W.E. Stevens

THE EFFECTS OF ROADWAYS ON POPULATIONS OF SMALL MAMMALS

by

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ABSTRACT

Four roadways of varying widths and traffic volume were used to assess the isolating effects of roads on populations of small mammals. Between 17 June and 12 September 1971, 253 small mammals were tagged and released in the four study areas, including 115 *Peromyscus leucopus* and 77 *Tamias striatus*. From a total of 214 recaptures during the study period, 5 marked mammals (2 *T. striatus* and 3 *P. leucopus*) were found to have crossed roadways, involving one-way movements of up to 27 m over open terrain. During 97 hours of observation at each of the four sites, 99 mammals were observed crossing the roads. Seventy-nine of these were medium-sized mammals (42 *Lepus americanus* and *Sylvilagus floridanus*, 28 *Procyon lotor*, 7 *Mephitis mephitis*, and 2 *Marmota monax*), and the remainder small mammals (11 *Microtus pennsylvanicus*, 6 *T. striatus*, 2 *Tamiasciurus hudsonicus* and 1 *Mustela erminea*). Width of the right-of-way or cleared areas along the roadway seemed of more importance as an isolating factor than traffic volume.

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INTRODUCTION

Roads are an integral part of the communications systems of our civilization, and yet detailed studies of their effects on organisms in areas traversed by them are virtually unknown. Pienaar (1968) summarized some of the possible effects of roadways in a National Park, including : 1. destruction of flora and fauna by construction, 2. erosion and habitat degradation due to poorly drained or designed roads, 3. alteration of the vegetation along the roadways, 4. the use of roadways as communication routes by larger mammals, 5. restriction of movements of many timid species due to traffic, 6. the use of bridges, etc. as routes of dispersal across faunal barriers, 7. the attraction of larger herbivores to vegetation along the road, or to the dry, warm surface of the road, and 8. the attraction of predators and scavengers which use the roads as a source of food.

Pienaar's (1968) comments were based on general observations rather than specific research. His observations are compatible with those concerning mortality along roadways (e.g. Simmons, 1938; Knobloch, 1939; Haugen, 1944; McClure, 1951; Hodson, 1966; Evenden, 1971; and Bellis and Graves, 1971). McClure (1951) concluded that road mortality was affected by many factors, including the habits of species involved and their familiarity with traffic, the populations of wildlife adjacent to the roadway and the density of cover in that area, and the nature of the road's surface by virtue of its effect on traffic speed and volume.

Roadways have provided mixed blessings for many species by facilitating access to, or increasing supplies of food, and at the same time resulting in damaging or fatal encounters between vehicles and wildlife. Bellis and Graves (1971) reported that Odocoileus *virginiana* frequently fed on the grassy road shoulders and as a result were frequently hit by vehicles. Taylor (1971) related numerous skeletal fractures in east African viverrids to their habit of catching prey along roadways and thus being hit by passing vehicles. For some microtine rodents, the roadways appear to be more generally beneficial by providing a ready supply of grass along the road verges, which has allowed them to flourish and, in some cases, to expand their ranges (Baker, 1971).

Roads and railways have been found to inhibit the movements of feral reindeer, but not those of domestic reindeer (Klein, 1971). Detailed work on the role of roadways as barriers to dispersal of mammals is lacking. The present study was undertaken near Ottawa, Ontario between 17 June and 12 September to test the isolating effects on populations of small mammals of four roadways with varying clearance and traffic volume. Live trapping and marking of populations adjacent to the roads, as well as direct observation of each road were employed to assess these effects.

STUDY SITES

Trapping and observations were conducted at the following locations:

1. Davidson Road, Gloucester Twp., Carleton Co., Ontario. Work was conducted between Hawthorne and Conroy Roads in an area of two lane gravel surface 8.0 m wide (Figs. 1D and 2D). The forest adjoining the road was predominantly maple, with some birch, pine and alders, and covered a total area of 1.02 sq. mi. (0.60 sq. mi. on the north side and 0.42 sq. mi. on the south side). Davidson Road was built in 1818 when it had a right-of-way of 9.5 m (Beldon, 1879); in 1951 the right-of-way was expanded in 20.3 m.

2. Notch Road, Hull Twp., Gatineau Co., Quebec. The studies were carried out one quarter mile south of the junction of Mine and Notch Roads in an area of two lane blacktop surface, 6.8 m wide (Fig. 1C and 2C). At this point the forest was mainly beech-maple, with scattered birch and pine, and represented part of an extensive forested area (over 3 sq. mi. on both sides of the road). Notch road was constructed in 1834 with a right-of-way of 9.5 m which was expanded to 20 m in the early 1960's (pers. comm. City Clerk, City of Hull, to D. Oxley).

