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POPULATIONS, TRAFFIC MORTALITY, AND HABITAT UTILIZATION
OF WOODCHUCKS, Marmota monax (RODENTIA : SCIURIDAE),
AT URBAN, SUBURBAN, AND RURAL INTERCHANGES
ALONG AN EXPRESSWAY

by

SUSAN MAUREEN WOODWARD, B.Sc.

A thesis submitted to the Faculty of
Graduate Studies and Research
in partial fulfilment
of the requirements for the degree of
Master of Science

Department of Biology

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Ottawa, Ontario

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ABSTRACT

Woodchucks were studied for 2 summers at 6 interchanges in rural, suburban, and urban settings along Highway 417 in Ottawa and Nepean, Ontario.

Proximity to peripheral Woodchuck reservoirs, reproduction, lack of predators, water-table level, and traffic mortality determined the population densities observed. The suburban interchange's fall density of 5.36 Woodchucks/ha exceeded any density previously reported.

These "road-wise" Woodchucks crossed 1-lane on- and off-ramps frequently and successfully; wider roads were crossed infrequently. Watercourses, the expressway, and associated slopes encouraged linear range-shapes. Most burrows were associated with slopes (especially with south aspects) and with isolated trees on flat areas.

The age-class distribution of roadkills mirrored that of the population, but the female-biased sex ratio of the population was not reflected among roadkills. Numbers of roadkills were highly correlated with interchange population densities and road-crossing frequency, but roadkills on ramps were poorly correlated with traffic speed and volume thereon.

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INTRODUCTION

Literature addressing the subject of urban wildlife has appeared during the past decade. Books (Gill and Bonnett, Burton 1976) and conferences and symposia (the 32nd North American Wildlife and Natural Resources Conference (Trefethen 1974), the Canadian Nature Federation Conference on Nature and Urban Man (McKeating 1975), and the Proceedings of the Symposium on Wildlife in Urban Canada (Euler et al. 1975)) mark the increased interest in urban wildlife.

To date the literature dealing with Woodchucks, Marmota monax, has concentrated on the physiology (Benedict and Lee 1938; Bigelow et al. 1964; Davis 1967, 1977; Young and Sims 1979) and behaviour (Barash 1974b) of laboratory animals, and the ecology (Hamilton 1934; Moss 1940; Grizzell 1955; de Vos and Gillespie 1960; Merriam 1960, 1966, 1971; Snyder and Christian 1960; Snyder 1962; Davis et al. 1964; Merriam and Merriam 1965; Schoonmaker 1966; Henderson and Gilbert 1978; Davis and Ludwig 1981) and behaviour (Bronson 1962, 1963, 1964; Hayes 1976) of free-living rural populations.

Studies have been done on urban Coyotes, Canis latrans (Gill 1965; Andelt and Mahan 1977, 1980); Red Foxes, Vulpes vulpes (Harris 1977); Fox Squirrels, Sciurus niger (LoBello 1974); winter birds and swallows (Erskine 1975, 1979); bird communities (Tomialojc and Profus 1977); and on Mallards, Anas platyrhynchos (Figley and VanDuff 1982). No studies of urban Woodchucks have appeared in the literature. However, Doucet et al. (1974) addressed the characteristics that accounted for high populations of Woodchucks on overpass embankments.

of highways in rural areas and the problems their burrowing activity created for maintenance crews. Geggie (1980) studied the effects of increasing urbanization and population density had on the behaviour of Woodchucks.

Ottawa's Queensway (part of Ontario Highway 417) represents a novel study area in a number of ways. It essentially bisects the city of Ottawa as it passes through rural, suburban, urban, suburban, and finally rural interchange areas. This, predominantly urban expressway and its environs provide a favourable herbivore habitat that is being exploited successfully to varying degrees by Woodchucks.

The purpose of this study is to document the Woodchuck populations at 6 interchanges of the Queensway (2 rural, 1 suburban, and 3 urban) and to describe these Woodchucks' use of the interchange habitat. Are there any behavioural differences between these Woodchucks and those not exposed to this type of Man-altered habitat that includes high-vehicle-volume roads?

By analysing burrow entrance associations (versus random distribution) and the movement patterns of individual Woodchucks, the effect of this habitat on utilization by Woodchucks can be determined.

Observed population levels result from a combination of factors including habitat characteristics, natality, immigration, emigration, and mortality. Although there are a variety of mortality factors acting on any animal population, traffic mortality appears to be the major decimating factor confronting these Woodchuck populations. I

examined some of the factors considered important in determining the observed numbers of Woodchuck roadkills and the sex, age-class, and temporal distributions of these roadkills.

Study of their habitat utilization, populations, and traffic mortality shows how the Man-altered habitat at expressway interchanges is being exploited successfully to varying degrees by Woodchucks.

STUDY AREA

The 4- to 6-lane Queensway (part of Ontario Highway 417) is an expressway running in an essentially east-west direction through the city of Ottawa (Fig. 1). My research was concentrated at the 6 interchanges from Moodie Drive in the west to Maitland Avenue in west-central Ottawa, inclusive. The Moodie Drive and Acres Road interchanges are in rural areas; that at Richmond Road is suburban; and those at Pinecrest Road, Woodroffe Avenue, and Maitland Avenue are in urban areas. A wide variety of terrestrial vertebrates is found at these interchanges.

Each interchange consists of grassy and/or shrubby areas divided by major roads and access or exit ramps into "parcels," which I define here simply as grassed areas (including shrubs and trees when present) enclosed by roads. Inner parcels are grassed areas enclosed by on- or off-ramps, an interchange road, and the Queensway. Outer parcels are road-enclosed grassed areas peripheral to inner parcels (Fig. 2). The parcels in this study ranged in area from 0.29 to 2.05 ha (Fig. 3). Each parcel is identified by its interchange road name, compass orientation, and either no numeral for an inner parcel, or "2" for an outer parcel. For example, the outer parcel in the southwest quadrant at Moodie Drive is identified as Moodie SW2. On- and off-ramps are similarly coded, with Moodie SW2 ramp being the outer ramp on the southwest quadrant.

Although all parcels provide lush grassform vegetation (See Appendix A for a list of vascular plant species found on the study

Fig. 1. Map of the western part of the Queensway (Highway 417) and its environs showing the 6 interchanges studied.

Fig. 2. Diagram of a typical interchange.

Fig. 2. Diagram of a typical interchange.

Fig. 3. Areas and vegetation categories of parcels studied.

Fig. 3. Areas and vegetation categories of parcels studied.

parcels sampled) suitable for Woodchucks, the different interchanges have different habitat characteristics.

Every 2 weeks from 24 May to 27 September 1981, single measurements (precision 0.5 cm) were taken with a metre-stick at 10 different, randomly selected points on 12 of the study parcels.

Figure 4 shows that the Moodie parcels and Acres SW were mowed infrequently and their vegetation was consistently high throughout the summer. The Richmond parcels and Acres NE were mowed more frequently and thus showed less variability, with consistently shorter vegetation, which never set seed. The urban interchange parcels were most frequently mowed, keeping the grass short and least variable in height. The Queensway results can be compared with measurements taken at a residential front lawn.

Moodie and Acres interchanges are low relative to surrounding areas and are tile-drained. Mature trees and shrubs are virtually absent at these rural interchanges, but are present at Richmond, Pinecrest, Woodroffe, and Maitland.

All parcels have roadside slopes. The steepest slopes on inner parcels are adjacent to the interchange roads. These slopes at Pinecrest, Woodroffe, and Maitland are covered with shrubs, primarily Lilacs, Syringa vulgaris, except at Woodroffe NW and SW where Scot's Pines, Pinus sylvestris, have been planted. A ditch surrounds the rounded portion of each teardrop-shaped inner parcel, providing slopes that rise to the central plateau ("flat area"), which comprises most of the total parcel area. These interchange-road and ditch slopes

Fig. 4. Ranges of heights of herbaceous vegetation on 12 study parcels and an urban lawn between 24 May and 27 September, 1981. Each black dot represents a biweekly mean height. The numerals above the X-axis represent the number of times the parcels and lawn were mowed.

rise at angles of about 30-60° from the horizontal plane.

Many Man-made perturbations in and around the study area, especially involving road resurfacing and modification, and changes in land use occurred during the 1980 and 1981 field seasons (April-October). These included:

- 1) the erection of noise barriers between interchanges, primarily in 1980 (Fig. 1);
- 2) the construction of a department store and playing field in 1980 and initial construction of a shopping center in 1981, at Pinecrest NW and SE, respectively (Fig. 1);
- 3) the partial reconstruction of the Richmond SW2 ramp in the spring of 1981;
- 4) the Mud Creek Project adjacent to the study area at Richmond SW2, for which flood/erosion barriers were constructed on both banks of Graham Creek;
- 5) the resurfacing of the Queensway and associated ramps from Acres to Pinecrest, inclusive, with the recurbing and reshouldering of the Queensway and ramps from Moodie to Woodroffe, inclusive, in 1981;
- 6) the removal of trees (primarily a few White Elms, Ulmus americana, at Maitland and Pinecrest in 1980 and 1981);
- 7) the planting of 1500 sycamore and maple saplings on the inner parcel slopes adjacent to Moodie Drive, and Acres and Richmond Roads in 1981; and
- 8) the construction of the Ottawa River Parkway extension, through the "greenbelt" (an open-field area which is infrequently mowed)

to the immediate west of the Woodroffe interchange,
in the late summer and fall of 1981, drastically affecting
Woodroffe NW2 and SW2.

METHODS

FIELD-WORK SCHEDULE

About 400 h of field work was done from 22 March to 15 October 1980. During this time parcels and burrow entrances were surveyed. Study-area roads were systematically searched for roadkills every other morning at 07:00 EST (or EDT); each search took 1-2 h depending upon the number and location of roadkills found. Live-traps were set at night after dark and checked for catches by 08:00 the next morning. The traps were left set and regularly checked until 14:00 if no Woodchucks were caught by 08:00. Twenty nights of this routine (from mid-May to late-July) resulted in the capture of only 3 Woodchucks.

From 15 February to 28 October 1981, 473 h of field work was done during evenings from 14:00-dark (evening convectional thunderstorms often curtailed work during July and August). Fifty-one nights (140 trap-hours) of live-trapping was done during evenings from about 15:00 to sunset. From 04 April to 07 July (34 trap-evenings) the proportion of Woodchucks captured per hour of trapping effort ranged from 8-15% (monthly means, See Appendix B). Twelve nights of trapping from 08 July to 12 August resulted in 0% trap success; thus trapping was temporarily suspended. From 06-12 September trap success rose to 17% (mean of 5 trap evenings). Disappearance underground of most Woodchucks by 12 September made further trapping fruitless.

In 1981, road searches for roadkills were done bidaily starting at 14:00. During road searches or independently, I "cruised" the study area to check for active marked Woodchucks before I settled at a

specific parcel to trap or observe previously marked individuals. The marked individuals for which data was presented were observed a total of 117 h. An observation period was ended when the individual went into its burrow and did not emerge within about 15 min. On many occasions 2 or more Woodchucks were observed simultaneously in an area. A single location at which a marked Woodchuck was seen is herein referred to as a "spotting". Most of the 129 spottings of these marked Woodchucks were made while I was cruising.

SURVEYING AND BURROW ENTRANCE PLOTS

A burrow system is defined as "the entrances and tunnels regularly used together by an individual (or occasionally by a family or other small group) Neither prolonged utilization by [1] individual nor underground physical continuity is implied" (Merriam 1971). A single entrance of a burrow system is herein referred to as a "burrow entrance".

A 25-m grid was staked on the 4 Moodie parcels and Acres SW to provide reference points for plotting the distribution of burrow entrances and Woodchuck movements on similarly gridded 1:1250 National Capital Commission-Regional Municipality of Ottawa-Carleton maps. Burrow entrances were plotted in the spring (March and April, as soon as the snow melted), summer (mid-June), and fall (October, once most Woodchucks were hibernating or at least had gone underground) of 1981. Those burrow entrances among dense shrubs at Pinecrest, Woodroffe, and Maitland were plotted only in the spring and fall, when foliage was not present.

CENSUS

Attempts were made to live-trap Woodchucks in 23 X 23 X 610 cm (9 X 9 X 24 inch) National live-traps, using as bait peanut butter mixed with rolled oats (to prevent running in the summer heat) and slices of MacIntosh apples. Traps were usually set in pairs, 1 at a burrow entrance along the runway where a Woodchuck was seen, and a second at another entrance the Woodchuck frequently used. In 1981, if the Woodchuck was not caught within 1.5 h, the traps were removed to attempt the capture of another individual, because only 9 traps were available for use.

