vehicle - deer accidents make them a serious form of human-wildlife interaction. Hansen (1977) estimated the average cost per accident to be $730.00. At this cost, such accidents could total $12 million per year in Michigan by the 1980's. To this dollar figure must be added the intangible costs of human suffering and loss of life.

Many descriptive studies have been reported on motor vehicle - deer accidents along Interstate or other large divided highways. Since the majority of motor vehicle - deer accidents in Michigan occur on state, county and local roads, studies of accidents along these road classes are warrented. Habitat analyses done in past studies appear to have been too general; more intensive habitat analysis may reveal important information about how local environmental factors influence deer road kills. Further investigation into regional trends in deer populations and seasonal concentrations would also aid in the understanding of this problem. To these ends, the following study objectives were formed:

1. Location of areas along undivided highways in southern Michigan which have had histories of motor vehicle - deer accidents.

2. Determination of interactions between motor vehicle - deer accidents and the following factors:
   a. traffic volume
   b. time of day
   c. seasonal changes in environment
   d. deer populations (as estimated by legal firearm deer kills)
   e. winter concentrations of deer
   f. local habitat and land use variables.

3. Testing of the applicability of the Michigan Land Cover/Use Classification System (MLCUCS) for use in analysis of deer habitat in southern Michigan.

4. Development of management recommendations to reduce local rates of deer road kills.

Workers studying deer road kills in Pennsylvania have reported bimodal patterns of monthly kills with a smaller spring peak, usually in June, and a larger fall peak, October through December (Bellis and Graves 1971, Carbaugh et al. 1975, Puglisi et al. 1974). These results correspond to those reported for southern Michigan (Allen and McCullough 1976). Bashore (1978) also reported similar bimodal patterns in seasonal road kill variation for eighteen states and four Canadian provinces.

Three causes for seasonal peaks in road kills have been reported: 1. seasonal changes in vegetation, particularly those in rights-of-way planted to grasses (Bellis and Graves 1971, Carbaugh _et al_. 1975, Puglisi _et al_. 1974); 2. seasonal changes in the behavior of deer (Allen and McCullough 1976, Arnold 1978, Bashore 1978); 3. hunting pressure (Puglisi _et al_. 1974).

Green vegetation growing in rights-of-way of roads in forested regions has been reported to induce deer to cross roads resulting in increased road kills (Bellis and Graves 1971, Puglisi _et al_. 1974); however, Allen and McCullough (1976) reported that changes in vegetation in rights-of-way have little, if any, influence on seasonal deer road kill peaks in agricultural areas. A comparison between deer road kills in a forested area and in an agricultural area reported that right-of-way vegetation is a significant food source in forested regions, but is not in agricultural regions (Carbaugh _et al_. 1975). Kasul (1976) studied wildlife mortality along an Interstate highway in southern Michigan, and reported the largest number of animals were killed where the median and at least one side of the road were wooded. Kasul (1976) believed that woody vegetation in medians attracted forest species to cross roadways away from areas they might normally have crossed.

Rutting behavior is cited as the single most important factor associated with the fall peak in deer road kills (Allen and McCullough 1976, Arnold 1978, Bashore 1978, Carbaugh _et al_. 1975, Puglisi _et al_. 1974). Peak seasonal periods in deer road kills in southern Michigan contain a large proportion of males, while females are more frequently involved than males the rest of the year (Allen and McCullough 1976). Endogenous reproductive changes in bucks during the rut lead to their increased movement and vulnerability to collisions with motor vehicles (Allen and McCullough 1976, Arnold 1978, Bashore 1978).

Puglisi et al. (1974) reported that hunting pressure may have resulted in more frequent collisions of deer with motor vehicles. In Michigan, however, fewer day time accidents during hunting season were reported (Allen and McCullough 1976), suggesting that hunting pressure does not push deer out onto the roads (Arnold 1978). Hunting takes place during daylight hours, and if it did contribute to increased deer road kills, one would expect an increase of accidents during that time period.

Explanations for spring peaks in deer road kills are even less definite than are those for fall peaks. Males form an increased proportion of deer road kills in June (Allen and McCullough 1976, Puglisi et al. 1974). If changes in food sources caused increased deer road kills in the spring, one would not expect males to be more prevalent than females in the total number killed. Bashore (1978) reported that spring peaks occur in June; while early spring green ups occur in April, the month with the lowest spring kills.

Endogenous changes in male reproductive behavior and nutritional needs associated with initiation of antler development may cause males to move more, resulting in increased male deer road kills in June. Robinson et al. (1965) reported increased testes weights of males coinciding closely to antler development. This condition may cause restlessness in males, increasing their movements (Allen and McCullough 1976).

Severinghaus and Cheatum (1969) reported that yearling males are abandoned by their dams during May and June. Dispersal of yearling bucks may contribute to spring deer road kill peaks (Allen and McCullough 1976, Puglisi et al. 1974).

Bashore (1978) proposed that seasonal peaks in deer road kills were caused by increased movements associated with "residual migratory activity", an artifact of cervid evolution in response to the onset of seasonal weather changes. Deer maintain a propensity to migrate by becoming active during spring and fall, and are "primed" for movement if conditions warrant it (Bashore 1978).

Reilly and Green (1974) reported that deer road kills on a study site in the northern Lower Peninsula of Michigan exhibited one seasonal peak which occurred during February to April. The concentration of road kills in the spring was attributed to the dispersal of deer from conifer swamp yards with the onset of milder weather conditions (Reilly and Green 1974). Milder winters induced less concentrated yarding resulting in fewer spring deer road kills (Reilly and Green 1974). Meyers (1969) reported a condition similar to this in a high deer density wintering area of Colorado where 75% of the yearly road kills occurred between January and April.

Deer road kills fluctuate diurnally as a function of deer activity and traffic volume (Allen and McCullough 1976). Peak deer activity occurs from 2 hours before to 2 hours after sunset (Montgomery 1963, McCaffery and Creed 1969, Progulske and Duerre 1964, Zagata and Haugen 1974). Allen and McCullough (1976) in Michigan and Pils (1977) in Wisconsin reported the daily peak in deer road kills occurred about 2 hours after sunset. Most accidents occurred in southern Michigan between 1600 and 0200 hours (Allen and McCullough 1976). Williams (1964) reported that most accidents occurred in Colorado between 1600 and 2200 hours.

In Michigan, 63% of all reported accidents occurred at night on unlighted roads, and only 9% occurred at dawn or dusk (Table 1). The shift to eastern daylight savings time in Michigan's Lower Peninsula in 1967 may have shifted traffic volume to periods of high deer activity, resulting in increased deer road kills (Allen and McCullough 1976).

Traffic volume has an important effect upon the number of deer road kills, but the nature of this effect differs depending on how it is evaluated. The percentage of deer road kills was reported to be closely associated with traffic volume between 1800 and 0700 hours in southern Michigan (Allen and McCullough 1976). However, correlation between traffic volume and seasonal percentages of deer road kills is low (Allen and McCullough 1976, Bashore 1978). Traffic

Table 1. Data summarized from Michigan State Police reports on motor vehicle - deer accidents in Michigan, 1971 to 1977.

Number of Accidents	
Total	87,983
Fatal	21
Injured	3,788
Property Damage	84,174
Number of People	
Deaths	24
Injuries	4,727
Serious injuries	781
Road Surface	
Dry	68,714
Wet	12,735
Ice	5,892
Other	642
Light Conditions	
Daylight	17,683
Dawn or dusk	7,598
Dark/road lighted	7,490
Dark	55,001
Not stated	211
Roadway Class	
Full control[1]	6,389
U.S. routes	11,701
State routes	24,124
Local[2]	45,749

[1]Full control roads consist of Interstates and other limited access highways.

[2]Local roads consist of county, local, and town roadways.

volume is highest in the summer months, the period of lowest deer road kills (Allen and McCullough 1976). Thus, traffic volume apparently influences daily patterns of deer road kills, but not seasonal patterns.

State Police records (1972 to 1978) for motor vehicle - deer accidents in Michigan reported that 10% of deer road kills occurred on Interstate or other limited access highways; over 51% occurred on roads classified as "local roads, N.K." (N.K. means class not known). Two-lane state highways accounted for 28% of all accidents (Michigan Department of State Police 1972 to 1978). Past studies (Bellis and Graves 1971, Carbaugh _et al_. 1975, Gilbert _et al_. 1971, Goodwin and Ward 1976, Puglisi _et al_. 1974, Reilly and Green 1974, Ward 1975) have reported deer road kills solely along Interstate highways, while others (Allen and McCullough 1976, Bashore 1978) have considered deer road kills on all road classes combined. No known study reporting on deer road kills has been found that concentrates solely on two-lane highways or local roads.

Carbaugh _et al_. (1975) analyzed 212 sixty-one meter long sectors along a roadway for relationships between the number of deer seen and three general habitat types (wooded, cultivated fields, and non-cultivated fields). The number of deer seen was greater in fields than in woods, and was greatest in unharvested hay fields (Carbaugh _et al_. 1975). The number of deer seen was reported to be more influenced by vegetation types in forested areas than in agricultural areas

(Carbaugh _et_ _al_. 1975). Puglisi _et_ _al_. (1974) reported that along unfenced sections of roads, mean deer road kills per mile were higher where one side of the road was wooded and the other a field.