3. Navan Road, Cumberland Twp., Russell Co., Ontario. The work was conducted between Ottawa-Carleton Concession Road 31 and MacKinnon Creek in an area where Navan Road has a blacktop surface 7.5 m wide (Figs. 1B and 2B). The forest, composed mainly of maple, with some beech, birch, pine, elm and alder , covered approximately 0.54 sq. mi. (0.25 sq. mi. on the north side and 0.29 sq. mi. on the south side). The road was first surveyed in 1796 with an original right-of-way of 9.5 m, and later expanded to 20.3 m.

4. Highway 417, Gloucester Twp., Carleton Co., Ontario. The study area was one mile east of Leitram Road, adjoining a newly constructed section of highway 417, a newly constructed,four lane highway with a sparsely forested (maple, birch and cedar) median (Figs. 1A and 2A). Each two lane surface is 8.0 m wide, and the minimum right-of-way is 92.3 m. The forest in the area is mainly cedar, spruce, and pine, with some maple, beech, birch, and alder , and covers an area of 1.30 sq. mi. (0.48 sq. mi. on the north side and 0.82 sq. mi. on the south side). Winter clearing for the road began in 1969, and this completed section was closed to all but local traffic when the study was conducted.

Supplementary data were gathered near Chaffey's Locks, Ontario (South Crosby Twp., Leeds Co.) between 26 and 30 July 1971 as part of a class project for Biology 332 from Queen's University. The road from

Chaffey's Locks to the Perth Road at its intersection with the road to the Queen's University Biological Station, and the road to the Queen's University Biological Station in the vicinity of the Station, were each observed for 24 hours. The road from Chaffey's Locks has a clearance of 8 m, and that going to the Biology Station a clearance of 7 m, in the vicinity of the study sites.

Diagrammatic representations of the cross sections of the roadways are shown in Figure 2. Total clearance is defined as the amount of space which mammals had to cross to get across the roadway, and was measured from forest edge to forest edge. The total clearance often exceeded the right-of-way. At Davidson Road dense rushes about 2 m high extended from the road to the forest edge, and the clearance there was considered to be the distance between the beds of rushes.

METHODS

Traps baited with a mixture of peanut butter and rolled oats and sunflower seeds, were deployed at the four study sites on a 2.5 hectare grid composed of 66 traps set in six lines parallel to the roadway (three on each side). The first line of traps was placed between the road shoulder and the forest vegetation and the second and third lines 25 m and 50 m respectively from the first. Eleven collapsible aluminium traps located at 25 m intervals over 250 m comprised each line of traps. At Highway 417, 11 extra traps at 25 m intervals were placed along the median.

All mammals caught on the grid were eartagged for individual identification (except *Blarina brevicauda*), and identified with respect to species, sex, breeding condition, behaviour after release, age (where possible), and point of capture on the grid. For recaptured animals, distances moved within the grid were measured from the original point of capture.

An observation point was located at the periphery of each grid on the road shoulder to record traffic volume and animal crossings. Eleven range stakes at intervals of 25 m along the road shoulders allowed rapid estimation of the distance along the road. Species, direction of movement, and point of cross-over were recorded for all mammals observed on the roadway. Weather conditions and road kills were also noted.

The schedule of trapping and observation at the four sites is shown in Table 1. The times of initiation of daily observations were varied and randomized to ensure coverage of the roadway during all daylight hours. Each site was trapped for a total of 12 days and observed for 97 hours.

RESULTS

Trapping

Two hundred and fifty-three small mammals were tagged and released at the four study sites, including 116 *Peromyscus leucopus* and 77 *Tamias striatus*. Other species trapped (details in Appendix 1) included *Mustela erminea*, *M. frenata*, *Zapus hudsonius*, *Napaeozapus insignis*, *Microtus pennsylvanicus*, *Clethrionomys gapperi*, and *Tamiasciurus hudsonicus*. Forty-two *Blarina brevicauda* were also captured during the study, but were not marked for future identification. *Tamias striatus* and *P. leucopus* accounted for 96.7% of the 234 recaptures and, for this reason, discussion of the trapping results is largely restricted to these species.

Population densities for *T. striatus* and *P. leucopus* were generally similar at the four sites (Tables 2 - 4). A small *P. leucopus* population, coincident with a large *Clethrionomys gapperi* population at Davidson Road, was related to habitat preference of these two species (Getz, 1969). Trapping results indicated that the highest populations of *T. striatus* and P. leucopus occurred at the Highway 417 site. We assume that the trapping success is an indication of the population density and that in this respect, the four sites are comparable because the same trapping ritual was followed at all sites. This assumption is supported by the abundance of Mustela erminea at Highway 415 (63% of the total encountered during the study), as high densities of predators are usually concurrent with high densities of prey.

The numbers of T. striatus and P. leucopus trapped on opposite sides of the road at the four sites were generally balanced. At least 40% of the total catch for T. striatus at all sites came from one side of the road. With the exception of Davidson Road, similar distribution was recorded for P. leucopus. At Davidson Road 75% of the P. leucopus were caught on one side. Because of the small number and the unbalanced distribution of P. leucopus at this site, data for this species at Davidson Road have been excluded from our analysis.