Trapped Woodchucks were handled with the aid of a Halvorson cone (Halvorson 1972) redesigned for Woodchucks (Appendix C). The sleeve was placed over the mouth of the trap and the trap door opened. The Woodchuck usually darted into the sleeve and cone when the sleeve was held up with my free hand allowing the animal to see light at the cone end. Sex, age-class, breeding condition, and mass were recorded for each captured Woodchuck. Woodchucks were classified as adults (≥ 1 year old) or juveniles (young-of-the-year). As juveniles matured and became more difficult to classify by obvious size and mass differences from adults, a combination of lower-incisor width, pointedness, and incisor staining was used (Merriam 1960, Davis 1964). In general, I found the white band of hairs posterior to the rhinarium more prominent on juveniles. Juveniles' lower incisors are narrower and more pointed and their incisors are virtually unstained when compared with adults' incisors. Incisor length, width, and wear were measured

on roadkills to determine if these measurements or length:width or length:wear ratios could be used to distinguish adult Woodchucks from juveniles reliably (Appendix D).

A black Nyanzol fur-dye was prepared as described by Melchoir and Iwen (1965). The dye was applied with a 2.5-cm-wide paint brush to uniquely mark the fur of Woodchucks using different positions or combinations of 1 or 2 block areas (Fig. 5). The dye remained clearly visible on the underfur for the duration of the season on post-moult individuals. One Woodchuck marked in July 1980 was still clearly marked in May 1981.

Serially numbered No. 3 monel eartags (National Band & Tag Co., Newport, Kentucky) were used to mark captured Woodchucks. Each individual received 2 identically numbered tags, 1 in each ear. "CARLETON UNIV." was stamped on 1 tag and "PH. SUE/231-3715" was stamped on its mate, in the hope that any tagged roadkills picked up by maintenance crews or passersby, carcasses brought home by dogs or cats, or wide-ranging animals otherwise found dead would be reported. No phone calls were received.

Infections of the ears at the sites of eartags were common although all tags were cleaned with 70% ethanol prior to application. The infected ears of recaptured animals were cleaned with 70% ethanol and sulfa powder was applied liberally. I noted that healing was better when a tag was applied to the thinner, outer part of the pinna, permitting free movement of the tag around the periphery.

Fig. 5. Dorsal-view schematic diagram of a Woodchuck showing 9 blocks of the animal's fur. These can be dyed singly or in pairs for individual marking.

No tag losses were noted although 1 tagged individual had an approximately 5-mm tear associated with the tag in 1 ear.

Because moulting resulted in dye loss and trapability dropped to zero between early July and mid-August, I had to use a tripod-mounted Bushnell 20-45X zoom spotting scope to identify individuals by reading their eartag numbers at close range (15-20 m). Some of the tags were mud-covered or had rotated and identification of their bearers was impossible.

Censusing was done in the spring (early April to mid-May) and fall (mid-August to mid-September) of 1981. The marked and unmarked individuals present on each parcel were counted. Unmarked Woodchucks were carefully observed for subtle natural markings to avoid counting them more than once.

MOVEMENTS

Marked animals were watched for 5- to 160-min periods and/or spotted during other operations. Their locations were plotted on 1:1250 maps, using plotted grid markers, burrow entrances, trees, light standards, and/or other features (sewers, raised manholes, and rocks) as reference points. Virtually no movement data were obtained at Moodie and Acres SW because of the lack of resident Woodchucks, my inability to locate emigrants, and the tall vegetation. Only 1 Woodchuck resided at Woodroffe throughout the 1981 season and Maitland had no resident Woodchucks.

The choice of Woodchucks for which data are presented was based

on a combination of their i) being marked, ii) remaining in the study area for a prolonged period of time, and iii) location(s) of activity being visible from my car (parked on an on- or off-ramp shoulder) or being such that I could observe them from an unobtrusive location on the parcel itself (preferably at a distance of over 100 m).

Movements were quantified in 2 ways. The area of the "range", containing all locations at which a marked Woodchuck was observed over the 1981 season, was estimated using the minimum area method (Haugen 1942, Godfrey 1954, Flyger 1960, Bronson 1964, Storm 1965, Pack et al. 1967). The area of a polygon formed by joining the outlying points at which an individual was observed was measured. Range length, the straight-line distance between the 2 most distant observed locations of a Woodchuck, was also calculated because Godfrey (1954) found it reached its maximum with fewer observed locations than did range area. Range width was measured as the distance between the 2 furthest points of the minimum area polygon at right angles to the range-length axis. A second range length and width was calculated similarly to remove the effect of obvious sallies and/or areas used for a short period of time prior to or after an individual relocated. A Woodchuck's range with a range length:range width ratio of more than 2.0 is considered to be "linear".

Road-crossing data were obtained from 35 marked Woodchucks at the 6 study interchanges. Nine of these individuals either were roadkilled, emigrated and could not be relocated, or wandered too much; thus insufficient data for meaningful range length:width

analysis was available for only 26. Movement data (including road-crossing) were collected primarily during the regular field-work hours (14:00 EST (or EDST) to sunset) while cruising, trapping, or observing marked Woodchucks. I assume these road-crossing data are representative of the interchange Woodchuck populations studied. Because of low numbers, statistical tests did not seem appropriate.

Marked Woodchucks will be referred to by their eartag number or "name", sex, and age-class (Ad=adult and j=juvenile).

MORTALITY

Bidaily road searches (driving in a car along the Queensway, on interchange roads, and on ramps in the study area) were done to check for roadkills of Woodchucks and other vertebrates from 01 April to 30 September in both 1980 and 1981. From mid-April to mid-September 1981, roadkills were also sought as I checked for Woodchuck activity at the various interchanges.

Roadkills were identified to species. Woodchucks were checked for tags, sexed, aged, weighed, and their incisors were measured. The poor condition of some carcasses did not permit collection of some of these data.

Observation over an evening (from 15:00 EDST to sunset) of Woodchuck carcasses in "good" condition showed that the direction in which the head pointed when first observed was not altered. I watched 2 individuals hit by cars and the orientation of their carcasses on the roads after impact was in the direction of movement when they were

hit. Thus the direction that unutilated carcasses faced when first found was considered relatively reliable evidence of their original heading when hit, assuming that the Woodchuck was run over by a vehicle's tire and did not bounce off it.

The parcels were checked for carcasses after mowing by large mowers. The activities of visiting domestic mammals were observed.

Summer traffic volume figures (1981) for ramps were obtained from the Ontario Ministry of Transportation and Communications. Because a single vehicle's speed changes along a ramp, posted maximum ramp speeds were used to represent mean speeds in comparing the numbers of roadkills per unit distance at different ramp speeds. Because of the great variability in vehicle speed associated with paving and other reconstruction activities throughout much of the field seasons and the resulting frequent traffic tie-ups, speed data for the traffic on the Queensway itself were not included in the analysis.

RESULTS AND DISCUSSION

GENERAL BACKGROUND ON THE STUDY POPULATIONS.

A. Populations

The study area was chosen so that rural, suburban, and urban populations of Woodchucks could be observed and comparisons of habitat characteristics important in determining population levels could be made. The numbers of burrow entrances per hectare in the fall of 1981 are shown in Fig. 6. The same relative numbers of burrow entrances was seen in the fall of 1979. Assuming that there is some direct relation between the number of burrow entrances and the number of Woodchucks inhabiting an area, Moodie, Acres, and Richmond were expected to have similarly high populations of Woodchucks. Pinecrest, Woodroffe, and Maitland interchanges are comparable in having low burrow-entrance densities compared with those of the 3 suburban and rural interchanges. The low densities of burrow entrances at these urban interchanges suggest that their Woodchuck populations are low.

During the 1981 field season 56 Woodchucks were live-trapped and tagged in the study area. Ten additional Woodchucks were individually distinguishable by natural markings. Fewer than 15% of the known resident Woodchucks eluded live-traps; the majority of these were juveniles. Table 1 shows the numbers of Woodchucks and the densities of their populations at the 6 study interchanges in the spring and fall of 1981. The Richmond interchange has by far the largest and densest population in the study area.

Fig. 6. Density of Woodchuck burrow entrances in the fall (late September and October) of 1981 on the 27 study parcels.

Table 1. Woodchuck populations at the 6 interchanges in the spring and fall of 1981.

Interchange	Setting	No. of Woodchucks		Density (Woodchucks/ha)	
		Spring	Fall	Spring	Fall
Moodie	Rural	2	3	0.38	0.57
Acres	"	2	3	1.13	1.69
Richmond	Suburban	28	39	3.85	5.36
Pinecrest	Urban	7	8	0.89	1.01
Woodroffe	"	1	3	0.16	0.49
Maitland	"	2	0	0.67	0.00

The Queensway interchange Woodchuck densities (Table 1) are generally higher than those of mostly rural populations found in a variety of habitats (Table 2). Only the fall density at Maitland did not exceed that reported by Doucet et al. (1974) along Quebec-Ontario highway overpass embankments (0.18/ha). Most densities exceeded that of Snyder et al. (1961) for Woodchucks living in an old-field habitat (0.34/ha). The high density of a Woodchuck population (3.33/ha) reported by Geggie (1980) illustrates the attraction of Woodchucks to vegetable gardens. However, the spring and fall population densities (3.85 and 5.36 Woodchucks/ha, respectively) at Richmond exceed this 'optimal' habitat density, and are the highest ever found to date.

The compositions of the populations of Woodchucks at the various interchanges are summarized in Fig. 7 with respect to the animals' status. Residents are animals that survived on a study parcel at a particular interchange throughout the season, although they may have moved from 1 parcel to another during this time. The Moodie Drive interchange had no residents. The Acres interchange appeared to have only 1 resident (an untagged female adult on Acres SW that was not 'uniquely' distinguishable, but appeared to be the same 1 seen at various locations on the parcel throughout the season). The Richmond interchange had the highest number of residents in the fall, 38% (15/39) of them being juveniles. The Pinecrest interchange had the next highest resident population, whereas Woodroffe and Maitland had virtually no resident Woodchucks.

Residents that were killed by road-driven vehicles are not

Table 2. Woodchuck densities reported in various habitats.

Density (Woodchucks/ha)	Habitat	Reference
0.01	Roadside adjacent to agricultural land New York	Manville 1966
0.02	Old-field associations Pennsylvania	Bronson 1962
0.05	Recessional moraine, marginal agriculture Ontario (southern)	de Vos and Gillespie 1960
0.07	Old-field associations and hedgerows Maryland	Grizzell 1965
0.18	Overpass embankments Ontario and Quebec	Doucet et al. 1974
0.34	Old-field associations Pennsylvania	Snyder et al. 1961
0.34	Urban park Ontario (Ottawa)	Geggie 1980
1.00	Occasionally grazed fields Quebec	Geggie 1980
3.33	University vegetable garden Ontario (Ottawa)	Geggie 1980

Fig. 7. Population composition at the study interchanges over the 1981 field season. Categories are defined in the text.

included as residents in Fig. 7, but as "residents killed"; these 2 categories are mutually exclusive. The Pinecrest population suffered a relatively higher number of roadkills of marked animals (4/11, 36%) than did the Richmond population (5/36, 14%).

Only 21% (10/48) of the Woodchuck roadkills at interchanges were known individuals. Because most of the residents, immigrants, and emigrants had been tagged or were naturally marked, unknown roadkills represent potential or actual visitors from peripheral areas (Fig. 7).

Visitors were Woodchucks actually seen visiting an interchange study area on which they were not residents (Fig. 7). Some were tagged; others were naturally marked. It is likely some very short-term visitors were not observed. Because of problems with high vegetation hindering visibility and because there were relatively high peripheral populations nearby, I suspect that the numbers of visitors at Moodie and Acres are underestimated, although most of the burrow entrances on Moodie NW, NE, and SE were at the roadside permitting observation of visitors. Unmarked roadkills (Fig. 7) were not included in the visitor category because it is not known if they actually made it to an interchange study parcel or were killed on a road prior to a visit.

B. Activity Patterns and Feeding

Although some of these Queensway Woodchucks were observed above ground in the morning, most of their activities during this time were restricted to sunning or simply sitting in an alert position at their

burrow entrances. Tree-stumps and raised manholes with burrow entrances around them were used by a number of the Woodchucks for sunning or as observation platforms. Very little feeding or movement activity was observed in the morning during the months of May to September inclusive. Activity peaked between 15:00 and about 21:00 (sunset) EDST. Grizzell (1955) and Hamilton (1934) personally observed a similar activity pattern, although Grizzell (1955) stated that summer trapping was equally successful whether done in the morning or evening. This latter finding was not true for Queensway Woodchucks; morning trapping proved to be highly unsuccessful during 1980. The bimodal summer activity pattern seen by Bronson (1962) and Hayes (1976) did not apply to Ottawa Queensway populations, nor did the pattern of a high proportion of feeding and related movements occurring in the morning observed by Merriam (1966).

Appendix A lists the common and some other plant species found growing on the rural, suburban, and urban study parcels. Although stomach analyses were not done, information on diets was obtained through direct observation of feeding Woodchucks. Suburban-urban Woodchucks most frequently ate the leaves and flowers of Common Dandelion, Taraxacum officinale, with Cow Vetch, Vicia cracca, Red Clover, Trifolium pratense, and White Clover, T. repens, being eaten less commonly. Hamilton (1934) found that Common Dandelion was "without question the most important food of early spring [April and May]. Captives prefer[red] leaves of this plant to that of any other food."