Allen and McCullough (1976) analyzed lengths of roadsides along sections of three highways in southern Michigan for association of three habitat classes (crops, unimproved fields, and forests) to the proportion of deer road kills. Accidents were found to have occurred in approximately the same proportion as the prevalence of each type, leading the authors to conclude that deer road kills did not concentrate about specific micro-habitats (Allen and McCullough 1976). However, Allen and McCullough (1976) did cite that deer preferred grazing on herbaceous foods in open lands, and that southern Michigan deer had a preference for agricultural crops.

STUDY AREA

Research was conducted in Michigan Depratment of Natural Resources (MDNR) Districts 9, 12, and 13, Region III (Figure 1). Twelve study sites were located along major two-lane roadways throughout Barry, Calhoun, Ionia, Jackson, Kent and Montcalm counties (Figure 2). Table 2 lists the specific location of each study site. Most of the land area of the six study counties lies within the Grand River watershed; the Rogue, Flat, Maple, Looking Glass, Red Cedar, and Thornapple rivers drain the area (Sommers 1978).

MDNR Region III consists of thirty-five Michigan counties covering 22,169 square miles (Great Lakes Basin Commission 1975). Physiography is basically rolling plains; elevation averages 1,200 to 1,400 feet above mean sea level; surface formations are inter-mixtures of glacial moraines, till plains, and outwash plains, varying from 10 to 200 feet in thickness; soils are predominately alfisols; and dominant forest types are oak (*Quercus* spp.) - hickory (*Carya* spp.) and maple (*Acer* spp.) - beech (*Fagus grandifolia*) (Sommers 1978).

The majority of Region III is well suited for farming. Mean annual precipitation is between 30 and 34 inches per year; mean annual temperature is between 46 and 48 degrees Fahrenheit, with frost free days ranging between mid-May and early

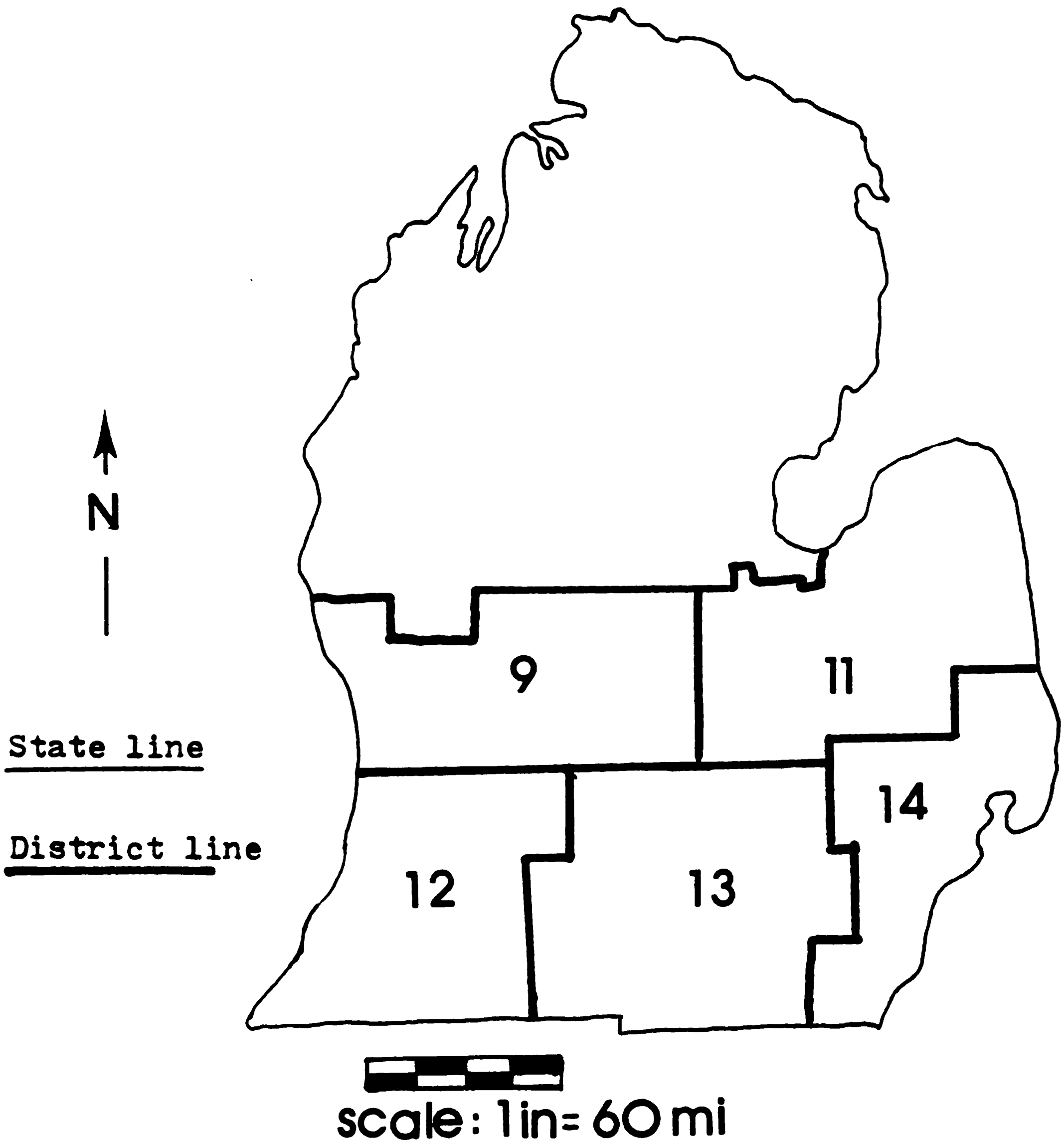

Figure 1. Michigan Department of Natural Resources districts according to number in Region III.

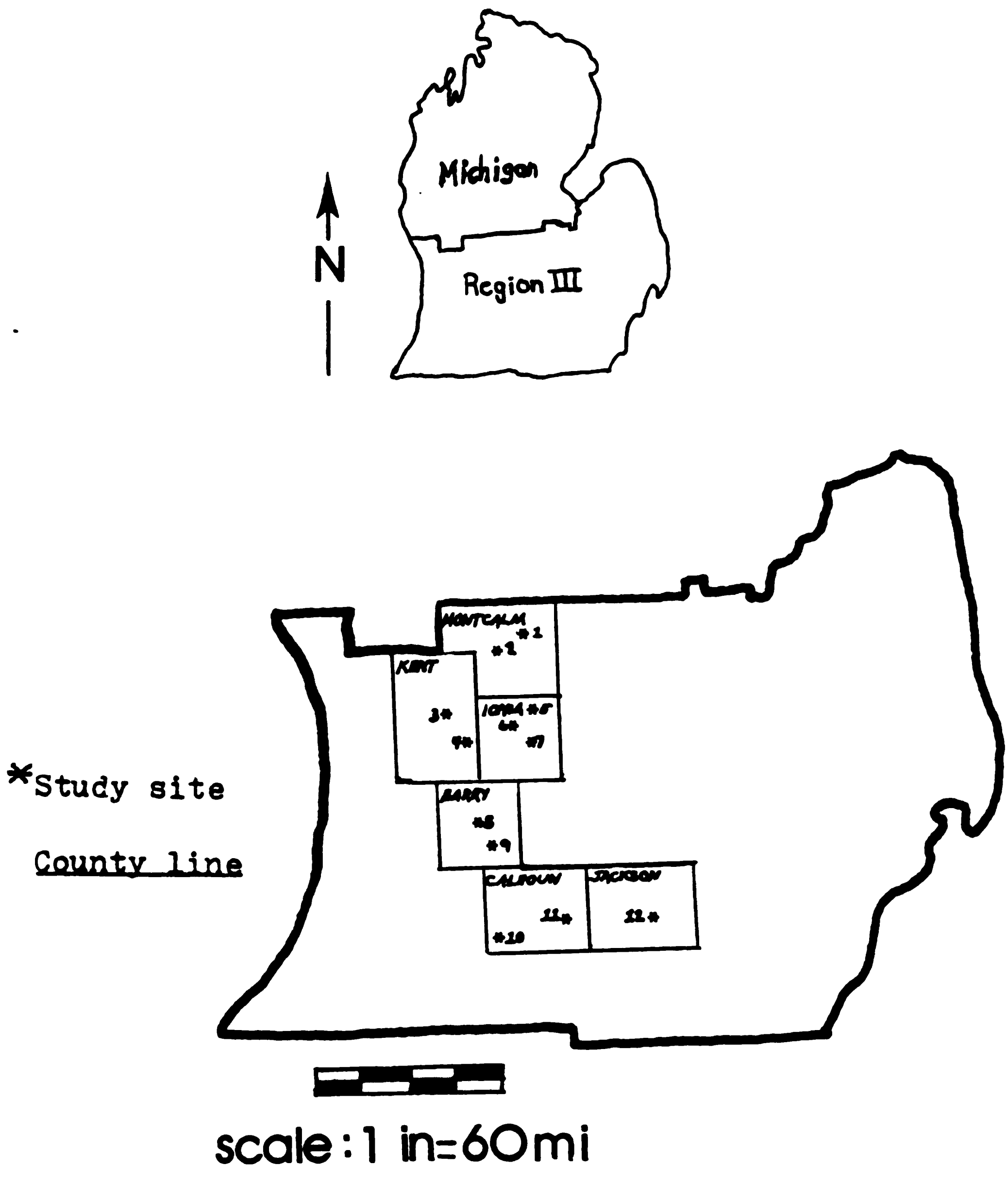

Figure 2. Locations of the twelve study sites in Michigan Department of Natural Resources Region III.