The distances covered by T. striatus and P. leucopus as indicated by recaptures along the grid, are shown in Tables 2 - 4. In all cases the greatest recorded movements occurred in areas with the highest population densities. Similarly, in most cases, the mean distances moved between traps on the grid were in excess of the clearance at the site, and therefore both species were capable of moving the distances required to traverse the roadway. At Highway 417, the average distance moved between traps was greater than the road clearance only for subadult P. leucopus. A two way analysis of variance of the average distance between captures showed that subadult P. leucopus moved significantly greater distances than adults of this species (Table 5) at all sites.

During this study, five marked mammals were captured across the road from where they were originally marked. Two T. striatus crossed at Davidson Road, one P. leucopus crossed Notch Road, and two Navan Road. The P. leucopus caught on both sides of the roads were subadults, which is consistent with the observations of distances moved by individual mice. All these movements were one-way displacements; in no case did a tagged individual subsequently re-cross the roadway.

Observations

During 97 hours of observation at each of the four sites, 99 mammals were observed crossing the roads. Seventy-nine of these were "medium-sized", including 42 lagomorphs (Lepus americanus and Sylvilagus floridanus), 28 Procyon lotor, 7 Mephitis mephitis, and 2 Marmota monax, and the remainder, "small mammals" including 11 Microtus pennsylvanicus, 6 T. striatus, 2 Tamiasciurus hudsonicus and 1 Mustela erminea. With increased road clearance, and, to a lesser extent, increased traffic volume, the number of crossings of the road diminished (Fig. 3). No mammals were observed crossing Highway 417 during the study period, although one M. pennsylvanicus was subsequently observed moving from the road edge to the median in an open area near the study site.

Two of the six road crossings by T. striatus occurred on bright days, three under conditions of heavy overcast, and one during light overcast.

During the 24 hours of observation at each of the supplementary sites near Chaffey's Locks, 30 crossings of the road by mammals were observed at each site. Forty-four of these involved T. striatus, 7 medium-sized mammals (Marmota monax, Felis catus, and Erethizon dorsatum), 8 unidentified "mice", and one Mustela sp. (Table 6). In several cases individual T.striatus were observed to regularly cross the roads, apparently during the course of normal foraging activity, as there was a one-way transport of food material from one side of the road to the other.

Four road kills were observed during the study period at the study sites. One Lepus americanus was killed at Davidson Road, one Procyon lotor at Notch Road, and one each of Mephitis mephitis and Marmota monax at Navan Road.

Biochemical

Analysis of variation at 9 loci using standard acrylamide gel electrophoretic techniques (for details of methods see Carmody et al., 1971) indicated individual variation at these loci. Due to the difficulty in obtaining samples for this study in the fall, complete analysis of these data is not yet available.

DISCUSSION

Roads

If roads had no influence on the movements of small mammals, crossings of the roads by them should have been random, especially since at least T. striatus and P. leucopus regularly moved distances of the required magnitude between traps on the grid. Movements of marked T. striatus and P. leucopus indicated that both species crossed roads of up to 27 m clearance, but such crossings were not common.

The observation data more clearly indicate that the presence of roads inhibits the movements of some mammals. Medium-sized mammals such as rabbits, large rodents, skunks, etc., were less inhibited by roads, and, not surprisingly, make up a high proportion of road kills (100% in this study).

Traffic volume and road surface did not seem to be critical factors in inhibiting movement at the sites studied. The site (Highway 417) with no crossings had the lowest levels of traffic observed in the study. Similarily, the data from the sites near Chaffey's Locks indicated equal incidence of road crossings in spite of a two-fold difference in traffic volume between the two sites.

Sprock et al. (1967) showed that laboratory rodents quickly became accustomed to noise from acoustical frightening devices, and noted that many species of feral mammals quickly adapted to sounds of trains, traffic and jets. Traffic noise, therefore, may not be a deterrent to movements across roadways.

Small mammals adapted to open terrain are less inhibited in their movements by roads than are those adapted to areas with more cover, eg. forests. This was demonstrated by the relatively high incidence of road crossings by *Microtus pennsylvanicus* (11 of 99 crossings during this study). One of us (Fenton) noted that in prairie habitat in western Canada, *Spermophilus tridecemlineatus* seemed almost totally uninhibited by the presence of roads. This species regularly ventured on to the travelled surfaces of roads, including secondary roads with light traffic volume and the more heavily used Trans-Canada Highway.

Other factors may also act as deterrents to passage over roads. Accumulations of lead along roads, the result of lead additives to gasoline, may affect the distribution of some species. As Pienaar (1968) observed, more timid species might be more susceptible to upset associated with vehicles. Fossorial forms would be limited in their movements by the presence of roads, since tunelling under asphalt roads is probably not a common occurrence.

The results of this study indicate rather clearly that the critical inhibiting factor, at least for species adapted to forest conditions, is road clearance. The deterrent stimulus related to road clearance may well be light intensity. This is supported by the fact that 4 of 6 crossings of the road by *T. striatus* observed during the study, occurred on overcast or dull days.