Cow Vetch was also common at the Moodie interchange and at Acres SW, but the low-growing plant species tended to be shaded out by the tall grasses. Woodchucks in these areas were observed eating unidentified grasses most of the time. Observation of these rural Woodchucks was possible only when parcels had been recently mowed.

C. Burrow Systems and Burrow Entrances

None of the observed Woodchucks remained at 1 burrow system throughout the season, although Mell⁹j at Pinecrest was roadkilled when dispersing from her natal burrow system. Rotation among 3 to 12 burrow systems was observed throughout the summer. These rotations usually occurred frequently. Less commonly movements to different burrows were part of a dispersal event or were exploratory in nature (where an individual was seen only once at a particular burrow system). Merriam (1971) stated that burrow system exchange occurs at a high rate and de Vos and Gillespie (1960) found that Woodchuck burrows are not inhabited continuously.

The burrow systems available proved to be utilized by many Woodchucks over the season. Usually the visits to a burrow system by different Woodchucks were temporally separated; however, simultaneous use of a burrow system was observed, regardless of the age and sex of the Woodchucks, as found by Hamilton (1934). Utilization of burrow entrances by associated animals and my observation of many interburrow movements encouraged abandoning my plans of assessing active and inactive burrows. Although de Vos and Gillespie (1960) and Henderson and Gilbert (1978) found 56% and 80%, respectively, of the burrow

systems active in the spring, these figures have little relevance for Queensway populations. Most Queensway burrow systems were visited regularly by a number of resident Woodchucks, sometimes at the same time or were used as stop-over locations for a succession of emigrants, immigrants, and/or visitors. Thus the vast majority of burrow systems was used at some time over the season by Woodchucks.

Figure 8 shows the number of new burrow entrances (includes new burrow system entrances and additions to existing burrow systems) that were dug between mid-March and early October of 1981 for each of the study parcels surveyed. Those new burrow systems and burrow entrances for which the individual digger responsible could be reliably identified are listed in Table 3. No age-related differences are apparent from this small sample. Only 3 of the 12 new burrow systems and 2 of the 8 new burrow entrances to existing burrows were dug by resident Woodchucks. The use of existing burrows is the general rule among the Queensway Woodchucks as found elsewhere by de Vos and Gillespie (1960).

On the inner parcels at the Pinecrest, Woodroffe, and Maitland interchanges mature shrubs are found on slopes adjacent to the interchange roads (e. g., Fig. 9). Of 12 Woodchucks immigrating to or visiting 1 of these inner parcels, 10 used burrow entrances in the shrubs adjacent to the interchange road and grazed on grassed areas within 10-15 m of cover. Eleven of the 12 Woodchucks were immigrating to or visiting previously unoccupied parcels; thus social interaction with resident Woodchucks does not explain this preference for burrows

Fig. 8. Burrow entrances added and lost over the 1981 field season at 27 study parcels.

Table 3. Comparison of Woodchucks that dug new burrow systems or entrances during 1981. (R=resident, RK=resident killed, I=immigrant, IK=immigrant killed, V=visitor, and VK=visitor killed)

New burrow systems (No. of burrow entrances)			New burrow entrances		
Adult	Juveniles	Woodchuck status	Adults	Juveniles	Woodchuck status.
* (2)		R	*		I
* (3)		RK	*		I
* (1)		I	*		VK
* (7)		I		*	R
* (4)		IK		*	R
* (1)		V		*	I
	* (1)	R		*	I
	* (2)	I		*	V
	* (2)	I			
	* (9)	IK			
	* (1)	I or V			
	* (1)	V			
6	6		3	5

Fig. 9. Pinecrest SW, illustrating the distributions of burrow entrances, trees, and shrubs.

in shrubby areas. This suggests that individuals unfamiliar with an area will seek cover, at least initially, when it is available. Also, the shrub-grass interface is slightly more elevated than a parcel's flat area providing greater visibility for these "naive" Woodchucks.

D. Road-crossing

Table 4 compares the success of road-crossing by marked individuals in the 2 age classes, adults and juveniles. The observed animals freely crossed 1-lane ramps, with juveniles showing a higher degree of success than adults. A single 2-lane ramp exists (Richmond NE2). This high-traffic-volume ramp was known to have been successfully crossed by #45♂Ad 6 times, whereas #43♂j was killed attempting to cross it. Those animals that attempted to cross the Queensway or interchange roads were less common. Three of 6 crossing attempts were successful (#3♂Ad at Moodie made 2 crossings of Moodie Drive and Mel2♂j crossed the Queensway at Pinecrest once), yet 3 of the 5 individuals known to have attempted to cross 4-lane roads were killed by vehicles.

Crossing of the 4-lane Queensway is dangerous. As Manville (1966) found with roadside Woodchucks, my study animals usually appeared quite unconcerned about passing vehicles. However, the honking of horns and the loud noises made by trucks driving over pavement irregularities invariably sent Woodchucks running to their burrow entrances. The Queensway traffic volume (40-50 000 vehicles/day) and speed (maximum speed limit 100 km/h) were much higher than those on associated ramps. Only 3 study Woodchucks are

Table 4. Road crossings observed or implied (by locations of marked Woodchucks) and percent mortality. Figures in parentheses are the numbers of marked Woodchucks killed (†) or hit but surviving (*) while crossing a road of specified width.

Width of road crossed	Age class	No. of road crossings	Percentage crossing mortality
1-lane	Adults (n=24)	60 (2†)	3
	Juveniles (n=11)	34 (1*)	0 (3%)
	Total (n=35)	94 (2†, 1*)	2 (1%)
2-lane	Adults	6 (0†)	0
	Juveniles	1 (1†)	100
	Total	7 (1†)	14
4-lane	Adults	3 (1†)	33
	Juveniles	3 (2†)	67
	Total	6 (3†)	50

known to have attempted to traverse the expressway; 1 of them (Mel2[♀]j) actually succeeded! Woodchuck #48[♀]Ad, who resided on Acres NE, crossed the Acres NE ramp on at least 5 occasions. One evening she approached the Queensway, actually venturing out onto the shoulder. When a series of 8 cars drove by in the right lane, she turned around quickly and ran back to her burrow entrance.

Some Woodchucks avoided crossing interchange roads by using the Queensway shoulders under interchange bridges to move from an east to a west parcel (or vice versa). Ledges under bridges (steel girders) large enough to permit passage by a Woodchuck-sized animal also exist and may be used by some animals to avoid traversing 4-lane interchange roads. Few Woodchucks were killed on interchange roads near bridges, whereas roadkills on the Queensway at bridges were more common. Initial sightings of immigrants near these ledge areas also suggest this mode of travel is used.

All of Nepean's storm sewers drain into Graham Creek, which runs through Richmond SW2. On the west side of this parcel, a cement culvert passes under the Richmond SW2 ramp. This culvert has a flood control tunnel (33.75 m long, 3.40 m wide, and 1.85 m high) situated above the creek throughway. Woodchuck #10[♀]Ad appeared to use this tunnel to cross beneath the Richmond SW2 ramp. Woodchuck #10 had been trapped on 19 April 1981 at a burrow entrance beside the Richmond SW2 entrance to the culvert's tunnel. She temporarily moved to the west side of the Richmond SW2 ramp from 30 April (at which time tracks were observed in the sand on the culvert floor) to 05 May. On 06 May #10

had returned to the location at which she was trapped. On 16 February 1982, Woodchuck tracks were observed in the snow on the tunnel floor, leading to and from a Richmond SW2 burrow entrance. Because these tracks led to and from a burrow entrance less than 5 m from the location at which she was last observed in 1981, I suspect that these tracks were made by #10.

A metal culvert 20.63 m long and about 30 cm in diameter running under the Richmond NE ramp had Woodchuck runways leading to both entrances; thus it must have been used at least as a refuge.

E. Associated Species

The presence of humans does not appear to upset the Woodchucks. At the Richmond interchange, children explore the ditch in Richmond SW and the creek running through Richmond SW2, and at Richmond and Pinecrest, pedestrians cut across parcels. The Woodchucks either retreated to their burrows without giving an alarm call and soon popped their heads out to observe, or simply ignored passersby. Geggie (1980) found that Woodchucks' tolerance to Man increases in habitats frequented by Man.

Eastern Cottontails, Sylvilagus floridanus, were living in the shrubby areas adjacent to the interchange road on all 4 Pinecrest inner parcels, 2 of the 4 Woodroffe inner parcels, and 1 of the 2 Maitland inner parcels. White-footed Mice, Peromyscus leucopus noveboracensis, were also live-trapped at Woodchuck burrow entrances in the shrubby areas at the 3 urban interchanges. A Striped Skunk,

Mephitis mephitis, inhabited a burrow system on Richmond SW2 for about a week during June. Although 5 Woodchucks were observed using this burrow system over the summer, none was seen at or near it for the week of the skunk's occupation. Meadow Voles, Microtus pennsylvanicus, were frequently seen taking refuge in Woodchuck burrow tunnels at the Moodie interchange parcels and at Acres SW, where there were high vole populations. Their burrowing activity at the mouths of Woodchuck burrow entrances and subsequent weathering action resulted in hastened collapse of the entrances, compared to burrow-entrance mouths at parcels where few to no Meadow Voles were present.

F. Summary

Frequent mowing at suburban and urban interchanges encourages the abundant growth of Common Dandelions, a food Woodchucks prefer. The shrubby areas provide cover for "naive" Woodchucks. Tree stumps and raised manholes are used as sunning and observation platforms. As will be presented in the following section, slopes and trees on flat areas provide preferred locations for burrow entrances. This combination of habitat characteristics produces a habitat that encourages successful exploitation by Woodchucks. The population densities, which generally exceed those reported for rural populations in a variety of habitats, attest to the attractiveness of these interchange areas to Woodchucks.

The Woodchucks residing at the interchanges appear to have become "road-wise," with single-lane ramps being crossed frequently with a high rate of success. Wider roads are crossed far less frequently by

these Woodchucks; those that do attempt the traversal of wider roads suffer a greater rate of mortality. Culverts, and the Queensway shoulder and ledges under bridges are used by Woodchucks in lieu of crossing ramps and the interchange roads, respectively.

HABITAT UTILIZATION

A. Burrow Entrance Associations

Burrow entrance location can be used as an indicator of the habitat selected or utilized by the Queensway Woodchucks.

Woodchucks prefer slopes to flat areas, with 327 (75%) of the 437 burrow entrances counted being on slopes on the 20 of the 27 study parcels where a choice between slopes and flat areas is available and burrow entrances are present (Table 5). This is striking for the total flat area greatly exceeds that available on slopes. Parcel data for several interchanges were pooled where the number of burrow entrances per parcel was less than 5. Based on land-area availability, an expected 1:1 distribution of burrow entrances on slopes and flat area conservatively tests these data for a non-random distribution of burrow entrances. Using the Brandt and Snedecor formula (Bailey 1959) for a 2 X 9 contingency test, there is a highly significantly greater number of burrow entrances on slopes than on flat areas ($\chi^2=29.64$, 8 df, $p<0.001$).

Isolated mature trees grow on the grassed flat areas of the Pinecrest, Woodroffe, and Maitland interchange parcels. These trees include an assortment of flowering crab, ash, maple, oak, and elm (Appendix A). For example, Fig. 9 illustrates the distribution of mature trees, shrubs, and burrow entrances on Pinecrest SW. Table 6 shows the numbers of burrow entrances on flat areas associated with and not associated with trees. Seventy-eight percent (32/41) of the

Table 5. Numbers of burrow entrances on slopes and flat areas on parcels where both choices were available.

Interchange and parcel	No. of burrow entrances		
	on slopes	on flat areas	Total
Moodie			
NW	26	0	26
NE	14	11	25
SW	21	4	25
Acres			
SW	21	19	40
Richmond			
SW	80	19	99
SW2	67	16	83
Pinecrest			
NW	12	7	19
NE	6	9	15
NW2	1	2	3
NE2	10	0	10
SW2	0	1	1
SW	12	7	19
SE	4	0	4
Woodroffe			
NW	15	2	17
NW2	1	4	5
NE	6	0	6
SW	10	1	11
SW2	6	0	6
Maitland			
NW	6	0	6
SE	9	8	17
Totals	327	110	437
Percentage	75	25	100

Table 6. Association of Woodchuck burrow entrances with trees on flat areas of the 3 interchanges with isolated mature trees.