Table 2. Locations of the twelve study sites in Michigan Department of Natural Resources Region III.

Study Site	Highway	Control Section[1]	Road Portion[2]	Legal Land Description[3]
1	M-66	59051	18.23 to 19.23	W-½, Sec. 6 and 7, T.11N., R.6W.
2	M-91	59032	8.72 to 9.72	W-½, Sec. 26 and 35, T.11N., R.8W.
3	M-44	41101	1.30 to 2.30	S-½, Sec. 7 and 8, T.8N., R.10W.
4	M-21	41043	9.95 to 11.45	S-½, Sec. 4 and 5, T.6N., R.9W.
5	M-66	34033	7.58 to 9.08	W-½, Sec. 6 and 7, T.8N., R.7W.
6	M-44	34081	9.29 to 10.79	S-½, Sec. 14 and 15, T.8N., R.7W.
7	M-21	34061	10.69 to 11.69	S-½, Sec. 22 and 23, T.7N., R.7W.
8	M-37	08032	2.43 to 3.43	S-½, Sec. 3 and 4, T.3N., R.10W.
9	M-43	08011	11.69 to 13.19	Sec. 10 and 15, T.2N., R.9W.
10	M-66	13031	4.99 to 5.99	Sec. 2 and 11, T.4S., R.8W.
11	M-60	13022	8.11 to 9.61	S-½, Sec. 1 and 2, T.4S., R.5W.
12	US-127	38111	3.65 to 4.65	W-½, Sec. 7 and 18, T.4S., R.1E.

[1]Control section numbers used by the Michigan Department of State Highways to identify specific portions of roadways in the state's trunkline system.

[2]Numbers refer to mileage designations along specified control sections.

[3]Approximate locations given.

October; growing season averages about 140 days (Sommers, 1978).

Region III land use includes 49% agriculture, 16% urban, and 17% forests (Great Lakes Basin Commission 1975). Land use varies by county substantially. In the six county study area, 57% of the land is agricultural, 6% is urban, and 27% is forested (Sommers 1978). Calhoun, Jackson and Kent counties are 15% urbanized; Barry, Ionia and Montcalm counties are only 2% urbanized (Sommers 1978). Metropolitan centers exist around the Grand Rapids area, Kent County; Battle Creek, Calhoun County; and Jackson, Jackson County. Traffic densities are highest around these urban areas.

Predominant agricultural use in the six county study area is dairy farming, including corn feed production. Small grain production is also important in Barry, Calhoun and Ionia counties. Fruit and nursery crops are important in Ionia and Kent counties, and field crops are important in Montcalm. Corn was the predominant crop observed on all study sites.

Eighty-six percent of Michigan's human population resides in the southern thirty-five counties where traffic volume averages 82% of the state total (Michigan Department of State Highways 1972 to 1978). The proportion of the state's deer herd found in southern Michigan has risen from 5% in the 1960's to 25% in the 1970's (Arnold 1978). The MDNR has desired to have one million deer in Michigan by 1981 (Arnold 1978). The deer population has probably exceeded one million, however, since 1976 (David Arnold personal communication). This means that approximately 250,000 deer live in a region inhabited by six million people who drive over 25 million vehicle miles per year. Since 1971, 50% of all deer road kills in Michigan have occurred in the southern one third of the state (Michigan Department of State Police 1972 to 1978).

METHODS

Computer files of motor vehicle - deer accident records maintained by the Michigan Department of State Highways and Transportation (MDSHT), Accident Analysis Section were analyzed for each year from 1974 to 1977. Program Q/430/57 listed yearly accident data for 0.5 mile segments of control sections along the state highway trunkline system which had recorded at least two motor vehicle - deer accidents in a given year. The analytical process was analogous to placing beads on a string. Accident data were recorded for each segment for 1974 to 1977, and contiguous 0.5 mile segments with four year histories of accidents were grouped together into accident concentration sites either 1 mile or 1.5 miles in length.

Only data from Barry, Calhoun, Ionia, Jackson, Kent and Montcalm counties were analyzed since these counties have had the highest number of motor vehicle - deer accidents in Region III for recent years (Michigan Department of State Police 1972 to 1978). Twelve study sites were selected: three in Ionia County; two each in Barry, Calhoun, Kent, and Montcalm counties; and one in Jackson county. A second study site in Jackson county, located near the State Prison, was abandoned due to the impracticality of conducting field work on restricted land.

Program Q/430/57 identified accident locations to only the nearest 0.5 mile, however program Q/430/34 identified accident locations to the nearest .01 mile, enabling more specific location of accidents. This program also supplied many other useful statistics (Appendix A).

Accidents from 1974 to 1977 were tabulated for each site, and accident rates were calculated by dividing the total number of reported accidents by the estimated traffic volume for each road section. Data from standard MDSHT traffic volume surveys formed the basis for traffic volume estimates. All accident rates were adjusted for differences in traffic volume among study sites by conversion to the number of accidents per 100 million vehicle miles driven, a standard way of reporting automobile accidents (1 vehicle mile = 1 vehicle unit driven over 1 mile of road length).

MDNR, Wildlife Division District Biologists in Districts 9, 12, and 13 supplied additional information on motor vehicle - deer accidents in their districts through questionnaires (Appendix B) and personal interviews.

Statistics on legal firearm deer kills, and total vehicle miles driven were tabulated for the six county area, Region III, and the State of Michigan for the years 1971 to 1977. Correlation analysis was used to test the association of numbers of accidents to traffic volume, and to legal firearm deer kills.

Information on seventeen known deer winter concentration areas (Masek 1979) located within a 10 mile radius of any given study site was obtained from MDNR Wildlife Biologists. An index of association between winter concentration areas and accident rates on the study sites was formulated taking into account three probable factors influencing this association: 1. the number of winter concentration areas within a 10 mile radius of a given study site; 2. the density of deer (number of deer/mile^2) in each concentration area; and 3. the distance in miles of each concentration area from a given study site.

Assuming an inverse relationship exists between the distance from a concentration area to a study site and the strength of their association, the winter concentration index (WCI) value for each study site was calculated by the formula:

$$\mathrm{WCI} = \sum \frac{1}{\mathrm{Distance}_{i-j}} \cdot \mathrm{Density}_j$$

where:

$\mathrm{Distance}_{i-j}$ = the distance in miles between the i^{th} study site and the j^{th} winter concentration area

Density = the number of deer/mile^2 in the j^{th} winter concentration area.

Distances between winter concentration areas and the study sites were divided into five classes: 0 mile to 1 mile, >1 mile to ≤ 3 miles, >3 miles to ≤ 5 miles, >5 miles to ≤ 7 miles, and >7 miles to ≤ 10 miles. The mid-point value of each class was used in the calculation of the WCI values.

Correlation analysis was used to test for significant association between WCI values and accident rates on all study sites. Kendall's nonparametric test of association (Hollander and Wolfe 1973) was also used to test for this association.

Copies of black and white aerial photos (RF 1:660) of individual township sections (1 mile^2) obtained from county Agricultural Stabilization and Conservation Service (ASCS) offices were used to form composite maps of study sites and adjacent areas. The photos were quite dated; ranging from 11 to 15 years old. Vegetative and land use analyses based on photos much older than 5 years can be unreliable and field checking of changes in land use and cover types was recommended (Kyle Kittleson personal communication). The amount of field work required to update the photos was proportional to their age. Crops changed on a yearly basis, and over 10 to 15 years, native vegetative communities changed seral stages.

Field work was done between September 15 and November 1, 1978. Identification of cover types and land use types was facilatated during this period since most crops were mature and still unharvested in the fields; and differences in foliage colors existed between hardwoods and conifers, and between upland types and lowland types.

Study sites were identified on the photo maps by correlation with MDNR county maps and MDSHT control section maps. Final locations were determined in the field by measuring mileage along designated control sections by automobile odometer.

A reconnaissance of each area was made from automobile noting general cover types, land uses, cultural features, drainage patterns, and topography. Measurements were recorded of the width of each road surface, each right-of-way (ROW), and the amount of woody cover along the side of each ROW.

Cover and land use units were classified and mapped on the photos for 1 mile back from the side of the ROW for the length of each study site. Classification followed criteria outlined in the Michigan Land Cover/Use Classification System (MLCUCS), a standarized four level hierarchial land inventory system for describing active land use and vegetative cover in Michigan (Michigan Department of Natural Resources 1976).

Where most of the land was in crops, classification was done by an observer from an automobile, or from along a roadside, conducting an occular survey aided by use of binoculars. Two-track roads were travelled to gain access to areas not visible from state or county roads. Classification of some forest types was done from automobile; however, where no roads were present, reconnaissance was made on foot.

Information from local residents aided in the classification of areas difficult to reach, like swamps, or large tracts of private land. Residents were questioned about their knowledge of deer and deer road kills in their areas.

The 1 mile distance back from each side of the ROW was subdivided into three sample units. The first unit extended ¼ mile back on each side of the ROW (total width = ½ mile). The second unit extended back to ½ mile on each side of the ROW (total width = 1 mile). The third unit extended 1 mile back from each side of the ROW (total width = 2 miles).

Within the three different sampling widths habitat data was organized to test which distance back from each ROW would result in the most efficient sample area.