Since the rights-of-way for highways are standard within provinces in Canada, or, for the Trans Canada Highway, nationally controlled, it is possible to see the extent of disturbance by roads. In Ontario, a four lane, paved highway must have a minimum right-of-way of 92.3 m. Two lane, paved highways (King's Highways) in this province have a minimum right-of-way of 30.8 m, and county roads one of 20.3 m. Private, lightly-used or unimproved rural roads have varied rights-of-way (L. Kelenyi, Ontario Department of Transport and Communications, pers. comm. to D. Oxley). Our data indicate that small mammals adapted to forest conditions would cross up to 27 m of open terrain associated with a road. Thus main, two lane highways may not act as barriers to movement, but the four lane, divided highways must certainly be serious deterrents to movement of forest forms.

Dispersal and Gene Flow

Dispersal of organisms may be random (Skellam, 1951) or initiated by various stimuli, and population density may be an important factor in this respect. The trapping data indicated that the population densities of *P. leucopus* and *T. striatus* were generally similar on both sides of the roads studied. If increasing population density were a stimulus for migration, in this case crossing of a road, the highest amount of movement should have occurred at Highway 417. In fact no mammals were observed to cross this road during the study period, either by trapping or by visual documentation.

Dispersal, in this case involving movement across roads, was not random during this study and not related to population levels.

Subadult *P. leucopus* had a significantly greater range of distances covered between points of capture than did adults, and were the only tagged representatives of this species encountered on both sides of the roads. These data are similar to those of Sheppe (1965) who determined that in P. leucopus subadults were almost entirely responsible for dispersal as the adults were relatively philopatric.

Crossing of the road by an animal does not, in itself, mean that the road is not a barrier to gene flow, which requires that the immigrant breed with members of the population which it joined. Thus the sexual maturity of the immigrant, the randomness of mating, and the time of arrival could affect the rate of introduction of genetic material into the population.

Rasmussen (1964), using his data and those of Howard (1949) and Dice and Howard (1951), estimated that the panmictic unit in populations of Peromyscus maniculatus varied from 12 to 99 mice. In this setting gene flow was limited by behaviourally defined limits of movement as well as by environmental constraints. Rasmussen (1970) suggested that the behavioural patterns of individual mice could produce a genetical structure in the species sufficient to present a mosaic pattern for the phenotype examined.

Temporary pairing, as observed by Howard (1949) for P. maniculatus, might further reduce the chances of an immigrant's being able to breed in the population. If the density of the population which the immigrant has newly joined is similar to that of the population he has left, he may be deterred from taking up residence and becoming part of the new population. Territory, agonistic behaviour, and social dominance, well documented for T. striatus (Blair, 1942; Wolfe, 1966; and Dumford, 1970), would similarily reduce the chances of survival and successful (re. breeding) immigration. Sheppe (1965) suggested that immigrant P. leucopus arriving out of the breeding season had low chances of survival until the next breeding season.

In the light of these data, the results of this study strongly suggest that by isolation of parts of formerly continuous populations of small mammals, roadways act as barriers to dispersal and to maintenance of genetically homogeneous populations.

Barriers

Crow and Kimura (1970) derived an equation showing that successful (re breeding) movement of one individual per generation between two populations was sufficient to maintain homogeneity in the populations. A barrier, therefore, may be considered as a phenomenon (intrinsic and/or extrinsic) which maintains a migration rate of less than one genetic exchange per generation. The more effective the barrier, the less genetic exchange between populations, and the greater the opportunity for evolutionary divergence of the populations.

While apparently no work has been done concerning the effectiveness of roads as barriers, there are many observations concerning the effect of water. Dice (1939 and 1949) found that populations of P. maniculatus on opposite sides of the Columbia River and one of its tributaries, the Snake River, were completely isolated and displayed parallelism on a microevolutionary scale. Fox (1948) observed that at its western end, the Columbia River was a complete barrier for P. maniculatus, but that there was some crossing of the river at its eastern end. Sheppe (1965) found that migration of P. leucopus to islands decreased with increased isolation of the island. In spite of a relatively high population level on an island 368 m from shore, no movement to or from this island was observed by Sheppe (1965). Islands closer to shore were not isolated from mainland populations as the mice readily crossed between them and the mainland. Werner (1956) obtained similar data for P. leucopus on islands in the St. Lawrence River, since these mice were found only on islands close to (less than 277 m) the mainland or other islands.

Crossings of a water barrier may involve swimming (Sheppe, 1965) or movement across the ice in areas where water bodies freeze over (Beer et al., 1954).

The data from this study indicate that roads are effective barriers to the dispersal of small forest mammals. A four lane highway with a clearance of 137 m may be as effective a barrier as a body of fresh water twice its size. Construction of highways has, in some cases, caused fragmentation of the large gene pools of nonvolant north temperate mammals (and other nonvolant terrestrial animals). We may discover in the near future if these large gene pools were vital to the survival of these species.