Interchange and parcel	No. of burrow entrances		Totals
	Associated with trees	Not associated with trees	
Pinecrest			
NW	4	3	7
NW2	2	0	2
NE	5	4	9
SW	5	2	7
SW2	1	0	1
Subtotal	17	9	26
Woodroffe			
NW	2	0	2
NW2	4	0	4
SW	1	0	1
Subtotal	7	0	7
Maitland			
SE	8	0	8
Total	32	9	41

burrow entrances are associated with trees. Even if one assumes an expected 1:1 ratio, (a very conservative test based on land-area availability) this association with trees is highly significant ($\chi^2=12.9$, 1 df, $p<0.001$), using a χ^2 -goodness-of-fit test (Lehner 1979).

Figure 10 shows that at all interchanges except Maitland and Richmond, there were higher proportions of burrow entrances facing south (90° sector facing from SW to SE) than facing in any other 90° sector. Burrow entrances on west-facing slopes exceeded those on north- or east-facing slopes at Acres, Richmond, and Woodroffe. The percentages of burrow entrances on flat areas or in hollows are not unexpectedly high (21% of the 504 burrow entrances), considering these non-slope areas constitute far more than one-fifth of the area of almost all parcels.

Although all parcels do not provide a choice of slopes with a full range of aspects, those that do not each have few (<26) burrow entrances. I consider that by summing the data from all parcels these inconsistencies become negligible. The numbers of parcels, from a total of 25 parcels, for which particular aspect choices are not available are: 2 parcels lack flat areas, 3 parcels lack east-facing slopes, 5 parcels lack north-facing slopes, 6 parcels lack west-facing slopes, and 5 parcels lack south-facing slopes. The numbers of these parcels lacking a particular aspect choice are highest for the latter 3 aspects. If anything, these data underestimate the south- and west-facing slope preferences. A χ^2 -goodness-of-fit test (Lehner

Fig. 10. Relative frequency of burrow entrances on slopes with different aspects at the 6 interchanges. F=flat areas or hollows, S=south-facing (90° sector from SW to SE). etc.

1979) shows that the overall aspect ratio (of the 400 burrow entrances on slopes, 20% were on north-, 33% on south-, 19% on east-, and 28% on west-facing aspects) shows a highly significant difference ($\chi^2=20.29$, 3 df, $p<0.001$) from a 1:1:1:1 ratio, assuming equal land area availability for each of the 4 aspects.

B. Movement

To obtain a more focused picture of how Woodchucks actually utilize their habitat on the study parcels, all locations at which marked animals were observed were recorded. Lines marked on maps to indicate movements are referred to as "movement-tracks" herein.

To conform with ecological tradition, and thus permit comparisons with the existing literature, movement data are presented as range sizes expressed as minimum range areas. Data sufficient for statistical analysis were obtained only for the Woodchucks of the Richmond and Pinecrest interchanges (Table 7) because of sparse populations at the other interchanges.

Welch's approximate t-solution (Scheffé 1970) was used to determine if the ranges of the Richmond and Pinecrest populations of Woodchucks were significantly different. A difference would indicate that the 2 populations were different and/or they were utilizing their habitats differently. Unexpectedly, the mean Pinecrest range area and length were not significantly greater than those of the Richmond sample (Table 7). This was probably due to small sample sizes and high variances. An F-max test (Lehner 1979) showed that their range

Table 7. Sizes of ranges of Woodchucks at the 2 interchanges with the highest populations.

Range measurement	Richmond N=17	Pinecrest N=7	t*	df	p
Minimum range area, ha					
Mean	0.34	1.38	2.05	6	>0.05
SD	0.22	1.33			
Range length, m.					
Mean	129.5	217.8	1.76	7	>0.05
SD	50.9	128.3			

* Welch's approximate t

area variances ($F=38.03$) and length variances ($F=6.36$) were significantly different ($p<0.05$). Because the Pinecrest sample was female-biased, a Student-Newman-Keuls multiple range test (Sokal and Rohlf 1969) was used to analyse range measurements for the various sexes and age-classes for Richmond Woodchucks (Table 8). All 6 combinations of sex and age-class pairs proved to be not significantly different at the 0.05 probability level.

These quantitative measures shed little light on the actual use of the interchange habitat by the Queensway Woodchucks. The summary of the analysis of their movement-tracks reveals generalizations upon, and variations in, behaviour and range characteristics (Table 9).

Figures 11-15 illustrate the high degree of movement between burrow systems that was evidenced by virtually all the observed Woodchucks. No obvious temporal pattern was evident.

Whiteye?Ad (Fig. 11) and #40?Ad travelled about the flat area of Pinecrest SW, making very little or no use, respectively, of existing slopes. This may have been because they were the only 2 Woodchucks on the 1.72-ha parcel. When Buff?j immigrated in July it resided at a burrow in the central area of the shrub-grass interface. Whiteye chased Buff back to its burrow on 2 separate occasions, not permitting Buff to wander on the parcel. More extensive movement by Buff was observed primarily after the 2 resident adults disappeared and, I assume, entered hibernation at the end of August. The initial linearity of Buff's range was enforced by Whiteye's aggression and the shrub-grass interface. Once allowed to move freely, Buff's range took

Table 8. Sizes of ranges of Woodchucks at the Richmond interchange compared between sexes and age-classes.

	Adults (Ad)			Juveniles (j)			Ad + j	
Range measurement	3 ♂♂	7 ♀♀	10 Ad	3 ♂♂	3 ♀♀	7 j*	6 ♂♂	10 ♀♀
Minimum range								
area, ha								
Mean	0.39	0.32	0.34	0.38	0.41	0.35	0.38	0.34
SD	0.14	0.25	0.22	0.33	0.07	0.23	0.22	0.21
Range length, m								
Mean	143.2	119.8	123.5	136.5	158.5	138.0	140.1	127.9
SD	24.3	41.5	38.4	72.4	78.2	67.4	48.5	54.4

* includes 1 unsexed juvenile.

Symbols for Table 9.

R	Resident
RK	Resident killed
I	Immigrant
E	Emigrant
V	Visitor
VK	Visitor killed
*	Burrow system(s) most often used
~	Burrow system(s) infrequently used
o	Dug a new burrow entrance or system
T	Burrow system(s) associated with tree(s)
S	Burrow system located among shrubs
X	Crossed a paved surface of known width
?	Crossed a paved surface of unknown width
+	Killed when crossing road of specified width
C	Used a culvert instead of crossing road itself
B	Travelled under bridge instead of crossing interchange road
W	Wandered too much to make range-shape analysis meaningful
GC	Movements associated with Graham Creek
Q	Movements parallel to the Queensway
Sh	Movements parallel to shrub-grass interface
Ra	Ranged on either side of an on- or off-ramp
F	Movements radiated over the flat area of a parcel
l/w	Length/width
()	Length/width ratio of range removing the obvious effect of sallies and/or areas used for short periods of time prior to or after an individual relocated

Table 9. Summary of range and habitat utilization characteristics of observed individuals.

Interchange	Woodchuck	Status	on slopes	Burrow systems used		Existing or No. Newly dug	Roads crossed (No. of lanes)			Range 1/w	Contributing factors
				on	flat		(1)	(2)			
								(4)			
Moodie Acres Richmond	3	♂ Ad	V	*	-	4	X	X	X	—	W
	48	♀ Ad	I	*	-	3	X	X	X	1.8 (1.2)	Ra
	10	♀ Ad	R	*	-	9	C	C	C	3.1 (6.2)	GC
	21	"	"	*	-	8	X	X	X	1.4	GC, Ra
	37	"	"	*	-	7	C	C	C	2.3	Ra
	39	"	"	*	-	5	X	X	X	8.1	Q
	46	"	"	*	-	3	X	X	X	6.1	Q
	44	♂	"	*	-	6	X	X	X	3.1	Q
	32	♀	RK	*	-	3	X	X	X	—	W
	7	♂	"	*	-	5	X	X	X	4.9	Q
	54	"	I	*	-	11	X	X	X	4.0	GC
	16	♀	E	*	-	6	X	X	X	2.2	GC, Ra
	45	"	V	*	-	5	X	X	X	2.5	Q
	53	"	R	*	-	7	X	X	X	1.7 (5.2)	Q
	60	"	"	*	-	9	X	X	X	1.9	Ra
Pinecrest	50	♂	"	*	-	3	X	X	X	4.3	Q
	Untag	♀	"	*	-	4	X	X	X	7.1 (5.1)	Q
	56	♀	RK	*	-	3	X	X	X	2.3	Ra
	43	"	"	*	-	4	X	X	X	—	W
	55	"	I	*	-	12	X	X	X	3.6	Q, P
	15	♀ Ad	R	*	-	10	X	X	X	1.2 (1.7)	F
	40	"	"	*	-	5	X	X	X	1.5 (1.4)	F
	Whiteye	♀	"	*	-	4	X	X	X	—	Q
	Darky	♀	RK	*	-	4	X	X	X	5.2	Q
	Mom	"	E	*	-	4	X	X	X	5.2	Q
	61	"	R	*	-	5	X	X	X	2.7 (4.6)	Q
	58	♂	I	*	-	8	X	X	X	—	W
	Mel2	♀	"	*S	-	6	X	X	X	1.6 (4.1)	F (Sh)
	Buff	♀	"	*S	-	3	X	X	X	—	Q
	Woodroffe Maitland	Mell	♀	VK	*	-	1	X	X	X	2.7 (5.5)
49		♀ Ad	R	*	-	5	X	X	X	—	Q (Sh)
G-Cheek		♀ Ad	V	*	-	5	X	X	X	1.3	F

Woodroffe
Maitland

Fig. 11-15. The ranges of 10 marked Woodchucks and the temporal distribution of their occupation of burrow systems.

Range Map

• Light standard	x Woodchuck burrow entrance
— Guard-rail	- Observed Woodchuck movement
— Fence	o Location Woodchuck spotted
— Hedge	(sometimes more than once)
— Ditch	
— Culvert	
Tree, shrub	
• Tree stump	

Grid interval = 250 m

Contour interval = 2' (60 cm)

Black Roads

Small Map

- n• Burrow system
- n Observed location of Woodchuck

Temporal Distribution of Burrow System Occupation

- Left column = Burrow system or location n
- Top row = Month (A = April, etc.)
- Number(s) in boxes = Date(s) of captioned month Woodchuck observed at specified burrow or location n.

PINECREST Whiteye? Ad (Observed 10.28h; 2 spottings)

TEMPORAL DISTRIBUTION OF
BURROW SYSTEM OCCUPATION

	J	J	A
1	5 15	6 7 19	
2	15 16	26 29	
3	1 15		7 13
4		16 22	
5	15	21	13
6	17		

Fig. 11.

RICHMOND #608j RESIDENT (Observed 3.67h; 3 spottings)

TEMPORAL DISTRIBUTION OF
BURROW SYSTEM OCCUPATION

	M	J	J	A	S
1	20				
2					9
3				28	
4				17 24	
5			7		
6			7	17	
7			7 23	17	
8			23		
9			7 22	17

Fig. 12.

RICHMOND #10♀Ad RESIDENT (Observed 8.30h; 4 spottings)

0 100 200 m

TEMPORAL DISTRIBUTION OF BURROW SYSTEM OCCUPATION

	A	M	J	J	A	S
1	19	6	5 16		12	
2	30	5				
3			8		12 20 27	
4			8			
5		7				
6						3 16
7		7	5 7 8 16	12

Fig. 13.

PINECREST #58d) RESIDENT (Observed 8.62h; 11 spottings)

TEMPORAL DISTRIBUTION OF BURROW SYSTEM OCCUPATION

Fig. 14.

	J	J	A	S
1	15 21	6 16	7	9 12
2		7 16	7	9 12
3		23	14 18 24	1 3
4			27	
5			14	
6			10	6
7		25	6	
8			12	15 16
9			24	5 6 7
			13	

PINECREST M0129j IMMIGRANT (Observed 4.68h; 8 spottings)

0 100 200 m

TEMPORAL DISTRIBUTION OF
BURROW SYSTEM OCCUPATION

	J	J	A	S
1	15 17 21			
2		6		
3		15		
4			12 13 14	1 3 5
5				6
6			27	6 9 27

Fig. 15.

on a non-linear shape as it explored both Whiteye's and #40's burrow systems on the flat area of the parcel (Table 9).

These Pinecrest Woodchucks living on flat areas more fully explored the parcel(s) upon which they lived than did Woodchucks observed at the Richmond interchange. Two other Woodchucks (#49♀Ad and G-Cheek♀Ad) utilized the flat areas of Woodroffe NW2 and NW, and Maitland SE, respectively, in a similar fashion (Table 9). Woodchuck #49♀Ad relocated to Woodroffe NW in late-June and resided in the shrubby area of this parcel for the remainder of the season. Her linear movements (essentially perpendicular to the Queensway) were probably reinforced by the shrub-grass interface for there were no other Woodchucks inhabiting this parcel.

The minimum-area polygons of the 4 Woodchucks associated with ramp-areas exclusively, or of the 2 associated with Graham Creek that had crossed ramps to relocate (#21♀Ad and #16♀Ad) sometimes had range length:width ratios of less than 2.0. Figure 12 illustrates that movements were generally associated with the roadside slopes and the necessary inclusion of the ramp in the range polygon obscured the internal linearity of the movement-tracks.