Acerage of each type was estimated by use of a dot grid and then converted to proportions of each sample area. A diversity index (DI) was calculated for each sample area by the following formula (MacArthur and MacArthur 1961):

$$DI = -\sum p_i \cdot \log_e p_i$$

where, for this study:

p_i = the proportion of each type in a given sample area.

The above formula was used to calculate index values for each area which accounted for the number of types in an area and their eveness. For areas with equal numbers of types, the areas with more eveness had higher DI values.

Habitat data were coded and keypunched on data cards for computer analysis. Variables coded for each study area were: 1. the calculated accident rate, or kill rate (KRATE); 2. the measured proportions of land use or cover types; 3. the calculated DI; and 4. the measured percent of woody cover along each roadside (PCR). Step-wise regression analysis was used to test the association between the dependent variable (KRATE) with the multiple independent variables (land use/cover types, DI, and PCR).

Dominant vegetative or land use types for 0.5 mile segments of each study site were classified in order to examine what effect differences in cover types from one side of a road to the other had on accident rates. For this analysis, classification was done on the basis of whether the roadside of a segment was dominated by fields, crops, or woods. Over all 0.5 mile segments (n = 30) five groups of crossing types were recorded and mean accident rates were calculated for each. A one-way analysis of variance (ANOVA) test of significant differences between the five group means was used. Tukey's multicomparison test (Steel and Torrie 1960) was used to examine which pairs of means were significantly different.

RESULTS

MDSHT motor vehicle - deer accident record files were determined to be the most reliable source of accident information available in the state. Program Q/430/34 gave specific accident data for individual accidents, including locations, not obtainable anywhere else but on individual accident reports. MDSHT accident data files contain accident reports from all state agencies collected together by the Michigan Department of State Police (Lt. Warder personal communication).

Deer road kills could be located only to township sections with reports from MDNR Conservation Officers. These reports were used to construct maps of deer road kills for each county that had a distainct "shot gun" pattern. Specific location of accidents closer than 1 square mile from these maps was impractical.

Interviews with MDNR District Wildlife Biologists in Districts 9, 12, and 13 revealed that MDNR field personnel are aware of the general problem of deer road kills, but that they lacked specific information about them. District Wildlife Biologists stated that reported accidents probably represented 65% to 90% of all accidents and that few accidents went unreported.

The three District Wildlife Biologists interviewed believed that deer road kills occurred over fairly long sections of roads in areas where high local populations of deer moved from wooded cover to feeding sites. The interspersion of cover, crops and open brushland were cited as factors influencing deer road kills (Ralph Anderson, Wilmur Bartels, and Robert Hess personal communication). The wildlife biologists reported that high winter concentrations of deer attracted to food patch plantings on State Game or Recreation areas may increase local rates of motor vehicle - deer accidents. A similar situation is reported to exist near the Rose Lake Wildlife Research Station in Clinton County, southern Michigan (Glenn Belyea personal communication).

Wildlife Biologist Wilmur Bartels of District 9 and Wildlife Biologist Robert Hess of District 12 felt that the number of road kills in their districts was increasing, while District 13 Wildlife Biologist Ralph Anderson felt that the number of deer road kills was stabilized in his district. All wildlife biologists reported that numbers of deer road kills rose in response to increases in traffic volume and local deer population levels. Antlerless deer quotas were thought to be adaquate, and antlerless deer kills were considered an effective means of controlling local deer numbers and reducing deer road kills. However, all wildlife biologists reported that administration of antlerless deer quotas was very difficult in their districts since most of the deer range is on private land.

Data summarized from MDSHT files for each study site showed that 86% of motor vehicle - deer accidents occurred in clear weather; 80% occurred on dry road surfaces; and 90% involved no special circumstances. This information essentially agrees with state wide data on motor vehicle - deer accidents (Table 1).

Traffic volume (Table 3) was found to be positively correlated to numbers of deer road kills on a state wide and regional basis for 1971 to 1977. The state wide correlation coefficient is $r = .839$ (significant at $\alpha = .05$, $n = 7$), and the correlation coefficient for Region III is $r = .798$ (significant at $\alpha = .05$, $n = 7$). Traffic volume was found not to be strongly correlated to numbers of deer road kills for the six county study area. The correlation coefficient for the study area is $r = .380$ (not significant at $\alpha = .05$, $n = 7$).

Table 3. Numbers of deer road kills, legal firearm deer kills, and traffic volume for Michigan, Region III and the six county study area, 1971 to 1977.

	State wide	Region III	Six County Area
Road kills	87,982	45,777	16,376
Buck kills	533,910	106,010	42,320
Antlerless kills	91,941	66,160	13,450
Vehicle miles[1]	174,454	168,483	20,414

[1]Expressed in units of 100 million.

Buck kills (Table 3) were used as an index of deer population levels since they are the only statistics available for such purposes in Region III (Lawrence Ryel personal communication). Yearly buck kills are strongly correlated to numbers of deer road kills on a state wide, regional or study area basis. The correlation coefficient for the state is r = .971 (significant at α = .05, n = 7); for Region III, r = .933 (significant at α = .05, n = 7); and for the study area, r = .971 (significant at α = .05, n = 7).

A correlation of antlerless deer kills (Table 3) with numbers of deer road kills was used to examine the effectiveness of antlerless kills in reducing motor vehicle - deer accidents. Antlerless kills were not strongly correlated to road kills on either a state wide, regional, or study area basis. The correlation coefficient for the state is r = .257 (not significant at α = .05, n = 7); for Region III, r = .466 (not significant at α = .05, n = 7); and for the study area, r = .551 (not significant at α = .05, n = 7).

Numbers of motor vehicle - deer accidents (n = 271) over the twelve study sites displayed a distinct seasonal pattern (Figure 3). Over 57% of all accidents occurred between October and December; 29% occurred in November alone. The lowest percentage of accidents occurred between June and September (9%). July had the lowest percentage of accidents of any month (1.5%). Thirty-four percent of all accidents occurred between January and May.

Motor vehicle - deer accidents varied hourly in a consistent manner over the four seasons of the years between 1974 and 1977 (Figure 4). The majority (51%) of all accidents

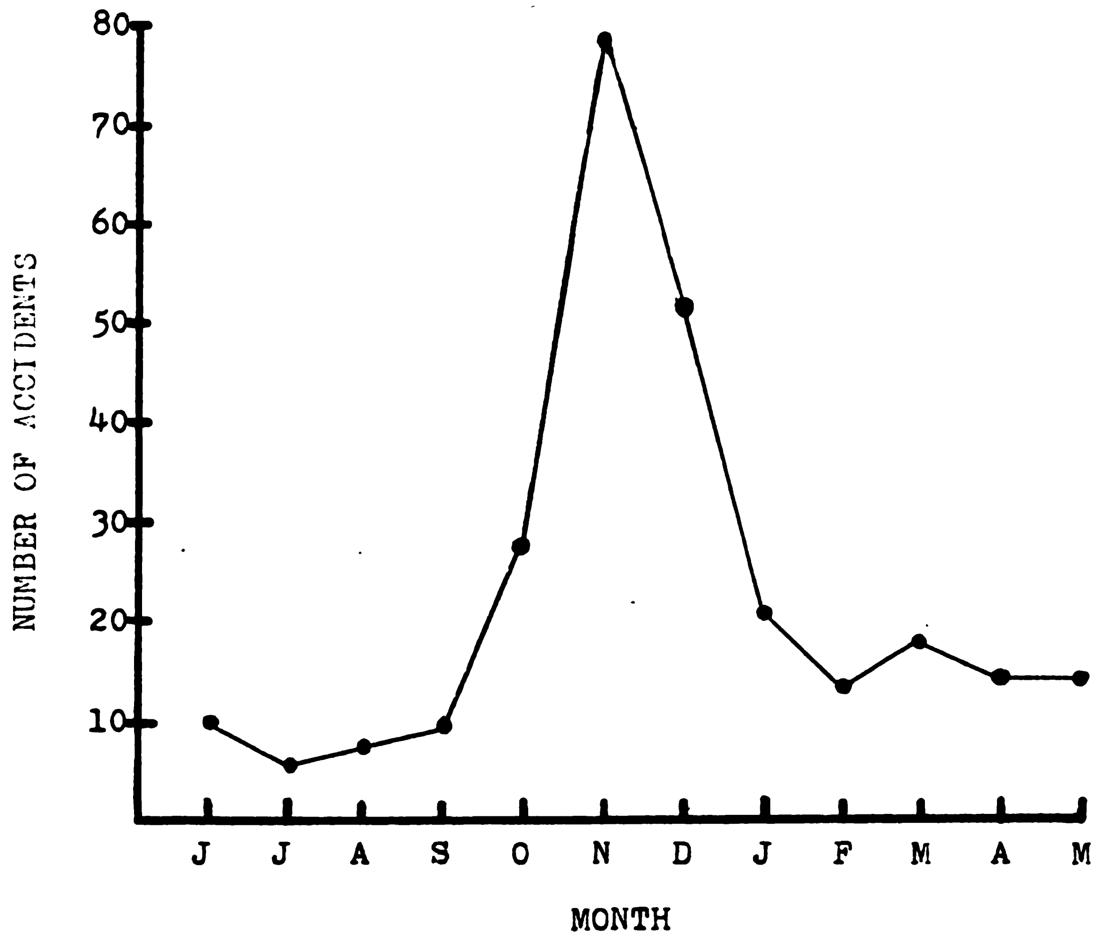

Figure 3. Monthly distribution of motor vehicle - deer accidents on twelve study sites in southern Michigan, 1974 to 1977.