CONCLUSIONS

1. Dispersal across roads by populations of small mammals is not a function of population density.

2. Road clearance appears to be the most critical factor in limiting dispersal across roadways by small mammals adapted to forest conditions.

3. Medium-sized mammals are less inhibited in their movements by roads and are, as a result, more common as road kills.

4. Subadult *Peromyscus leucopus* move significantly greater distances than adults, and in this case, were the only representatives of this species observed to cross roads.

5. Four lane, divided highways appear to be as effective as barriers as bodies of water twice their size (i.e. where road clearance = 0.5 distance over water).

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Table 1

Schedule of trapping and observation patterns

at the sample sites.

Date	Site	Daily Activity (in hours) trapping	observation
June			
18 to 21	Navan Rd	3	6
25 to 28	Davidson Rd	3	6
July			
2 to 5	Highway 417	3	6
8 to 11	Notch Rd	3	6
14 to 18	10 hours of observation amoung all 4 sites		
21 to 24	Navan Rd	3	6
27 to 30	Davidson Rd	3	6
August			
2 to 5	Highway 417	3	6
8 to 11	Notch Rd	3	6
14 to 18	10 hours of observation amoung all 4 sites		
21 to 24	Navan Rd	3	6
27 to 30	Davidson Rd	3	6
September			
2 to 5	Highway 417	3	6
8 to 11	Notch Rd	3	6

Table 2

Trapping results from the four sites for *Tamias striatus*

	Davidson Rd	Notch Rd	Navan Rd	Highway 417
total tagged and released	22 (9-13)*	13 (7-6)*	17 (7-10)*	25 (10-15)*
total recaptures / no. of individuals recaptured	21/11	14/8	20/8	38/14
range of movements in m	0 - 175	0 - 85	0 - 100	0 - 235
mean distance moved in m	55.3	40.2	39.7	61.4
no. of individuals trapped on both sides of road	2	0	0	0

*indicates numbers trapped on either side of road

Table 3

Trapping results from the four sites for adult *Peromyscus leucopus*

	Davidson Rd	Notch Rd	Navan Rd	Highway 417
total tagged and released	8 (6-2)*	26 (10-16)*	30 (10-20)*	33 (15-18)*
total recaptures/ no. of individuals recaptured	11/3	19/12	42/19	37/17
range of movements in m.	25 - 260	0 - 150	0 - 125	0 - 235
mean distance moved in m.	75.0	45.5	35.0	92.8
no. of individuals trapped on both sides of road	0	0	0	0

*indicates the numbers trapped on either side of road

Table 4

Trapping results from the four sites for subadult *Peromyscus leucopus*

	Davidson Rd	Notch Rd	Navan Rd	Highway 417
total tagged and released	0	4 (2-2)*	8 (5-3)*	7 (5-2)*
total recaptures / no of individuals recaptured	0	6/3	10/6	8/4
range of movements in m	0	0 - 125	25 - 127	50 - 200
mean distance moved in m	0	56.3	62.2	144.5
no of individuals trapped on both sides of road	0	1	2	0

*indicates the numbers trapped on either side of road

Table 5

Analysis of variance for data on movements

of adult and subadult *Peromyscus leucopus*

source of variation	sum of squares	degrees of freedom	mean square	F
Sites	19,406.72	1	19,406.72	25.50**
Age Class	105,559.98	2	52,779.99	10.48**
Interaction	4,807.11	2	2,403.56	1.29*
error	218,524.45	118	1,851.90	-