The Richmond SW2 Woodchucks residing adjacent to Graham Creek made almost all of their interburrow movements along the slopes where burrow systems were present (e. g., Fig. 13). Grazing took place on the flat areas of the parcel, with movement usually not radiating more than 30 m from the burrow system in use. This produced somewhat barbell-shaped habitat utilization patterns and/or linear range

shapes. Thus the 2 individuals (#10♀Ad and #54♂Ad) associated exclusively with Graham Creek exhibited linear ranges (Table 9).

No study Woodchucks were seen either wet or swimming in Graham Creek at Richmond SW2, although wet ditches were readily traversed at Moodie SW and Richmond SW. For 3 days in August Graham Creek was drained because of construction upstream, and Woodchuck tracks were seen in the mud of the creek-bed. Animals using both banks of Graham Creek travelled over the cement culverts on the east and west sides of the parcel, circumventing this water-barrier by using Man-made structures.

The interchange Woodchucks seem to be frightened by fast-moving, noisy, high-volume traffic. Movements along the slopes and flat areas were essentially parallel to the Queensway (e. g., Fig. 14). Ramps were crossed freely. Because movement around the burrow system in use rarely exceeded about 30 m, linear range shapes resulted. This noise-vehicle barrier could account for the range linearity of 14 observed individuals for the long axes of their ranges ran virtually parallel to the Queensway (Table 9). All but #50♂j, #53♀j, and Untag?j at Richmond SW2 crossed at least 1 ramp during observed movements.

Figures 14 and 15 illustrate the common and sometimes extensive movement of Woodchucks between interchange parcels. No tagged Woodchuck carcasses were found between interchanges and no tagged animals successfully dispersed from 1 interchange to another.

C. Discussion

Queensway Woodchuck burrow entrances are significantly associated with slopes. This finding agrees with the findings of Henderson and Gilbert (1978), yet in their study a consistent relationship with drainage was not found. Moss (1940) found no definite relationship between burrow entrance location and topography.

Although drainage was not directly investigated, the associations of burrow entrances with slopes and trees on flat areas suggest that drainage is of some importance, contrary to the opinions advanced by Henderson and Gilbert (1978). Grizzell (1955) suggested that drainage may be an important factor in influencing hibernation mortality or death of young that have not yet emerged. Merriam (1971) found that "of 112 burrow systems, all but [9] (8 per cent) were on well-drained soils, although a greater area of imperfectly drained soils was available." He also stated that high densities of burrow systems were seen in areas where the boundary contact between well and poorly drained areas was greatest. His study Woodchucks frequently grazed on less well drained areas. Queensway Woodchucks did not graze adjacent to the wet ditches adjacent to ramps but instead chose to feed on the elevated flat areas.

Burrow system and burrow entrance association with trees has also been observed in Beechey Ground Squirrels, Spermophilus beecheyi. Owings and Borchert (1975) found that their squirrels' burrow systems showed a significant association ($r=0.620$) with large objects and a weaker preference for tree canopy cover ($r=0.231$). Where trees are

available, Queensway Woodchucks may be selecting similar microhabitats.

Doucet et al. (1974) found no apparent preference for north- or south-facing slopes along highway overpass embankments in Quebec and Ontario. However, any highway embankment does not provide a full choice of aspects; thus the Woodchucks use what is available.

My south-facing aspect data showed the largest deviation from the expected values; thus given a choice, my Woodchucks preferred south aspects. Indeed, my data may have underestimated this preference. If colonizing Woodchucks chose the preferred aspects first, subsequent immigrants would have had less choice available, eventually having to utilize north-, west-, and east-facing slopes.

Barash (1973) found that Olympic Marmots, Marmota olympus, preferred south-facing slopes, although wintering mortality was lower in a colony inhabiting a north-facing slope, where snow depth was greater. He found no correlation between emergence and snow depth. Casual observation of my Woodchucks and snow tracks in 1981 and 1982, respectively, suggested that individuals hibernating in south-facing burrows are the first to emerge. Davis (1967) suggested that Woodchucks hibernating in burrows on south-facing versus north-facing slopes may emerge earlier. This may partially account for the observed south-aspect preference. Queensway Woodchucks also spent a considerable amount of time sunning at the mouths of burrow entrances and/or on Man-made structures throughout the summer.

When undertaking this study I expected the Woodchucks' movements to conform to the traditional concept of "home range" (Burt 1943). Although I observed some animals over a number of months, no long-term "established homes" were evident, and what Burt (1943) termed "occasional sallies" from the home range often became difficult to identify. Getty (1981) briefly summarized some of the practical limitations of the home-range concept. A more detailed discussion of these and other limitations implicit in the areal quantification of movement data for Queensway Woodchucks is given in Appendix E.

There are a number of reservations about the samples used in my analysis that should be explained. As the mean range measurements for the Pinecrest Woodchucks were higher (not significantly) and the variances were significantly higher than those for Richmond Woodchucks, only Richmond data were used for multiple range test analysis.

Two male Woodchucks (1 adult, 1 juvenile) were immigrants for which movement data before immigration to the Richmond interchange are absent. Another 2 males (1 adult and 1 juvenile) were roadkilled soon after being marked. Each of these animals was spotted on 4 occasions and observed for 1 h in total; their carcass locations were included in their range. For each of adult and juvenile male groups, this leaves only 1 individual that remained in the study area throughout the season. Of the 7 males trapped at this interchange, 3 'mysteriously disappeared' and 1 male proved to be a visitor, staying only 2 days after capture.

The Student-Newman-Keuls test showed that none of the sex or age-class differences in mean area or length of range were significant. This result is not surprising in view of the small sample size, high variance, and the inclusion of immigrants and roadkilled residents in both male age-classes. A biased adult sex ratio and the extensive movements observed were unexpected, resulting in good sampling of adult females and the loss of many Woodchucks (necessitating their exclusion from analysis), respectively. Variable observation effort for marked individuals reflects the level of above-ground activity of the Woodchucks and my consequent ability to observe them.

Although Grizzell (1955), de Vos and Gillespie (1960), Barash (1974a), and Henderson and Gilbert (1978) found that juveniles range more extensively than adults, no significant differences in range size of the age-class samples from the Richmond interchange existed. Most Queensway emigrants were adults. Davis et al. (1964) found that Woodchuck emigrants were usually juveniles. Most Richmond juveniles, however, remained on their natal parcel and it was common to see juveniles with their mother even as late as September, as found by Hamilton (1934). Sanderson (1966) indicated that in many species adults generally range farther than do juveniles, although this is apparently not the case with Richmond Woodchucks. Had range information been obtained for emigrants and immigrants outside the study area, adult ranges may have proved to exceed those of juveniles.

Some of the extensive movements attributed to adults may have

involved yearlings. Because successful trapping was done for only 1 season, the number of these so-called adults that were yearlings is unknown. de Vos and Gillespie (1960) and Schoonmaker (1966) stated that yearlings move around extensively, suggesting that some of my study animals may have been yearlings, and that the adult sample was not homogeneous. Because these Queensway populations have not been previously studied, nothing is known about the survivorship of the Woodchucks. Davis et al. (1964) reported that about 30% of an unharvested spring population is composed of yearlings. Grizzell (1955), however, pointed out that the percentage of a spring population that is composed of yearlings varies from year to year, dependent upon the climate and reproductive success of the preceding year. With a sample size of 12 Richmond adults, a yearling-bias may exist.

At the Letterkenny Army Ordnance Depot, Chambersburg, Pennsylvania, adult Woodchuck home ranges measured from 0.3-6.3 ha (Bronson 1963). New York Woodchucks living in pasture land and shrubby old fields ranged over 0.39-1.00 ha (Merriam 1960, 1971). Twitchell's (1939) Woodchucks living in Missouri agricultural areas had a mean home range area of 1.48 ha. Hayes (1977) studied 5 animals living in burrows on the periphery of a hay field in Arkansas; their home ranges measured 0.47, 0.80, 0.82, 1.11, and 4.00 ha. The range areas of Richmond interchange Woodchucks ($\bar{x}=0.34\pm0.22$ ha) compared with the lower part of these values from rural areas. The Pinecrest Woodchucks' mean range of 1.26 ± 0.98 ha approaches the upper part of the range of the previously cited home range areas. Although my 2

largest ranges were observed at Pinecrest (3.99 and 2.38 ha for Mel2[♀] and #15[♂]Ad, respectively), the ranges at Pinecrest were not significantly larger than those of Richmond individuals. This non-significant difference was unexpected and likely due to small sample sizes and high variance.

Sanderson (1966) stated that it is generally accepted that as a species' population density increases, the average home range size decreases. Grizzell (1955) and Davis and Ludwig (1981) found that where populations of Woodchucks were sparse, the animals moved more extensively. However, de Vos and Gillespie (1960) pointed out that where food is abundant, high densities and decreased movement are to be expected. As there appear to be equally adequate food supplies at Pinecrest and Richmond, the disparities (although not statistically significant) in range length and area between them seem to result from the high Woodchuck density at Richmond relative to that at Pinecrest.

The observed linearity of range evidenced by many of the observed Woodchucks at expressway interchanges is striking. Stumpf and Mohr (1962) discussed numerous examples of linear home ranges or territories being characteristic among many mammals and birds. They concluded that compact ranges may attract predators and that "extreme linearity for any given species [was] an expression of unsuitability of physical and biotic conditions in the area in which an animal live[d]." This does not seem applicable to Queensway Woodchucks. The lack of predators and suitability of the habitat encourage high populations of Woodchucks.

Corridors of suitable habitat for animals living along roads can enforce linearity of home range (Linsdale 1929, Stumpf and Mohr 1962). The Woodchucks I studied are not faced with an extremely narrow habitat corridor along the Queensway. The Queensway appears to function much as a watercourse where animal movement parallels the dispersal barrier and its associated slopes. Most of the aforementioned animals at least visited a series of burrow systems, which were more or less equidistant from the Queensway.

The linearity of ranges of the Richmond SW2 Woodchucks residing adjacent to Graham Creek is consistent with earlier findings that animals associated with watercourses often exhibit linear home ranges (Linsdale 1929, Stumpf and Mohr 1962, Sanderson 1966). Woodchuck #10[♀]Ad (Fig. 13) used a flood-control tunnel to move to and from the Richmond SW2 parcel and the west side of the Richmond SW2 ramp. The association of Woodchucks with Graham Creek and the total absence of mortality on the Richmond SW2 ramp in the culvert area suggest that animals are 'funnelled' into this culvert's tunnel rather than up to the ramp area.

POPULATIONS

This section describes the Woodchuck populations at the 6 interchanges studied and addresses some of the factors that appear to be important in determining the size of these populations.

A. Population Structure and Natality

Figure 16 illustrates the sex and age-class distribution of Woodchucks trapped or otherwise seen at close range on the different parcels studied. Because Davis et al. (1964) stated that the 2 sexes are equally vulnerable to trapping, these figures are considered to represent actual sex ratios. Furthermore, most adult resident, immigrant, and emigrant Woodchucks were trapped. Because trapping success dropped to zero in July and August, only 12 of the 20 resident-born juveniles that emerged were trapped.

The numbers of Woodchucks sexed at the various interchanges were too low to test the significance of the individually tabulated sex ratios in Table 10, but the tendency of females outnumbering male adults was consistent for all interchanges except Moodie and Woodroffe. The sex ratio among adults on the whole study area (29 ♀♀:10 ♂♂) was significantly female-biased whereas that of juveniles (11 ♀♀:6 ♂♂) was not significantly different from a 1:1 sex ratio (Table 10).

In 1981, 8 litters were known to be born in my study area; 6 of these litters were at the Richmond interchange (Table 11). It appears that fewer than 35% (6/17 of the adult females bore litters at the

Fig. 16. Sex and age-class distribution of Woodchucks trapped or otherwise examined at close range on the different parcels during the 1981 field season.

Table 10. Sex ratios of adult and juvenile Woodchucks sexed at the 6 interchanges.

Interchange	No. of Woodchucks					
	Adults		Juveniles		Adults and juveniles	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
Moodie	2	1	0	2	2	3
Acres	0	4	0	2	0	6
Richmond	7	17	5	5	12	22
Pinecrest	0	5	1	2	1	7
Woodroffe	1	1	0	0	1	1
Maitland	0	1	0	0	0	1
Total	10	29	6	11	16	40
χ^2	9.3		1.5		10.3	
df	1		1		1	
p	<0.005		>0.05		<0.005	

Table 11. Data on Woodchuck litters in 1981.