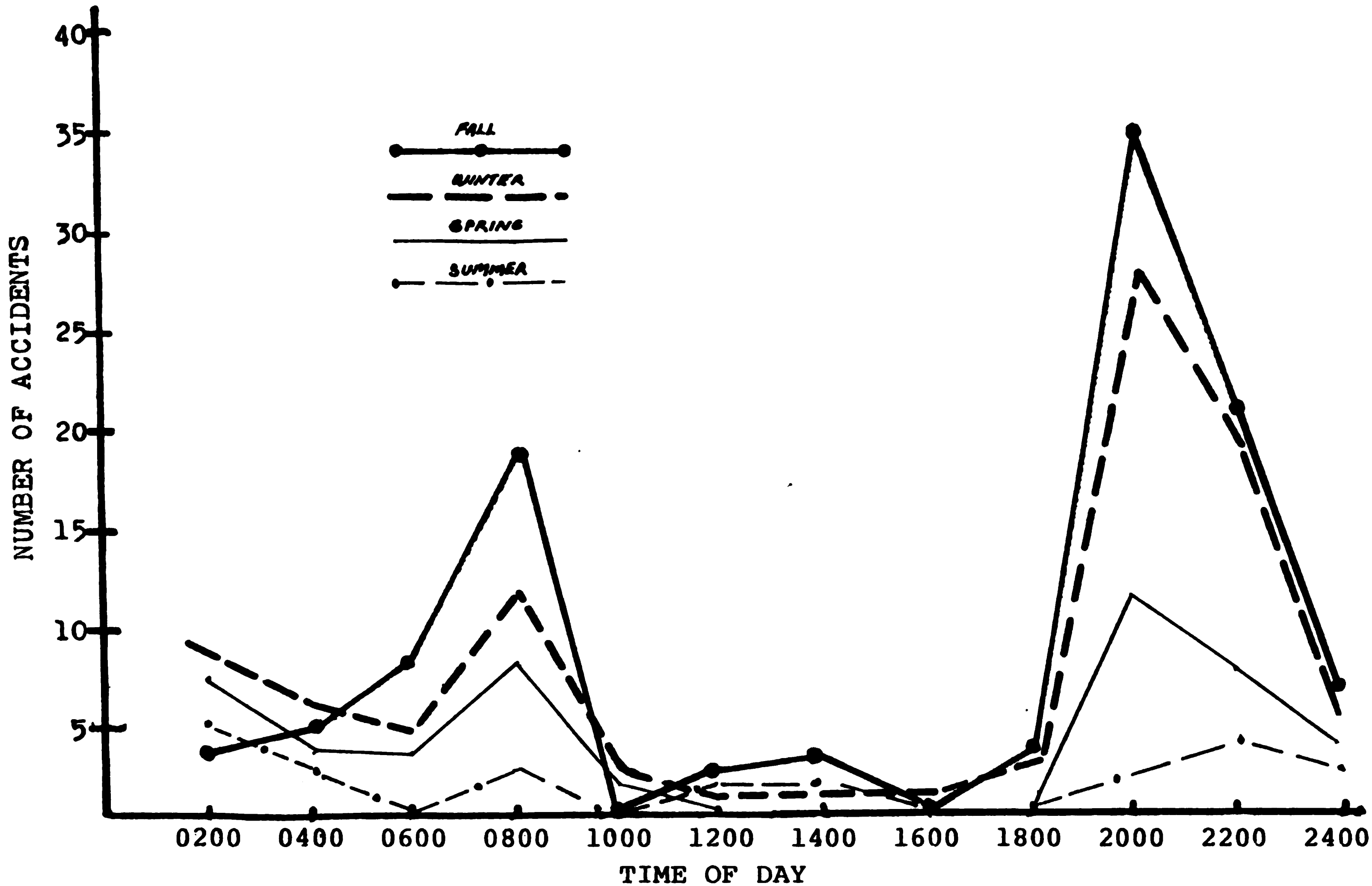

Figure 4. Hourly distribution of motor vehicle - deer accidents by season on twelve study sites in southern Michigan, 1974 to 1977.

occurred between 1800 and 2400 hours. A smaller daily peak (22%) occurred between 0600 and 1800 hours.

A reconnaissance of 0.5 mile road segments (n = 30) over all twelve study sites revealed crossing areas could be classified into five types based on the changes in dominant cover from one side of the road to the other. A one-way ANOVA (Table 4) demonstrated that significant differences exist in the mean accident rates of the five crossing types due to changes in dominant cover (significant at $\alpha = .05$, n = 30). Tukey's multiple comparison test of significant differences between means (Steele and Torrie 1960) demonstrated that the mean accident rates were significantly greater where cover changed from field to crops or from field to woods than where cover was unchanged from field to field or woods to woods (Table 5).

Table 4. One-way analysis of variance in mean accident rates due to differences in deer road crossings along thirty 0.5 mile road segments in southern Michigan, 1974 to 1977.

Source	df	SS	MS	F
Crossing Types	4	3784458.6	946114.7	23.76*
Error	25	995876.8	39835.1	
Total	29	4780335.4		

*Significant at $\alpha = .05$ level

WCI values indicate the strength of the association of accident rates on each study site to nearby winter concentration areas. The range of WCI values indicates an overall trend and does not show a precise relationship between areas. Correlation between WCI values (Table 6) and accident rates was strong, $r = .835$ (significant at $\alpha = .05$, $n = 12$). Nine of the twelve study areas were within 10 miles of deer winter concentration areas. Ten of seventeen winter concentration areas studied occurred on or near ($<$ 1 mile) State Game or Recreation areas. Peak deer concentrations are reported to occur between December and March; timing is influenced by weather severity (Masek 1979). Kendall's nonparametric test for independence (Hollander and Wolfe 1973) showed that winter concentration index values are strongly correlated to accident rates ($\bar{\tau} = .67$, significant at $\alpha = .05$, $n = 12$).

Table 5. Types of deer road crossings and their mean accident rates along thirty 0.5 mile road segments in southern Michigan, 1974 to 1977.

Crossing Types	Field to Crops	Field to Woods	Crops to Woods	Field to Field	Woods to Woods
Mean Accident Rate[1]	467.7	430.6	385.7	251.7	244.8

Means not underscored by the same line are significantly different at $\alpha = .05$ level according to Tukey's test procedure.

[1]Rate is expressed as the number of accidents per 100 million vehicle miles.

No significant improvement in R^2 values was obtained when habitat variables further than 0.25 miles back from both sides of the ROW were used in the analysis, indicating that most of

Table 6. Relationship between motor vehicle - deer accident rates on twelve study sites with deer winter concentration areas and state land in southern Michigan.

Site No.	Accident[1] Rate	No. of Winter Concentration Areas[2]	WCI[3]	Nearby State Land
1	396.5	2	25	Vestburg SGA[4] Stanton SGA
2	384.3	1	50	Langston SGA
3	377.8	2	11	Lowell SGA
4	200.3	2	31	Lowell SGA
5	439.6	2	119	Flat River SGA Ionia RA[5]
6	583.7	2	119	Flat River SGA Ionia RA
7	430.9	1	75	Ionia RA
8	428.5	2	108	Middleville SGA
9	628.1	2	153	Barry SGA
10	211.1	2	14	-
11	302.7	2	30	-
12	184.6	2	21	-

[1]Accident rates expressed in number of accidents per 100 million vehicle miles.

[2]Located within 10 miles of the study area.

[3]Winter Concentration Index values.

[4]SGA = State Game Area

[5]RA = Recreation Area

the variation in deer road kills due to regression with habitat variables is accounted for within this area.

Field mapping of cover and land use types over all sample areas resulted in the identification of twenty-five MLCUCS types (Table 7). Initial regression analysis using all twenty-five variables resulted in very low R^2 values. Significant improvement in R^2 values was obtained when the twenty-five MLCUCS types were grouped into eight ecological or land use associations (Table 8). Use of DI and PCR values for each study site in the analysis added to the R^2 value, indicating that these two variables aided in accounting for variation in accident rates due to regression with habitat variables; therefore, they were retained for use in regression analysis along with the eight type associations.

Results of the step-wise regression analysis program (Appendix C) are presented in Table 9. Ten steps were used to fit ten variables into the regression model, essentially "over fitting" the data to the model (Stanley Zarnoch personal communication). A plot of the change in R^2 and the change in the mean square residual terms against the number of variables entered into the analysis indicated that the R^2 value at step three could be considered better than other values since beyond this step, the error term increased significantly.

The regression coefficient (R^2) equaled .684 at step three in the analysis, and three interactions between variables accounted for this value. The interactions, including the transformed variables formed the following model:

$$\hat{Y} = B_0 + B_1X_1 + B_2X_2 + B_3X_3$$

Table 7. List of Michigan Land Cover/Use Classification System codes used in mapping land use and cover type units on twelve study sites in southern Michigan.