** p 0.05

* not significant

Table 6

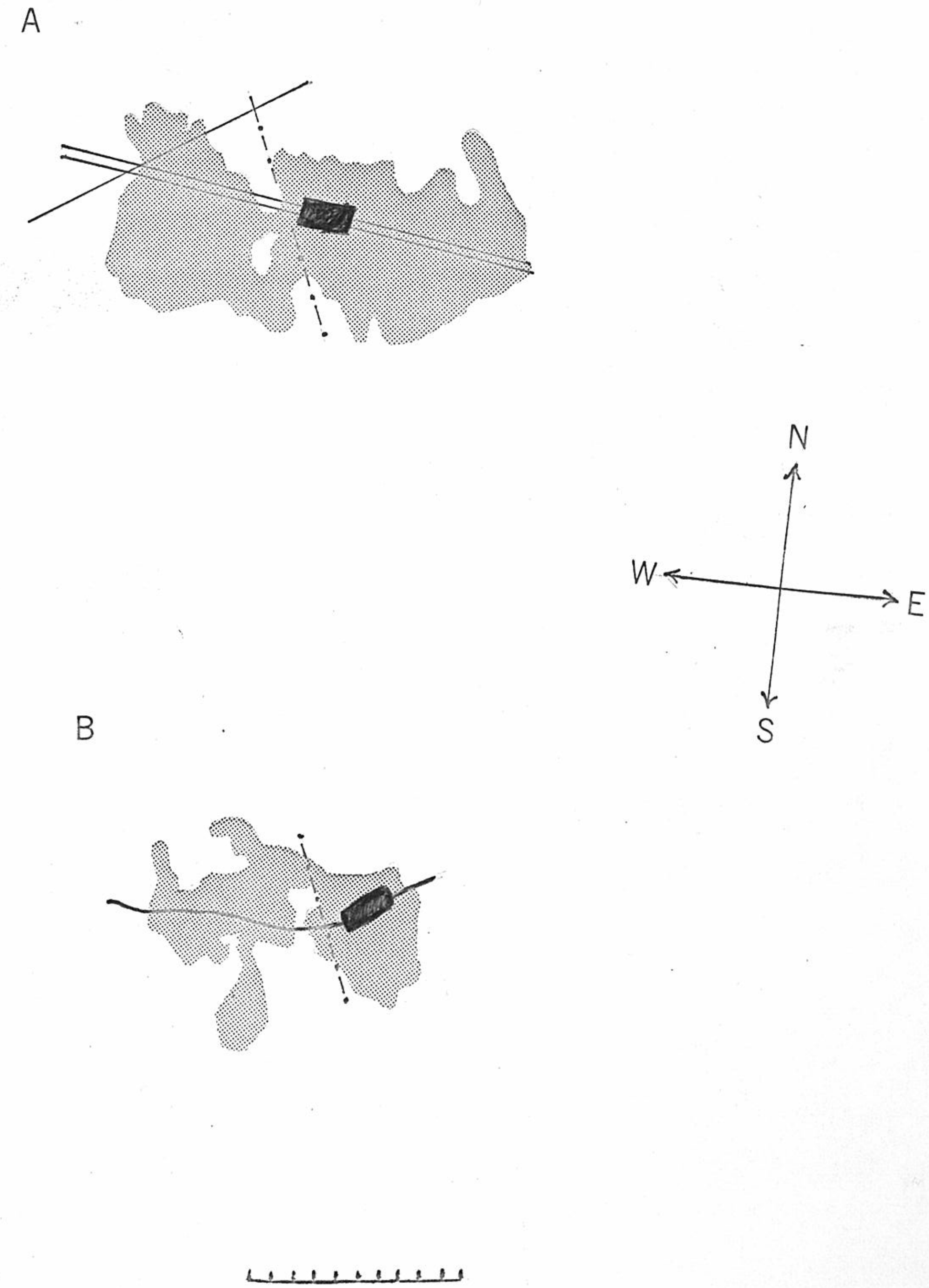
Observation data from supplementary sites

near Chaffey's Locks, Ontario

Site	Species Crossing	Number Crossing	Clearance in m	Traffic Volume in vehicles/ hour
Chaffey's Locks Rd.	_Tamias striatus_	23	8	6.92
	Marmota monax	3		
	Mice (unidentified)	2		
	Felis catus	1		
	Tamiasciurus hudsonicus	1		
	total	30		
Queen's University Biological Station Rd.	_Tamias striatus_	21	7	2.75
	Marmota monax	2		
	Tamiasciurus hudsonicus	2		
	Erethizon dorsatum	1		
	Mustela sp.	1		
	Mouse (unidentified)	1		
		30		

Figure 1.

Maps showing the relative distributions of forest (stippled), trapping grids (darkened), and roadways at the four study sites. Four lane, paved highways are represented as ═══ , two lane, paved roads as ──── , and gravel roads as —·—·— .
The scale is 1:50,000.
A - Highway 417; B - Navan Road; C- Notch Road; and D - Davidson Road.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C