Interchange and parcel	No. of adult ♀♀ marked	No. of litters	No. emerged per litter	Sex of juveniles marked		Maximum expected no. of juveniles†
				♂	♀	
Moodie	0	-	-	-	-	0
Acres SW	5	1	2	0	2	23
Richmond SW	4	1	3*	-	-	18
		1	5	-	2	-
SW2	8	1	4	1	2	37
NE	2	1	4	2	1	9
NE2	2	1	1	-	-	9
SE	1	1	3	-	5	5
Subtotal	17	6	20	3	5	78
Pinecrest NE	6	1	2	1	1	28
Woodroffe NW2	1	0	-	-	-	5
Total	29	8	24	4	8	134

* Number of placental scars in uterine horns of roadkilled resident.

† Assuming average number of young per litter was 4.6 (Grizzell 1955).

Richmond interchange) of the adult females were gravid at any interchange.

Figure 17 shows the absolute number of Woodchucks inhabiting each of the study parcels. If it is assumed that all so-called adult females present on the study parcels were capable of breeding successfully, the maximum numbers of juveniles produced (based on a mean litter size of 4.6 (Grizzell 1955)) can be calculated; they are presented in Table 11. Excluding the possibility of a high rate of juvenile dispersal, Fig. 7 illustrates that the near-equality of adult immigrants and emigrants counteract any substantial gains or losses of individuals at the study interchanges by movement. Roadkilled residents were generally few and movement between parcels partially accounts for changes in the individual parcels' densities between spring and fall. Thus the absolute numbers of Woodchucks at any particular parcel did not change drastically between the spring (early May) and fall (late August-early September) census in 1981.

These absolute numbers are expressed as densities in Fig. 18. Occasionally such relative expressions of population size can be misleading because a single animal moving to a previously unoccupied small parcel can suggest a sudden increase in population density to a relatively high level. For example, Acres NE has a parcel area of only 0.26 ha (Fig. 3) and had no Woodchuck occupants in the spring; when 1 Woodchuck immigrated to this small parcel in mid-June and remained there, the fall density became 3.6 Woodchucks/ha, a higher fall density than any recorded in my study area other than some at

Fig. 17. Absolute numbers of Woodchucks present on individual parcels on the spring (early May) and fall (late August-early September) censuses in 1981.

Fig. 18. The densities of Woodchucks on the parcels censused in the spring and fall of 1981.

Richmond Road.

Figures 19A and 19B show the relations between numbers of Woodchucks per parcel and parcel area during spring and fall, respectively. The only parcels inhabited by 4 or more Woodchucks in either the spring or fall census are located at the Pinecrest or Richmond interchange. Even Acres NE, the smallest study parcel, was inhabited by a Woodchuck from 15 June to the end of the field season. If the high data points approximate or underestimate the maximum carrying capacities of interchange parcels, Woodchuck populations in the remaining parcels are "underpopulated" and it is unlikely that these populations are limited by parcel area alone. The approximate saturation level shown for the fall exceeds that for the spring because resident and immigrant juveniles are present.

Overt aggression was observed on only 3 occasions over the 1981 season. Once was on 17 May when an untagged lactating female on Richmond SW chased #21 Ad (from Richmond SW2) from the former's burrow system, and was subsequently killed on the Richmond SW ramp. The other 2 occasions involved Whiteye Ad (Fig. 11) chasing a juvenile immigrant (Buff?j) into the shrubs on Pinecrest SW in July and August.

B. Mortality

Many decimating factors may potentially affect the Woodchuck populations inhabiting the interchanges studied. Because of Woodchucks' fossorial habits, deaths resulting from indirect human injury, disease, or senility are unlikely to be detected if they occur

Fig. 19. The relations between numbers of Woodchucks counted and parcel areas in the (A) spring and (B) fall of 1981.

underground.

A female adult with 2 female juveniles, all 3 probably suffering from mite infestation, had totally bare patches at a variety of body locations. These 3 animals, although initially residing on Acres SW, were using a burrow system on the south side of the Acres SW ramp outside the study area prior to their disappearance. It is unlikely that all 3 'succumbed' simultaneously, so I assume they emigrated to a neighbouring field.

Gun use is prohibited at all the study areas. Even though Moodie and Acres are in essentially rural areas and illegal shooting may occur, tall vegetation and high traffic volume probably act as further deterrents to shooters and no gun-shot Woodchucks were observed in 1980 or 1981.

Parcels were checked for carcasses after mowing. Although no mangled carcasses were found in 1981, 1 orphaned juvenile was killed in this manner in 1980 at an interchange later deleted from the study area.

Deaths resulting from vehicle injury undoubtedly do occur, but because injured Woodchucks take refuge in burrows their deaths would not be noted. A juvenile was hit by a car and survived at Acres SW. A badly limping Woodchuck visited Richmond SW2, but could not be trapped to assess the injury.

As previously mentioned a lactating female (Richmond SW resident) was roadkilled on the Richmond SW ramp. Three placental scars were

counted in her uterine horns. The young were too young (about 3-4 weeks) to be successfully smoked out of the burrow, and thus perished.

Hibernation mortality could not be considered because of the short-term nature of this study. Mass gains over the summer were to be investigated, comparing the rural area gains (tall vegetation, poor visual contact, and expected low mass gain over the season) to those at suburban-urban interchanges (short vegetation, good visual contact, and expected high mass gain over the season). Inadequate populations and poor trapability made this field extension to Bailey's (1965) study impossible. Meagre trapping of fall juveniles at Moddie, Richmond, and Pinecrest, however, suggested that unsatisfactory pre-hibernation masses (<3.0 kg) (Davis and Ludwig 1981) are more common at rural locations where visual contact is inhibited by the tall vegetation.

Potential predators include a variety of domestic and wild animals. Domestic cats, Felis catus, Domestic Dogs, Canis familiaris, Red Foxes, Vulpes vulpes, Red-tailed Hawks, Buteo jamaicensis, and Marsh Hawks, Circus cyaneus, although occasionally present at some of the study parcels, appear to pose little or no threat to these Woodchuck populations at interchanges.

Although any animal population is faced with a wide array of decimating factors, road-driven vehicles appear to be the greatest single agent acting upon the populations of Woodchucks at the interchanges and immediately surrounding areas.

Woodchucks constituted about two-thirds of the mammalian roadkills recorded between March and September (61 of 91 in 1980 and 52 of 90 in 1981) and surpassed all other vertebrate species in all months in both years. Their "habit of crossing" roads, as evidenced by range maps (Fig. 12, 14, and 15) and the habitat utilization summary (Table 9), makes them (sometimes literally) walking targets for vehicles.

Figure 20 shows the directions carcasses in 'good' condition faced at the 6 study interchanges. The pattern of the carcasses' locations and headings on roads at the interchanges is radial in appearance. Crossing and resulting mortality were more common at sites where burrow entrances were concentrated (Moodie SE, Acres NE and SW) and on the Queensway at bridge overpasses (Acres, Richmond, and Pinecrest).

On Acres NE2 a litter of 4 emerged in mid-May 1980. By mid-June, 4 juveniles had been killed on the Acres NE ramp (3) and the Queensway (1), within 30 m of the natal burrow system (location marked 'x' on Fig. 20B).

In 1980, 3 juveniles were killed under the Pinecrest overpass. These deaths coincided with the disappearance of 3 juveniles from a 5-pup litter born on Pinecrest NW (location marked 'x' on Fig. 20D).

The age distributions of Woodchuck roadkills for 1980 and 1981 show consistent trends (Fig. 21), with June of 1980 and July of 1981 being months of maximal mortality. Queensway Woodchucks emerged in

Fig. 20. Locations of Woodchuck roadkills at the 6 study interchanges, with arrows showing the directions carcasses were heading when found.

Fig. 21. Temporal distribution of age-classes among all roadkilled Woodchucks.

mid-March when snow was still present, with the first individual being sighted on 13 March in 1981. Adult roadkills peaked in May and June both years.

The first litters emerged on 28 May in 1980 and 17 May in 1981. Juvenile roadkills first occurred in late May (actually 30 May 1980) or June, peaked in July, and were considerably reduced in August (Fig. 21).

The distributions of roadkills at each interchange for 1980 and 1981 (Fig. 22A and B, respectively) show consistent trends. Moodie, Acres, and Pinecrest interchanges had comparable numbers of roadkills, whereas Richmond exceeded all interchanges in the number of roadkilled Woodchucks. To compare the numbers of adults and juveniles killed on roads, an expected adult:juvenile ratio of 4:3, based on the total numbers of adults and juveniles at all of the study interchanges in the fall census (Fig. 17), was used. A χ^2 -goodness-of-fit test (Lehner 1979) shows that the number of adults killed on the roads was not significantly greater ($p > 0.05$) than that of juveniles in 1980 ($\chi^2 = 1.21$) and 1981 ($\chi^2 = 1.46$); thus the roadkills reflect the age-class distribution of the interchange populations.

Because many of the 1980 roadkills could not be sexed, the scanty data for sex are not presented. Although sexing is sometimes virtually impossible because of poor carcass condition, in 1981 field work was done almost every day, and carcasses were retrieved and examined earlier. About one-third of the carcasses still could not be sexed, but available data show that female Woodchucks outnumbered

Fig. 22. Age-class distribution of roadkilled Woodchucks at individual interchanges.

males among roadkills during May, June, and July and overall (21 ♀:14 ♂) (Fig. 23). This latter difference, however, is not significant ($\chi^2=1.4$, 1 df, $p>0.05$) using the pooled annual sex ratio in a χ^2 -goodness-of-fit test (Lehner 1979).

Some of the factors potentially important in explaining the number of roadkills of Woodchucks were examined. Because dead Woodchucks showed up on the Queensway, interchange roads, and associated ramps, the total interchange densities (number of Woodchucks present on interchange study area in the spring or fall divided by the total area of the interchange study parcels) were compared with the total number of roadkilled Woodchucks at the respective interchange (Table 12). As expected, a high correlation exists between total Woodchuck spring ($r=0.99$) and fall ($r=0.99$) density and number of observed roadkills. Spring adult density correlates better with adult interchange roadkills ($r=0.96$), whereas fall juvenile density produces a better correlation ($r=0.94$) with juvenile interchange roadkills.

By counting all Woodchucks for which road-crossing was implied by a change in location or actually witnessed during the 1981 field season on an interchange's study parcels (including all residents that crossed roads, immigrants, emigrants, and visitors) a "crossing index" for each interchange is obtained. This crossing index represents the relative frequency with which associated roads are known to have been crossed by Woodchucks at each interchange. The index assumes that the average number of crossings made by the individuals tabulated in the

Fig. 23. Temporal distribution of sexes among all Woodchuck roadkills in 1981.

Table 12. Relations between the numbers of roadkills and the spring and fall densities of Woodchucks at the 6 interchanges during 1981.

Interchange	All Woodchucks			Adults			Juveniles		
	Woodchucks/ha		No. of roadkills	Woodchucks/ha		No. of roadkills	Woodchucks/ha		No. of roadkills
	Spring	Fall		Spring	Fall		Emerged	Fall	
Moody	0.378	0.567	5	0.378	0.189	4	0	0.378	1
Acres	1.134	1.701	8	1.134	1.134	6	1.134	0.567	2
Richmond	3.842	5.352	18	3.842	3.019	11	2.333	2.333	7
Pinecrest	0.886	1.012	7	0.886	0.506	4	0.253	0.506	3
Woodroffe	0.163	0.488	3	0.163	0.448	1	0	0	2
Maitland	0.670	0	4	0.670	0	4	0	0	0
r	0.99	0.99		0.96	0.89		0.87	0.94	
r ²	0.98	0.97		0.91	0.80		0.76	0.88	

index does not vary from 1 interchange to another. A high correlation ($r=0.96$) exists between total crossings and number of observed roadkills (Table 13). These correlations explain more than 75% ($r^2=0.75-0.94$) of the total variance (Spiegel 1975). The correlation for adults ($r=0.86$) is lower than that for juveniles ($r=0.97$).

The data collected from 31 study area ramps were used to analyse the relations between the numbers of Woodchuck roadkills and total vertebrate roadkills and posted ramp speeds and traffic volumes (Table 14). None of the coefficients show a high interdependence of the variables.

Figure 24 shows the 1980 and 1981 Woodchuck and total vertebrate roadkill data for the 40- and 50-km/h ramps. The differences between the mean numbers of roadkills/km for both years and categories are not significant at the 5% level using Welch's approximate t-test (Scheffe 1970). Although 40-km/h ramps more frequently had no roadkills over a season than did 50-km/h ramps (Table 15), this difference was not significant for Woodchuck or all vertebrate roadkills at the 5% level ($\chi^2=0.021$ and 0.001 , respectively, 1 df), using the Brandt and Snedecor formula (Bailey 1959).

A partial correlation was done to remove the linear effects of interchange Woodchuck density in a traffic volume:mortality/km correlation. Although the partial correlation coefficients are relatively higher than those without a density index shown in Table 14, traffic volume still explains less than 5% of the total variance ($r=0.031$ and 0.041 , for spring and fall densities, respectively) in

Table 13. Relations between the numbers of Woodchuck roadkills and the crossing indices for all Woodchucks that crossed roads during 1981 at 5 interchanges.