Code No.	Description
113	residential - single family and duplex
126	urban - institutional
193	open - outdoor recreation
2111	croplands - corn
2119	croplands - other row crops
212	rotation, permanent pastures, or hay
221	fruit orchards
311	upland herbaceous rangelands
312	lowland herbaceous rangelands
321	upland shrub range lands
411	broad leafed forests - upland hardwoods
412	broad leafed forests - aspen, birch
413	broad leafed forests - lowland hardwoods
421	upland coniferous forests
433	lowland hardwoods and conifers
511	small streams and waterways
512	medium streams and waterways
513	rivers
522	ponds
524	small lakes
525	medium lakes
526	medium lakes
534	medium reservoirs
612	shrub swamps - forested wetlands
623	marshes - nonforested wetlands

where:

$$X_1 = Z_1 \cdot \ln Z_2$$

$$X_2 = Z_3 \sqrt{Z_4}$$

$$X_3 = Z_3 \sqrt{Z_5}$$

and

Z_1 = the proportion of corn

Z_2 = the proportion of bodies of water

Z_3 = the proportion of early seral communities

Z_4 = the proportion of mature upland cover types

Z_5 = the percentage of woody cover along a roadside.

Table 8. List of habitat types used in regression analysis resulting from groupings of original Michigan Land Cover/Use Classification System codes mapped.

Type (Association) Number	MLCUCS Codes Included	Description
Type 1	113, 126, 193	human habitation
Type 2	2111	corn
Type 3	2119, 212	agricultural fields
Type 4	221	fruit orchards
Type 5	312, 413, 433, 612, 623	low/wet lands
Type 6	311, 321, 412	early upland successional types
Type 7	411, 421, 431	mature upland cover types
Type 8	521, 522, 524, 513, 525, 534	bodies of water

Table 9. Summary table of results from the computerized step-wise regression analysis used to test the association between habitat variables and rates of motor vehicle - deer accidents on twelve study sites in southern Michigan.

ROAD KILL REGRESSIONS 05/02/79 SPSS V7.0 .11.30.23. PAGE 15

FILE [illegible] (CREATION DATE = 05/02/79)

. . . . M U L T I P L E R E G R E S S I O N . . . .

DEPENDENT VARIABLE.. KRATE

S U M M A R Y T A B L E

STEP[1]	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	IA3[2]		4.25565	.066	.54637	.29852	.29852	-.54637	4.25565	.066
2	IA7[3]		5.37008	.046	.74878	.56066	.26214	.27155	5.74275	.025
3	IA10[4]		3.10834	.116	.82680	.68360	.12293	.00625	5.76147	.021
4	UI		5.79315	.047	.90933	.82688	.14328	-.18411	8.35836	.008
5	SHTYPE7		.72258	.428	.91950	.84548	.01861	-.28335	6.56620	.020
6	IA1[illegible]		.86165	.396	.93177	.86820	.02271	-.34717	5.48927	.041
7	IA1[illegible]		7.94541	.048	.97768	.95587	.08767	.43541	12.37590	.014
8	IA[illegible]		3.60759	.154	.98993	.97996	.02410	.04107	18.33921	.018
9	IA1		11.24359	.079	.99849	.99697	.01701	.02068	73.21283	.014
10	IA11		44.99335	.094	.99997	.99993	.00296	-.15683	1519.78568	.020

[1]Interpretation of results is limited to step 3 of the analysis.

[2]IA3 = the interaction between the proportion of corn and of bodies of water in an area.

[3]IA7 = the interaction between the proportion of early successional associations and of mature uplands in an area.

[4]IA10 = the interaction between the proportion of early successional associations and the percentage of woody cover along a ROW.

DISCUSSION

Until the development of the MDSHT computerized accident record files, collection of deer road kill data was extremely difficult. Allen and McCullough (1976) had to analyze over 2500 accident reports obtained from the Michigan State Police in order to collect accident data for their study. This means of data collection obviously must have been very tedious, explaining possibly, why data for only two years (1966 and 1967) were collected.

Attempts to collect counts of wildlife road kills through field investigations can also be difficult. Kasul (1976) studied wildlife mortality along a 15.5 mile section of Interstate 96 in Ingham County, Michigan. Kasul (1976) reported many worthwhile results, but limitation of the study to one site, somewhat limited its applicability to other areas. A researcher may collect little or no data on deer road kills when he monitors only one location over time. Kasul (1976) reported six deer road kills on a study site between August 20, 1975 and March 15, 1976, and his results were mainly directed to small and medium sized mammals and birds (Kasul 1976).

Data from MDSHT computerized accident record files, allowed identification of motor vehicle - deer accident concentration areas on a regional basis. This process reduced the time necessary to locate study areas and allowed the results of the study to be applicable to a wide area of Michigan.

The process of searching the MDSHT files was, however, a lengthy task, a fact which may still deter some researchers from using them as a data source. Caltrans Environmental Branch (undated) reported that a computerized file search system aided in the location of severe accident areas ("Hot Spots") on a regional basis. The development of such a file search system for use with MDSHT accident record files would reduce the effort necessary to locate accident concentration areas and increase the accuracy of data collection.

The use of aerial photos appears to be the only practical way to map cover and land use types for analysis of white-tailed deer habitat in agricultural regions like southern Michigan. Composite aerial photos gave the proper perspective of the scale on which work needed to be carried out, and they formed a workable base for field mapping.

Ocular surveys and other reconnaissance methods were adequate for habitat mapping of large agricultural areas. In southern Michigan no land units were found to be truely inaccessible, a fact which allowed for complete mapping coverage in a relatively fast and efficient manner. Information on land use history from local residents supplemented field mapping.

Use of the MLCUCS facilitated consistent classification of land units since type designations were clearly and logically defined. The MLCUCS was specifically developed for use in Michigan, and MLCUCS type codes can be of use to various state agencies. Presently, the Planning and Environmental sections of the MDSHT use the MLCUCS for type mapping of land units in Michigan.

The MLCUCS was designed to allow expansion of type codes beyond the four levels currently used. For example, Davis et al. (1978) proposed expansion of the MLCUCS to include references to soil associations, drainage regimes, wildlife species, or endangered and threatened species as an aid for highway personnel to determine potential and actual impacts of highway construction.

Results of this study showed that the MLCUCs requires modification for its use in analysis of white-tailed deer habitat. Results of regression analysis of motor vehicle - deer accident rates with habitat variables involving use of twenty-five MLCUCS land types (Table 7) indicated that MLCUCS typing criteria were too specific for describing deer habitat. The improvement in R^2 values obtained when land types were grouped into ecological associations (Table 8) before their use in analysis, indicated that a more general form of habitat classification could have been used.

The MLCUCS codes could be modified by adding a fifth digit to them, indicating their inclusion in particular ecological associations. For example, MLCUCS type code 4333 (lowland hardwoods with coniferous associations, red maple predominates) could be expanded to 43335, where the "5" would designate the inclusion of this type into the low/wetland association. By use of an expanded coding system, a researcher could map an area, and obtain information on white-tailed deer habitat, while preserving the basic MLCUCS codes for use by other interested parties. In this way, duplication of field work could be reduced among the various individuals, groups, and state agencies concerned with land and wildlife in Michigan.

In Michigan it is accepted that increased vehicular traffic in areas of high deer populations will naturally result in more deer road kills. Arnold (1978) stated that the motoring public accepts deer on the state's roadways as part of the normal scene. As both the number of deer and the number of miles driven by motorists have risen in Michigan, the number of deer road kills has climbed higher year after year. Deer population levels and traffic volume clearly affect deer road kills, but their role in determining the number of deer road kills differ.

In southern Michigan, buck kills are a less reliable population index than they are in the more northern parts of the state. One is forced, however, to use buck kills as a population index for southern Michigan deer since no other estimates are available.

Arnold (1978) reported that annual deer road kills in northern Michigan were more closely correlated to traffic volume than to yearly buck kills, although they were strongly related to both. Correlation analysis of data used in this study for the six county area indicated that yearly deer road kills were more strongly associated to buck kills ($r = .971$, significant at $\alpha = .05$, $n = 7$) than to traffic volume ($r = .380$, not significant at $\alpha = .05$, $n = 7$). The later correlation results suggest that regional deer population levels were a more important influence on rates of deer road kills than was traffic volume.

This situation can be explained by the fact that deer populations in the study area have grown much faster than has traffic volume. Arnold (1978) reported that in southern Michigan during the 1960's, the number of deer road kills increased 430%, and traffic volume only 36%. Furthermore, traffic volume was concentrated largely in the eastern region of southern Michigan (Michigan Department of State Highways and Transportation 1972 to 1978) while the highest densities of deer were found in the west-central part of Region III.

The results of this study show that deer populations influenced deer road kills on a regional basis, and on a local basis. However, developing an index of deer populations for local areas is difficult. Masek (1979) suggested the use of aerial censuses of winter concentration areas, noting counts of trails and signs of foraging as indices of deer population trends in southern Michigan. Although this method needs to be tested, it may be sound since southern Michigan deer are really observable only when they group on wintering areas.

Assuming deer densities on wintering areas reflected local population trends, I examined what effects winter concentration areas might have had on the rates of deer road kills on the study areas. The WCI values were formulated in an attempt to quantify three variables which appeared to have influenced the relationship between deer densities on wintering areas and rates of deer road kills on the study sites. The three variables chosen to calculate the WCI values (the number of deer wintering areas within 10 miles of the study sites, the distance between the wintering areas and the study sites, and the densities of deer on the wintering areas) may not be the only variables that explained this relationship, but they were reasonable choices and reflected the general nature of this relationship.

The strong correlation between the WCI values and the rates of deer road kills on the study sites ($r = .835$, significant at $\alpha = .05$, $n = 12$) indicates that local deer population levels influenced deer road kills. The results of Kendall's nonparametric test of association (Hollander and Wolfe 1973) also showed that this association was strong and positive ($\bar{\tau} = .76$, significant at $\alpha = .05$, $n = 12$), and increased the confidence with which this relationship may be stated to exist. These statistical results agreed with what MDNR District Wildlife Biologists believed to be the relationship between deer road kills and winter concentration densities of deer.