D

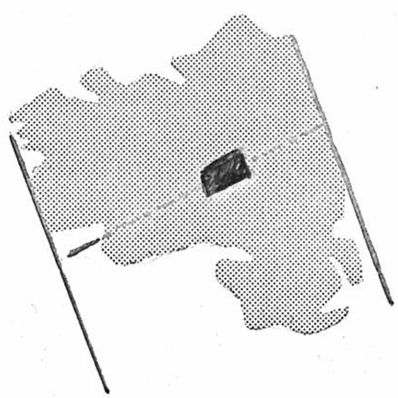
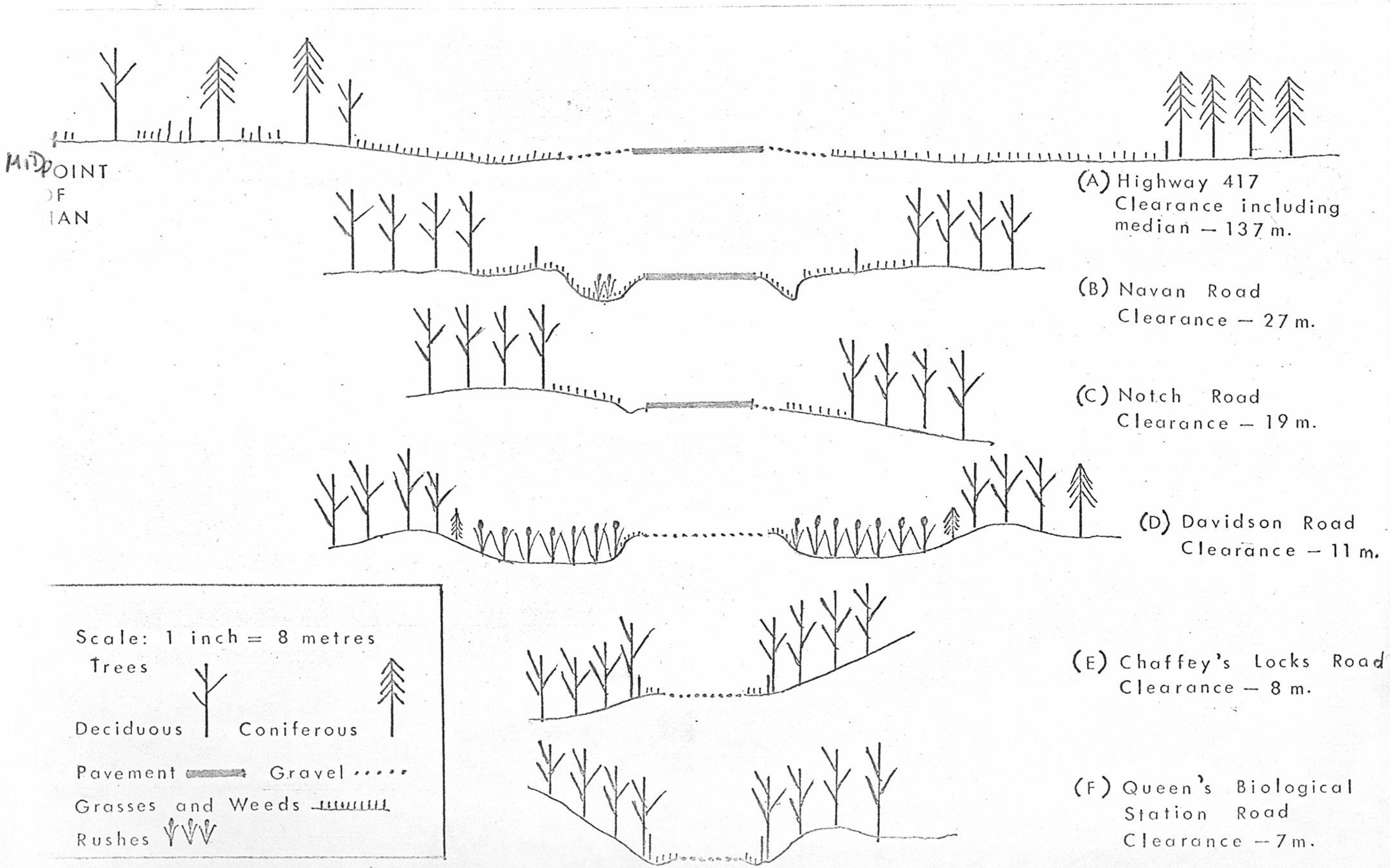


Figure 2.