Interchange	All Woodchucks		Adults		Juveniles	
	Crossing index	No. of roadkills	Crossing index	No. of roadkills	Crossing index	No. of roadkills
Acres	8	8	5	6	3	2
Richmond	45	18	28	11	17	7
Pinecrest	15	7	8	4	7	3
Woodroffe	7	3	5	1	2	2
Maitland	4	4	3	4	1	0
r	0.96		0.86		0.97	
r^2	0.92		0.75		0.94	

* Moodie interchange was excluded because all parcels were not studied.

Table 14. Correlation coefficients for the relationships between numbers of roadkills/km and ramp traffic volumes and posted maximum ramp speeds (n=31 ramps).

Roadkill victim	Potential significant factor	Correlation coefficient			
		1980		1981	
		r	(r ²)	r	(r ²)
Woodchucks/km	Volume	0.106	(0.011)	0.180	(0.032)
		*0.176	(0.031)	0.202	(0.041)
	Speed	0.077	(0.006)	0.016	(0.0003)
All vertebrates/km	Volume	0.194	(0.038)	0.370	(0.137)
	Speed	0.052	(0.003)	0.031	(0.001)

* Partial correlation removing linear effects of density.

Fig. 2. Diagram of a typical interchange.

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Fig. 24. Relative numbers of Woodchucks and all vertebrates killed in 1980 and 1981 on ramps posted at 40 or 50 km/h maxima.

Table 15. Number of on- or off-ramps for which there was zero mortality.

	No. of ramps			
	1980		1981	
	40 km/h	50 km/h	40 km/h	50 km/h
Woodchucks	8	5	9	5
All vertebrates	8	2	7	1
No. of ramps at posted speed	16	12	16	12

the data used.

C. Discussion

Road mortality appears to be the major factor culling these interchange Woodchuck populations. At least 8 factors can play significant roles in determining the numbers of animal roadkills observed in an area:

- 1) population density (Gordon 1932, Dickerson 1939, Davis 1940, Haugen 1944, McClure 1951, Bellis and Graves 1971, McCaffery 1973, Oxley et al. 1974);
- 2) traffic volume (Russell and Amadon 1938, McClure 1951, Klein 1971, Oxley et al. 1974, Gibson 1980);
- 3) traffic speed (Knobloch 1939, Davis 1940, Haugen 1944, McClure 1951, Klein 1971, Oxley et al. 1974, Gibson 1980);
- 4) the animals' seasonal activities (Dickerson 1939, Davis 1940, Davis 1940, McClure 1951, Klein 1971, Oxley et al. 1974);
- 5) road width (McClure 1951, Oxley et al. 1974);
- 6) weather conditions (Dreyer 1935, Dickerson 1939, McClure 1951);
- 7) food supply (Dickerson 1939, Davis 1940, McClure 1951, Klein 1971, Bellis and Graves 1971); and
- 8) cover (Haugen 1944, McClure 1951).

I consider the first 5 factors to be important in determining the number of Woodchuck roadkills in my study populations.

Areas with high population densities would be expected to experience a greater number of roadkills than low-density areas for more Woodchucks would be crossing roads. Seasonal aggression and

dispersal levels (possibly density-dependent) would be expected to affect the observed number of roadkills. The more frequently roads are crossed by individuals, the more likely they are to become "targets", unless road-crossing experience produces behavioural changes that serve to increase the individuals' likelihood of successfully crossing roads.

On high-traffic-volume roads I would expect a Woodchuck to have a poor chance of making a successful crossing for numerous vehicles must be avoided. Wide pavement surfaces (2- and 4-lane roads) present a longer distance to be traversed without being hit than do 1-lane roads and road width is usually related to traffic volume. Finally, vehicles travelling at high speeds give a Woodchuck that is crossing the road little escape time. Also, by the time the driver of a fast-moving vehicle sees a Woodchuck crossing the road, there is little time to avoid hitting the animal, even if the driver so desires.

As the adult:juvenile ratio of roadkills in 1980 and 1981 was not different from the age-structure of the interchange populations (assuming 1980's age-structure was similar to that of 1981), juvenile inexperience (McClure 1951) does not appear to be an important factor in determining the proportion of juvenile Queensway Woodchucks dying on roads. Age-class ratios of roadkills were not different from the interchanges' fall-census age-class ratio. Adults, which represent larger targets, and human sentiment against killing young animals may influence these roadkill age ratios in opposite directions.

The sex ratio of Queensway roadkills in 1981 was 21 ♀♀:14 ♂♂ although this difference from equality was not significant. Except at Moodie (adults) and Woodroffe (juveniles), female roadkills consistently outnumbered or equalled those of male Woodchucks in 1981. The interchange cumulative sex ratio (21 ♀♀:11 ♂♂:13 ??) of roadkills mirrors the sex ratios of Woodchucks trapped at the interchanges. These ratios do not support the contention that males move more extensively (or at least cross roads more readily) than do females (Grizzell 1955, de Vos and Gillespie 1960), assuming that the sexes of badly mutilated carcasses would not skew the results in favour of males.

The female-biased sex ratio of interchange populations was unexpected. Fewer than 35% of the so-called adult females at any of the interchanges bore litters during 1981. Davis et al. (1964) reported that unharvested Woodchuck populations have about 30% yearlings in the spring. As previously mentioned, Grizzell (1955) stated that the percentage of yearlings in spring populations is dependent upon the climate and reproductive success of the preceding year. The low percentage of gravid females during 1981 may have resulted from a shortage of males. Also, because of unsuccessful trapping during the 1980 field season, the actual proportion of yearling females (breeding or non-breeding) could not be determined.

A female-biased sex ratio is common among Marmota and Spermophilus species. For example, Michener and Michener (1971), and Michener (1979) found low proportions of adult males in their

Richardson's Ground Squirrel, Spermophilus richardsonii, populations. Although juveniles "showed a 1:1 sex ratio in the field throughout their first summer," there was a low persistence of adult males (Michener and Michener 1971). They suggested that differential predation, dispersal, and overwintering mortality were the major contributing factors, favouring the latter possibility. There is no evidence of differential predation or dispersal of members of my study populations. Differential mortality during hibernation may partially explain the observed excess numbers of female Woodchucks in my study areas.

Pattie (1967) observed a female-bias in his population of Yellow-bellied Marmots, Marmota flaviventris. If a greater proportion of males than females disperse (in Yellow-bellied Marmots and Woodchucks), I would expect it to be reflected in the sex distribution of roadkills, assuming similar road-crossing behaviour and frequency for the 2 sexes. As in my Queensway Woodchucks, there was no difference between the sexes of Yellow-bellied Marmots with regards to highway mortality of juveniles. Pattie (1967) could not account for the unequal sex ratio observed in the population he studied.

The 1:1 sex ratio of roadkilled Woodchucks indicates that males are within the vicinity of the interchanges but are not permanently residing on the study parcels. Merriam (1971) maintained that "almost all other species of Marmota are colonial and at least vestigial coloniality in Marmota monax would not be surprising." The population demography of Queensway Woodchucks may be similar to that observed by

Armitage and Downhower (1974) in Yellow-bellied Marmots. The interchange populations observed may compose a "colonial" population, with a small number of males servicing the females physiologically capable of breeding. The areas surrounding the interchanges could represent "satellite" populations in which surplus males reside. If "early-spring" (February to March) activity is nocturnal, as suggested by Hamilton (1934), road-crossing by male Woodchucks likely would be successful for usually there is little traffic on the Queensway and associated roads after 22:00-23:00 EST. The light provided by regularly-spaced street-lights may aid the Woodchucks' vision during nocturnal activities. However, telemetry study of Woodchucks throughout many nights by Merriam (1971) showed that no nocturnal movements occurred. Because field work was not done during the night nor daily during these early spring months it is not known if in fact nocturnal activity occurs in the spring. Furthermore, because maintenance snow-removal is still done in the early-spring, roadkilled Woodchucks may have been 'lost' and subsequently were not recorded.

Numerous authors have found that the annual road mortality curve for various species of mammals is bimodal. The first peak is in the spring when breeding and associated wandering of males occur; the second is in late summer, when populations are high and juvenile dispersal activity occurs (Hamilton 1934, Haugen 1944, Oxley et al. 1974). Haugen (1944) found that over 60% of the Eastern Cottontails killed in the spring were males. Virtually no Woodchuck roadkills occurred in March and April, when males were expected to wander in search of mates; this expectation is based on observations reported by

Hamilton (1934), de Vos and Gillespie (1960), and Schoonmaker (1966). Mating takes place by the end of March among the Queensway Woodchucks studied. In both years road mortality of adults peaked in May and June (post-breeding) and that of juveniles peaked in July (consistent with 'dispersal'), resulting in a distinctly unimodal temporal distribution of roadkills.

Bronson (1964) found that the rates of agonistic interactions of the Woodchucks he studied were significantly higher during May and June. He attributed the decrease in agonistic observed after June in part to progressive vegetation growth increasingly obscuring visibility and thus the rate of contact between neighbouring Woodchucks; clearly this does not apply to of contact between neighbouring Woodchucks, does not apply to my suburban-urban populations. Bronson (1964) found "higher than normal" rates of interaction in August and September for 2 aggregates of Woodchucks "which were living on a freshly mowed timothy field where density was higher than normal and visibility was good." The lack of obvious aggressive behaviour in my study populations suggests, as Geggie (1980) found in her dense study population, that avoidance rather than a high level of overt aggression occurs in high-density populations of Woodchucks. Armitage (1962) also found that agonistic behaviour was not directly related to population density in Yellow-bellied Marmots. Thus, the May-June peak in adult road-crossing and resulting mortality is likely a result of stabilization of neighbour relationships and the occurrence of breeding, when females are protecting their young (Bronson 1964).

Single-lane ramps were more frequently and successfully crossed by my Woodchucks than the 4-lane interchange roads or the Queensway. McClure (1951) noted that animals are more likely to cross narrow roads (particularly gravel surfaces) than wide surfaces of pavement. Oxley et al. (1974) found that wider pavement surfaces were crossed almost exclusively by medium-sized mammals.

Partial regression analysis could not be used for traffic speed and volume data and Woodchuck density because the data distributions were not normal. Because construction along the Queensway hampered traffic, associated data were not included in the analysis of traffic speed and volume. The fact that Woodchucks seem to perceive this 4-lane expressway as a barrier further justifies this decision.

Ramp speeds were assumed to be indexed by posted maximum speeds, because curves and safe merging procedure require the speed of a single vehicle to vary along a ramp. Personal experience indicated that drivers frequently exceed posted speeds. To further confound the data interpretation, 28 of the 31 ramps were posted at 40 or 50 km/h. Thus a low correlation coefficient was expected because a difference of 10 km/h in vehicle speed is unlikely to make a significant difference in the escape time (Knobloch 1939) for a crossing animal. Although 40-km/h ramps experienced zero mortality over a season more frequently than did 50-km/h ramps, this difference was not significant.

Comparison of mortality and traffic volume produced low correlations for both Woodchuck ($r < 0.180$) and all vertebrate ($r < 0.370$)

roadkills per unit distance. Ramp volumes ranged from 200-6650 vehicles per day. Much of this traffic is associated with "rush hours" based on office work hours. With the observed Queensway Woodchucks being most active between 15:00 and sunset, morning rush-hour traffic volumes (07:00-09:00) are not correlated with Woodchuck activity peaks. The volumes used may not be proportional to those influencing Woodchuck road mortality.

As expected Woodchuck road fatalities correlated highly with interchange population densities. As the total density at the 6 interchanges changed little the 1981 season, thus spring and fall density correlations had similar values (Table 12). A high correlation ($r=0.77$) was also obtained by McCaffery (1973) for road-killed White-tailed Deer, Odocoileus virginianus, using reliable hunting harvest records of antlered bucks as an index of deer population trends.

Because more adult Woodchucks were killed, suggesting that they were crossing roads more frequently, during May and June (Fig. 21), the spring density:mortality correlation is higher than that of the fall density:mortality (Table 12). Juveniles, however, do not emerge until late May and increased roadkills in June and July seem consistent with dispersal (Fig. 21). Thus fall density better describes juvenile populations, and a higher correlation is obtained.

The relative frequency of crossing roads was also expected to yield a high correlation coefficient. Unavoidably, the crossing index used is not independent of density. However, the adult crossing index

does not correlate as well with the number of roadkills observed as does that for juveniles (Table 13). Of the 26 adult Woodchucks killed at the study interchanges, 7 were marked individuals (27%). Similarly, 3 of the 17 juvenile roadkills (18%) were marked Woodchucks. McClure (1951), Bellis and Graves (1971), and Klein (1971) suggested that experienced and wary animals more frequently cross roads successfully. Compared to adults, a higher proportion of juvenile roadkills appear to be inexperienced Woodchucks. This could partially explain the higher correlation coefficient obtained for the juvenile age-class.