The relationship of wintering areas to deer road kills in southern Michigan is different than that which was reported for northern Michigan. Reilly and Green (1974) reported that most deer road kills in northern Michigan occurred in the spring months following the dispersal of deer from the winter yarding areas. No such sharp spring peak existed on the areas studied, however, spring highway mortality of deer on the study areas was 36% of the total. This figure is higher than the spring rate reported by Allen and McCullough (1976) for southern Michigan. The higher spring rate of deer road kills on the study areas may have resulted from the dispersal of deer from their wintering areas, although this hypothesis needs to be tested before a definite statement can be made about it. More information about when deer leave wintering areas, how far they travel, and where they travel to needs to be collected to better understand this relationship.

The seasonal distribution of deer road kills that occurred on the study areas conformed to that reported for southern Michigan by Allen and McCullough (1976). Fifty-six percent of all deer road kills occurred between October and December. Therefore, densities of deer on wintering areas may have increased spring rates of deer road kills slightly, but did not cause a change in their overall yearly pattern.

Deer winter food sources (corn) planted by the MDNR had a significant effect in raising levels of local populations of deer, as these levels are reflected in deer wintering densities and deer road kills. Ten of seventeen known wintering areas studied were on or within 1 mile of State Game or Recreation areas. The goal of the MDNR to have a large number of deer in the state can not be accomplished, apparently, without increased motor vehicle - deer collisions on the state's roads. Whether the social costs of having a large number of deer in Michigan are offset by the benefits is not a decision that can be made by the MDNR alone. As long as people in Michigan indicate that they want more deer, the MDNR will probably act to support the deer herd with food sources to supplement their winter diet.

If it is ever decided by people in Michigan to reduce the number of deer in the state, the only sound management method would be to increase the antlerless deer kill. Presently, antlerless deer quotas are set partly to help reduce motor vehicle - deer accidents in local areas. However, antlerless kills have run far behind the growth of the deer herd. Antlerless deer kills in the study area were weakly correlated to the number of deer road kills ($r = .551$, not significant at $\alpha = .05$, $n = 7$), indicating that they have not kept pace with the increase of motor vehicle - deer accidents. Antlerless deer kills need to be drastically increased if they are to be effective in reducing rates of motor vehicle - deer collisions.

The diurnal pattern of deer road kills on the study sites (Figure 4) indicates that deer were more active at night. Fifty-one percent of all accidents ($n = 271$) occurred between 1800 and 2400 hours, the time of peak deer activity. The peak in deer road kills shifted to later in the evening during the summer months (Figure 4), reflecting the increased length of daylight hours for that time of year. Traffic volumes reached peak levels during this time period (Allen and McCullough 1976) and the evening peak in deer road kills resulted from the interaction between increased deer activity and heavy volumes of traffic.

Local land use and cover types affected the rate of deer road kills significantly on the study sites. Results of step-wise regression analysis (Table 9) indicate that the proportions of corn, early successional associations, mature upland hardwoods and bodies of water, together with the percentage of woody cover along a ROW interacted to affect rates of deer road kills in local areas.

Three interactions regressed with rates of deer road kills resulted in a R^2 value equal to 0.6836 (Table 9). The order that the variables were entered into the regression equation indicated their relative contributions to explaining variation in deer road kills.

The first interaction entered (IA3) involves the proportion of corn with the proportion of bodies of water (ponds, lakes, or large rivers) in an area. The importance of the bodies of water is probably more an indication of the effect of the presence of associated lowland vegetation, and not the presence of water itself. Deer utilized lowland vegetation for cover and for food. Lowland vegetation was dense, providing excellent concealment. Some highly preferred browse species such as silky dogwood (*Cornus amomura*), red-osier dogwood (*Cornus stolonifera*), and red maple (*Acer rubrum*) were found in the lowland areas, providing good food sources. Furthermore, lowlying areas near water were often the only areas left undeveloped in agricultural regions due, in part, to difficulties associated with operating heavy equipment on poorly drained soils.

Four of the twelve study sites had bodies of water on them. Mean percentage of the areas occupied by the bodies of water was 8%, and the mean percentage of corn present on these areas was 10%. Interspersion of these two types was also an important factor affecting deer road kills. Corn was found in these areas in lowlying areas next to rivers, ponds, or lakes. Study site No. 4, typical of these four sites is located along Route M-21 in Kent County in an area where corn was planted in a lowlying flood plain next to the Grand River. Cornfields bordered vegetation growing right on the banks of the river, and small wooded swamps were interspersed among the fields of corn.

The heavy use of corn as a food source by white-tailed deer in agricultural areas is well documented in the literature. Masek (1979) reviewed literature on this subject and reported that corn is ranked as the number one food source for deer in agricultural areas during the winter months. A linear relationship existed between corn and deer population density, suggesting that it was a major factor in the selection of areas of winter concentration (Masek 1979). Corn may influence deer population levels during other times of the year, especially when it occurs in close proximity to thick lowland cover and good browse.

Upland communities occurred on the opposite sides of the roadways from the corn and wetland types on the four study sites. One may assume that many deer were struck as they crossed the roadways while moving from upland to cultivated areas. The mean motor vehicle - deer accident rate for these four sites was 408.7 per 100 million vehicle miles, somewhat higher than the mean average motor vehicle - deer accident rate for all twelve sites (380.7 per 100 million vehicle miles). Study site No. 9 had the highest motor vehicle - deer accident rate of all the study sites (628.1 per 100 million vehicle miles). This site is located along Route M-43 in Barry County where the road passes through an area where lowland and upland cover types are interspersed. Long Lake is located near the highway, and many other lakes, ponds, and marshes are close to the area.

The two interactions between habitat variables brought into the regression analysis next involved the proportion of early successional associations in an area, one with the proportion of mature upland types, and the other, with the percentage of woody cover along a ROW.

Early successional associations used in the regression analysis (Table 8) consisted of mixed and pure stands of aspen (<u>Populus</u> spp.), birch (<u>Betual</u> spp.) and both herbaceous and shrubby old field vegetation. The definition of "early" successional associations used was broad and actually included mid-seral stage cover types as well as pioneer cover types. The main criteria used to define this association was that it would be succeeded by other seral stages of vegetation if left to follow the natural ecological changes that could be expected to occur in southern Michigan over time. This association was structured such that much of the vegetation was within or near the reach of deer and it is differentiated from mature upland communities by a lack of a tall, dense overstory and sparse understory.

When vegetative communities grow beyond early and mid-seral stages, white-tailed deer habitat declines, as has been the case for Michigan's Upper Peninsula (Jenkins and Bartlett 1959). On the other hand, abandoned farmland reverts to native vegetative cover types relatively quickly, providing improved deer habitat and increasing deer populations (Arnold 1978).

A comparison among four of the counties sampled revealed some interesting results. Jackson and Calhoun counties averaged 42% of sample areas in row crops, and 18% in early successional associations. Barry and Ionia counties averaged 29% of sample areas in row crops, and 31% in early successional associations. Furthermore, much of the early successional associations mapped in Ionia and Barry counties were represented as actively cultivated fields on old ASCS photos, indicating abandonment of farm land in these two counties since the photos were taken. The mean motor vehicle - deer accident rate for Jackson and Calhoun counties was 232.8 per 100 million vehicle miles, while the mean accident rate for Barry and Ionia counties was 502.1 per 100 million vehicle miles. It appears that as the proportion of farmland decreased and the proportion of early successional associations increased, deer road kills increased in a dramatic rate.

Results of a reconnaissance of dominant cover types for 0.5 mile road crossing areas (n = 30) also indicated that early successional associations had an important influence on rates of deer road kills. Motor vehicle - deer accident rates were significantly higher where cover changed from old fields (non-cultivated) to crops or woods than where cover remained unchanged (Table 4). This result indicated that the relative position of cover types to the roadway influenced deer road kills.

The effect of old fields upon the variation in mean motor vehicle - deer accident rates indicates that the presence of early seral stages has increased deer road kills. This result supports the result of the step-wise regression analysis which identified a significant relationship between early successional associations and rates of deer road kills.

Woody cover along a ROW provides concealment cover for deer near the road, hiding them from the view of motorists. Deer emerging from heavy cover are not visible until they are on the roadway, allowing little time for a driver to avoid a collision. A large proportion of motor vehicle - deer collisions occurred in Michigan in this manner (Arnold 1978).

Removal of woody cover along a ROW could give motorists a better chance to spot deer before they cross in front of their cars. However, much of the woody vegetation observed along roads in the study areas was in fence rows, small woodlots, or shelter belts. Little of the woody vegetation observed was off private property.

The MDSHT mowed and removed woody vegetation from the ROW of roads, often up to private fence lines. But the average width of the mowed and cleared ROW on the study sites was about 10 feet. The area where the state could influence roadside vegetative cover is, therefore, limited. Furthermore, it appears impractical that woody vegetation occurring on private land next to state roads could be cleared and managed in order to reduce rates of deer road kills.

No predictive model has been suggested based upon habitat variables. The results of the step-wise regression analysis have been conservatively interpreted as identifying those habitat variables which have a significant effect on the rates of deer road kills on the study sites. Because of the small sample size of study sites (n = 12), confidence limits on the regression model would be wide, limiting the usefulness of the model as a predictor.