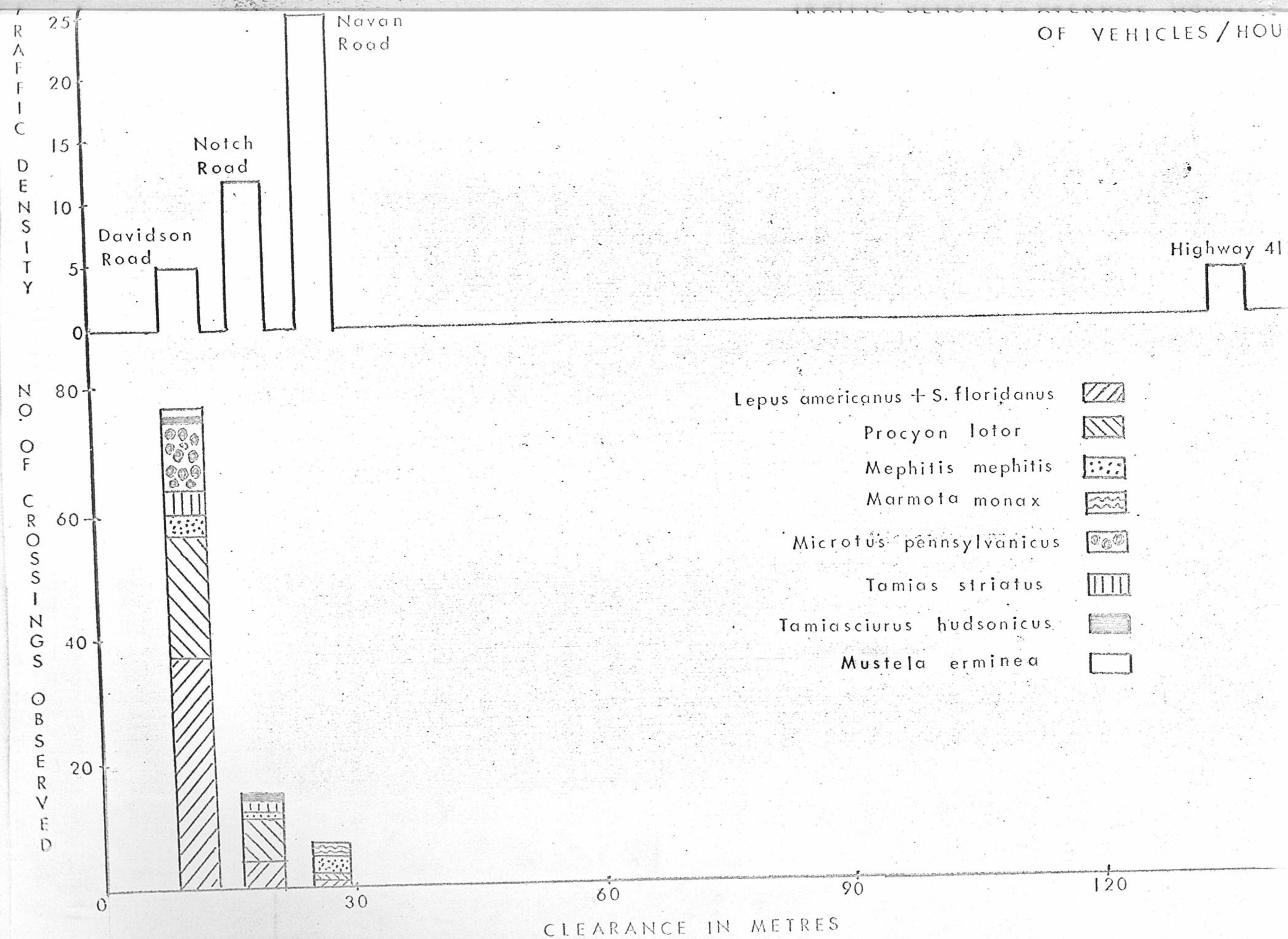
Diagrammatic cross sections of the four main study sites (A- Highway 417; B- Navan Road; C- Notch Road; D- Davidson Road), and the two supplementary sites (Chaffey's Locks Road and Queen's University Biological Station Road).



MIDPOINT
OF
IAN
(A) Highway 417
Clearance including median — 137 m.
(B) Navan Road
Clearance — 27 m.
(C) Notch Road
Clearance — 19 m.
(D) Davidson Road
Clearance — 11 m.
(E) Chaffey's Locks Road
Clearance — 8 m.
(F) Queen's Biological Station Road
Clearance — 7 m.
Scale: 1 inch = 8 metres
Trees
Deciduous
Coniferous
Pavement
Gravel
Grasses and Weeds
Rushes

Figure 3

Crossings of roadways by mammals as observed during the present study with corresponding traffic volumes.


OF VEHICLES / HOU
TRAFFIC DENSITY
25
20
15
10
5
0
Davidson Road
Notch Road
Navan Road
Highway 41
NO. OF CROSSINGS OBSERVED
80
60
40
20
0
30
60
90
120
CLEARANCE IN METRES
Lepus americanus + S. floridanus
Procyon lotor
Mephitis mephitis
Marmota monax
Microtus pennsylvanicus
Tamias striatus
Tamiasciurus hudsonicus
Mustela erminea

Appendix 1

List of the small mammals tagged and released

at the 4 study sites between 17 June and 12 September

Site	Species	Number tagged and released
Highway 417	Peromyscus leucopus (Rafinesque)	40
	Tamias striatus (L.)	25
	Mustela erminea (Hall)	12
	Blarina brevicauda (Say)	8*
	Tamiasciurus hudsonicus (Erxleben)	6
	Napaeozapus insignis (Miller)	4
	Zapus hudsonius (Zimmerman)	2
	Clethrionomys gapperi (Vigors)	2
	Microtus pennsylvanicus (Ord)	1
	total	100
Navan Road	Peromyscus leucopus	38
	Tamias striatus	17
	Blarina brevicauda	13*
	Mustela erminea	2
	Tamiasciurus hudsonicus	1
	Zapus hudsonius	1
	Clethrionomys gapperi	1
	total	73
Notch Road	Peromyscus leucopus	30
	Blarina brevicauda	14*
	Tamias striatus	13
	Tamiasciurus hudsonicus	3
	Mustela erminea	1
	total	61
Davidson Road	Tamias striatus	22
	Clethrionomys gapperi	19
	Peromyscus leucopus	8
	Blarina brevicauda	7*
	Mustela erminea	3
	Tamiasciurus hudsonicus	1
	Mustela frenata (Lichtenstein)	1
	total	61

*Blarina brevicauda were not tagged.