Despite the lack of a predictor equation, several important factors related to motor vehicle - deer accidents have been identified by this study. First, it appears that deer road kills were more strongly related to deer population levels then they were to traffic volume. Secondly, the increase in old field communities adjacent to food and cover has been shown to have been related to the increase in deer road kills. Lastly, roadside cover appears to have strongly influenced rates of motor vehicle - deer accidents.

Although accurate estimates of the number of southern Michigan deer are difficult to make, the strong correlation of the rates of deer road kills to both the annual buck kills and the WCI values indicated that deer road kills were closely related to the increase in deer numbers. Furthermore, the District Wildlife Biologists interviewed all indicated that they believed that high winter concentrations of deer increased local rates of deer road kills. Motor vehicle - deer accidents apparently were more related to deer population dynamics than to human driving patterns.

That the increase in old field communities lead to an increase in deer road kills can be best demonstrated by the results of the ANOVA (Table 4) and of Tukey's test (Table 5). The sample size used in these analyses (n = 30) is large enough that the results can be stated with much more confidence than can those of the step-wise regression analysis.

The proposed role that roadside vegetation plays in increasing deer road kills is supported by the results of the step-wise regression analysis and from accounts found in the literature. Furthermore, it makes sense that woody roadside cover would increase deer road kills by reducing the visibility of deer to the drivers.

Of the three factors discussed above, only the level of the deer population appears to lend itself to management on a regional basis by the state. This is so since the other two factors could only be managed by large scale vegetative manipulation, a practice which would be impractical in a region where most of the land is privately owned.

RECOMMENDATIONS

The following recommendations are made to those wildlife professionals, highway safety personnel, and others who are concerned with reducing numbers of motor vehicle - deer accidents in Michigan.

1. Development of a computer file search system for MDSHT accident record files. Such a search system could identify concentration areas of motor vehicle - deer accidents by rapid search of accident data files.
2. Expansion of MDSHT motor vehicle - deer accident data record files to include county, local and town roads. This would permit location of deer road kills on the road classes where the majority of them occur.
3. Modification of the MLCUCS for wildlife habitat studies by expansion of the present four level code. Expanded codes could identify ecological components of wildlife habitat, as was done in this study, or other habitat designations which may fit research or management needs.
4. Development of a reliable index of deer population trends for southern Michigan based on surveys of deer winter concentration areas, deer road kill data, or a combination of both. Knowledge of deer population

trends will be essential for the future sound management of southern Michigan deer.

5. Reassessment of the present MDNR policy of allowing the deer herd to grow to the limits of the carrying capacity of their range (Arnold 1978). The high number of costly, and dangerous motor vehicle - deer accidents in southern Michigan may signal that we have "enough" deer now.

6. Reduction of the southern Michigan deer herd, if such a thing should ever become socially desirable, by an increase in the current antlerless deer kill. Although there may always be deer road kills as long as motor vehicles are driven where there are deer, a decrease in the number of deer may significantly lower their rate of occurrence. The harvest of more deer would also allow a greater public utilization of this valuable natural resource, especially in southern Michigan.

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APPENDIX A

APPENDIX A

Sample Printout of MDSHT Program Q/430/34
for a Designated Road Segment of the State's Trunkline System
in Southern Michigan, 1975

Q/430/34 GENERAL ACCIDENT PROGRAM 1975 SELECTED DEER ACCIDENT LOCATIONS/LEO S. AAU 8-22-78 PAGE 5

010175-123175 CONTROL-59043 POB-00,120 POE-01,190

DIST	CONTROL SECTION	MILEAGE	AREA	LOC	DIRECTN V1	DIRECTN V2	DRIVER INTENT D1	DRIVER INTENT D2	MSP ACC TYPE	2VEH ACC TYPE	IMPACT PRIME	IMPACT SECND	CIRCM STNCE	WEATH	SURF COND	ALIGN	DATE	HOUR OF OCCURENCE	ACC REPORT NUMBER	SEVERITY PD	SEVERITY KLD	SEVERITY INJD
05	59043	00.300	3	99	W		15		UTURN		ROLLED		NONE	CLEAR	DRY	STR	06 08 75	10PM-11PM	108939			1
05	59043	00.400	3	99	E		01		ANIML		FRNT-R		NONE	CLEAR	DRY	STR	01 09 75	07PM-08PM	012817	X		
05	59043	00.500	3	99	W		01		ANIML		FRONT		OTHER	CLEAR	DRY	STR	10 26 75	07PM-08PM	239525	X		
05	59043	00.600	3	99	W		01		ANIML		FRONT		OTHER	CLEAR	DRY	STR	09 19 75	07AM-08AM	221520	X		

APPENDIX B

APPENDIX B

Questionnaire Sent to MDNR District 9, 11 and 12 Wildlife Biologists Concerning Motor Vehicle - Deer Accidents on Undivided Roads in Their Respective Districts

QUESTIONNAIRE

RE: MOTOR VEHICLE-DEER ACCIDENTS ON UNDIVIDED ROADS IN REGION III

PURPOSE: TO GATHER INFORMATION WHICH WILL AID IN IDENTIFYING AND CHARACTERIZING LOCALIZED AREAS OF HIGH DEER ROAD KILLS

Section 1

1. Does your office have more details on the locations of deer road kills than you submit on your monthly report to Lansing, which gives only county information; do you have information by township, or by sections?
   _____YES _____NO If YES, specify:

2. Do you have data on the sex, age, or other vital statistics of road killed deer by county, township, or section?
   _____YES _____NO If YES, specify:

3. Are there localized areas in your district where high numbers of deer road kills occur?
   _____YES _____NO If YES, how many areas?

4. Do any of these areas have a history of being high road kill areas for several or more years?
   _____YES _____NO If YES, for how many years?

5. Can you locate these areas on county maps, if you have not already done so?
   _____YES _____NO

6. Would you describe these areas as being specific to particular points along a road, such as a trail crossing, or are they associated with larger areas?

7. For what reason do you feel deer use high kill areas?
   _____for feeding on road side vegetation
   _____for traveling through from one area to another
   _____other (specify)

8. Do you feel that high kill areas may be associated with certain habitat types?
   _____YES _____NO If YES, specify what types:

9. Has anyone from your office ever investigated any high kill areas?
   _____YES _____NO If YES, do you have a summary of the study results and any pertinent data available for these areas? _____YES _____NO

10. Are there one or more high kill areas which you feel are especially notable in your district?
    _____YES _____NO If YES, give specific locations:

11. Do you have data for these notable areas?
_____YES _____NO

12. Considering factors other than traffic volume, traffic patterns, or road type, road conditions, etc., what do you feel may cause areas to be high kill areas? (briefly)

Section 2

13. How are deer road kills reported to you? specify:

14. What percentage of the total number of accidents do you feel that reported accidents represent?
_____%

15. Do you feel that the number of high accident areas is increasing or decreasing?
_____increasing _____decreasing

16. To what might you attribute this increase or decrease? explain:

17. Do you feel that these accident areas represent a serious safety hazard to Michigan motorists?
_____YES _____NO

18. Do you feel that these accidents may ever get to be so common as to justify fewer deer in southern Michigan?
_____YES _____NO

19. How effective do you feel increasing the antlerless deer kill is in reducing the frequency or distribution of deer road kills?
_____very effective
_____effective
_____no effect

20. Check any of the following methods you may feel are, or could be, effective in reducing deer road kills?
_____motorists warning signs
_____fencing
_____underpasses for deer
_____control of road side vegetation
_____other (specify)

APPENDIX C

APPENDIX C

Listing of Computer Program and Data List For Step-wise Regression Analysis Used to Test the Association Between Habitat Variables and Rates of Motor Vehicle - Deer Accidents on Twelve Study Sites in Southern Michigan

```
RUN NAME        [illegible] REGRESSIONS
DATA LIST       [illegible] KRATE 8-11(1) TYPE1 TO TYPE8 12-51(4)
                [illegible] 54(2) DI 55-58(3) RG 59-60
DO REPEAT       [illegible] TYPE1 TO TYPE8/
                    SRTYPE1 TO SRTYPE8
COMPUTE             SRT(8)
END REPEAT
DO REPEAT           TYPE1 TO TYPE8/
                    LTYPE1 TO LTYPE8
COMPUTE             [illegible]
END REPEAT
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
COMPUTE         [illegible]
N OF CASES      [illegible]
READ INPUT DATA
08032 [illegible]            0592 4405 1235 0293 261613 3
13027 [illegible]            1472 1366 1034      261637 2
13031 [illegible]            2213 1018 2189      541501 1
34033 [illegible]            2314 5608 1548      471581 3
34061 [illegible]            1016 4158 2653      761336 3
34081 [illegible]            1313 1809           321630 3
38111 [illegible]            1116 2071 2030      321691 1
41091 [illegible]            1165 3080 1793 1360 621996 1
41101 [illegible]            1117 1796 0741 1427 531991 2
59200 [illegible]            1026 3708 0279      141451 2
59051 [illegible]            1323      0156      441062 2
08011 [illegible]            2367 1600 2671 0182 591683 3
REGRESSION      [illegible]TYPE5,LTYPE6,SRTYPE7,SRPCR,DI,KRATE,IA1
                [illegible]
                [illegible] WITH TYPE2,SRTYPE5,LTYPE6,SRTYPE7,SRPCR,DI,
                [illegible]
CONDESCRIPTIVE  [illegible]
STATISTICS      [illegible]
FINISH
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