Variable driver behaviour and Woodchuck road-crossing behaviour can also affect the success of an animal traversing pavement. On the 2 occasions I observed a Woodchuck hit by a car, the driver made no attempt to avoid the animal by either decelerating or steering away from it.

Visibility of the Woodchucks is not a problem because the animals' size, the low vegetation in suburban-urban areas, and the gravel shoulders, upon which the Woodchucks usually stop before crossing roads, permit clear visibility to drivers. Woodchucks will, however, dart in front of an approaching vehicle, giving a unsuspecting driver little or no time to react. Thus the Woodchucks' behaviour, the drivers' awareness, and their disposition affect the outcome of a road-crossing attempt.

Finally, where natal dens are close to a road, juveniles are likely to be killed during normal investigative and play activities

while still with their mother.

SUMMARY DISCUSSION

The purpose of this study was to document the populations of Woodchucks at rural, suburban, and urban interchanges along a 4-lane expressway and to examine the factors contributing to the observed population levels. Use of this 'artificial' habitat by the Woodchucks was of additional interest.

Based on burrow entrance counts and expected Woodchuck populations at the 6 interchanges, I hypothesized that corridor movement between interchanges, with distance from farmland Woodchuck reservoirs acting as a barrier, accounted for the decrease in density of Woodchuck populations in urban settings. Gill and Bonnett (1973) emphasized the importance of corridors to wildlife in the city.

Animals tend to fill empty spaces but cannot do so without routes for dispersal. Furthermore, where small areas of suitable habitat exist in isolation, connecting corridors permit exchange, thus preventing inbreeding and allowing re-establishment in the event of population extermination.

No evidence to substantiate this hypothesis was obtained over the 1981 season, although such movement may occur over longer periods of time. Movement between interchange parcels, however, is common and sometimes extensive. Movement to and from parcels is radial in nature, as shown by carcass locations and headings (Fig. 20), with no indication of Woodchuck movement being restricted to the grassy corridors adjacent to the Queensway.

Table 16 summarizes the factors that I think play important roles in producing and maintaining existing populations at the 6 interchanges studied. These factors have not been proven, but are consistent with the level of Woodchuck populations observed at the different interchanges.

Figure 25 shows that the monthly rainfall from May to October 1981, with the exception of July, far surpassed that normally received at Ottawa International Airport, which is approximately 9.5 km SE of the midpoint of my study area and generally exceeded that received in 1980. All parcels studied except those at Moodie Drive and Acres SW appeared relatively well drained, for they were not excessively wet and no ruts were made by maintenance vehicles.

Both Moodie and Acres interchanges are less elevated than the suburban and urban interchanges. The soils are ancestral lacustrine-fluvial sediments because the Ottawa River once inundated the area (personal communication, Dr. R. W. Yole, Department of Geology, Carleton University). Extensive marsh/swamp and seasonally inundated land exist within 2.5 km NW and 3.0 km SW of the Moodie interchange (Ottawa [Topographic], 1976). The Moodie parcels and Acres SW have a gridded tile system laid 46-70 cm below ground level to provide quick upper-surface drainage (personal communication, John B. Armstrong, Highway Maintenance Supervisor, Ontario Ministry of Transportation and Communications, Ottawa Office). In 1981 he observed surface flow indicating that the water-table level was above that of the tiles for the first time since 1968, when the Moodie and

Table 16. Comparison of the relative levels of Woodchuck populations and some characteristics of the interchanges studied. Asterisks (*) mark factors I consider important in influencing population levels.

Interchange	Resident Woodchuck density	No. of litters (No. of juveniles that emerged)	Land use of surrounding area (Woodchuck reservoirs)	Proportion of marked Woodchucks killed on roads	Potential predators	Vegetation height	Water table level
Moodie	0	0	Farmland	0/6	Red Fox Red-tailed Hawk Marsh Hawk	High	*High
Acres SW	Very low	1(2)†	Farmland	1/7	Red Fox Domestic Cat	High	*High
Richmond and Acres NE	High	*6(17)	*Farmland and urban	*5/36	Domestic Cat (hunting Meadow Voles) Domestic Dog (rarely seen)	*Medium-low *Low	*Low
Pinecrest	Medium low	*1(2)	*Open fields ('lost' recently) and urban	*4/11			*Low
Woodroffe	Very low	0	*Greenbelt 'lost' (construction) and urban	0/1		*Low	*Low
Maitland	0	0	*Urban	1/2		*Low	*Low

† Adult female and 2 juveniles emigrated in June.

Fig. 25. Total precipitation recorded at Ottawa International Airport during 1980 and 1981 (Environment Canada 1980-1981). Normal precipitation is represented by 30-year monthly means (1941-1971).

Acres interchanges were constructed. I observed large ruts 17-36 cm deep made in June and July by mowing equipment at Moodie SW, SE, and NE and Acres SW. Finally, flooded Woodchuck burrow entrances were seen at Moodie NE and Acres SW in late September.

Spring "residents" emigrated and only visitors were seen throughout the summer, usually at roadside burrow entrances, at the Moodie interchange. Vegetation heights were consistently high, suggesting that without the attractive farm crops as a food source, poor visual contact may be sufficient to discourage residency (Bailey 1965). Farmland Woodchucks preferred fencerows about the periphery of actively cultivated and grazed farm fields at Acres and Moodie, as was earlier found elsewhere by Schoonmaker (1966) and Henderson and Gilbert (1978). Natural predators were present at both Moodie and Acres SW, although their impact on Woodchuck populations remains unknown. Thus the high water table is sufficient to account for the absence of Woodchucks there during the 1981 season.

Richmond and Acres NE were grouped together for a number of reasons. Both are suburban in nature with both farmland and urban areas nearby. Acres NE has steep slopes adjacent to Acres Road and the Acres NE ramp and these provide good drainage. The burrow entrance mound soil is sandy. No evidence (tire ruts, soggy ground, or flooded burrow entrances) of a high water table was noted at the Richmond interchange or Acres NE. Mowing frequency was sufficient to permit good visibility by the Woodchucks at Richmond parcels and Acres NE. No natural predators were observed, and Domestic Cats were

successfully hunting Meadow Voles. Thus road mortality appears to be one of the major decimating factor at these suburban interchanges.

The Richmond Woodchucks produced 6 litters of young in 1981. Thus this suburban environment permits reproduction and immigration from nearby reservoirs to compensate for emigration and road fatalities. Potential immigrants or visitors form the bulk of the Woodchuck roadkills.

Figure 1 shows that Moodie, Acres, and Richmond interchanges are adjacent to farmland and greenbelt areas, which provide reservoirs of Woodchucks. High peripheral populations exist along farmland fencerows (near Moodie and Acres) and along Graham Creek (at Acres and Richmond). Woodchucks were commonly seen on the grassy corridors on either side of the Queensway between these 3 interchanges.

The remaining 3 interchanges are classified as urban in nature. Pinecrest had 2 open fields that could have provided population reservoirs, although both areas were 'lost' with the construction of a department store and playing field (1980) and a shopping center (1981) (Fig. 1).

The Woodroffe interchange has a greenbelt area to its west although the southward extension of the Western Ottawa River Parkway was under initial stages of construction (blasting) therein during 1981. Assuming a radial dispersal pattern, as seen at the Queensway interchanges, greenbelt Woodchucks are more likely to move into adjacent residential areas. The Woodchucks' attraction to backyard

gardens, a common problem experienced by human residents adjacent to Ottawa greenbelt areas, would tend to limit the continued movement of Woodchucks toward the Queensway. No Woodchucks resided adjacent to the Queensway at the mouths of this greenbelt and no roadkills were observed at this location in 1980 or 1981.

The land surrounding the Maitland interchange is entirely urban in nature with no significant potential reservoirs, although an individual Woodchuck resided along the chain-link fence running along the Maitland SE2 ramp and the Queensway. No Woodchucks resided on the study parcels in the summer of 1981.

According to accounts heard over the past 2.5 years, Domestic Dogs and irate gardeners likely play a role in the killing of some urban Woodchucks as they move into residential backyards.

The rural and suburban interchanges are likely to remain populated by Woodchucks in future years. The urban interchanges studied will probably never become equally well populated. The high levels of movement and road-crossing associated with a low Woodchuck density at Pinecrest resulted in a proportionately high road mortality of the residents, counteracting any population gains from reproduction and/or immigration.

The Queensway interchanges present a Man-altered habitat that affects Woodchucks and their populations in a number of ways. The habitat characteristics encourage high populations. The semi-enclosed nature of the interchanges may be encouraging a

colonial-and-satellite-type of population demography and this possibility merits further study. Traffic mortality appears to be the major decimating factor with which these populations are faced; density and a crossing index are best correlated with the observed number of roadkills; yet, the Woodchucks living on the interchange parcels appear to have become road-wise. Single-lane ramps are crossed frequently with a high rate of success, whereas wider roads are avoided by most of the Woodchucks observed, so that the movement-tracks (and resulting range-shapes) of the animals are moulded by the topography of the habitat.

The results of my study illustrate the flexibility of Woodchucks that permits the species to cope successfully with the ever-increasing number of land-use and technological changes being made by Man in and near urban environments.

CONCLUSIONS

1. The suburban Richmond interchange had a higher population density (5.36 Woodchucks/ha) than any reported in the literature.
2. Most study Woodchucks rotated among several burrow systems during 1981. The majority of burrow systems were at least visited during the season. Generally resident Woodchucks used existing burrows. Slopes associated with roads and Graham Creek provide excellent habitat for Woodchuck burrow systems and are preferred to flat areas. Burrow entrances on flat areas at the urban interchanges are associated with isolated mature trees. South-facing slopes are preferred locations for burrow entrances.
3. The Woodchucks associated with Graham Creek or the high-volume, noisy Queensway had linear ranges; movements were made by Woodchucks along the slopes associated with movement barriers. One-lane ramps were crossed frequently with a high rate of success, whereas wider pavement surfaces were infrequently crossed with a proportionately high rate of mortality. These interchange Woodchucks appear to be road-wise; four-fifths of the roadkills involved unmarked individuals. The Woodchucks living in shrubby areas adjacent to interchange roads also exhibited linear ranges, whereas those living on flat areas had non-linear ranges, with movements radiating over the parcels upon which they lived.
4. Vehicles appear to be the major decimating factor for the Queensway Woodchuck populations; two-thirds of the mammalian roadkills observed were Woodchucks. Mortality of adult Woodchucks peaked in May

and June (post-breeding), whereas juvenile mortality peaked in June and July (consistent with dispersal). The annual Woodchuck temporal mortality curve is distinctly unimodal. The roadkill age-class distribution mirrored that of the population ratio of adults:juveniles. Although female Woodchucks outnumber males at the study interchanges, the sex distribution of roadkills was not different from a 1:1 ratio. Population density and an index of road-crossing frequency show high correlations with the number of Woodchuck roadkills at the study interchanges. On the other hand, traffic volume and speed are less important factors influencing the rate of mortality of Woodchucks on on- and off-ramps associated with the study interchanges.

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Family and scientific name	Common name	Mo		Ac		Ri		Pi		Wo		Ma	
		NE	SW	NE	SW	NE	SW	NE	SW	NW	SW	NW	SE
ACERACEAE													
Acer rubrum	Red Maple												
" saccharinum	Silver Maple			A		R		P		W	W		
" saccharum	Sugar Maple									P	W	W	M
VITACEAE													
Parthenocissus vitacea	Virginia Creeper		M										
MALVACEAE													
Malva neglecta	Common Mallow					R		P					
HYPERICACEAE													
Hypericum perforatum	Common St. John's-wort		M										
ELAEAGNACEAE													
Eleagnus sp.*	olive								P				
ONAGRACEAE													
Epilobium coloratum	Purple-leaved Willow-herb							R					
Oenothera biennis	Evening-primrose												
OLEACEAE													
Fraxinus americana	White Ash									P	W	W	M
" pennsylvanica	Red Ash												
Syringa vulgaris	Lilac									P	P		M
ASCLEPIADACEAE													
Asclepias incarnata	Swamp Milkweed		M	M	A	R	R	R					
" syriaca	Common Milkweed				A								
BORAGINACEAE													
Echium vulgare	Blue-weed					R	R	R					M

Family and scientific name	Common name	Mo		Ri		Pi		Wo		Ma	
		NE	SW	NE	SW	NE	SW	NW	SW	NW	SE
COMPOSITAE cont'd											
Taraxacum officinale	Common Dandelion	A		R	R	P	P	P	W	M	M
Tragopogon dubius	Goat's-beard	A		R	R	R	R	P			
sp.		M									
Xanthium strumarium	Cocklebur										

* Not listed in Gillett and White (1978).

† Gillett, J. M., and D. J. White. 1978. Checklist of vascular plants of the Ottawa-Hull region, Canada. National Museum of Natural Sciences. Ottawa, Ontario. vi+155 pp+map.

APPENDIX B. Proportion of woodchucks captured per hour of trapping effort in 1981.

APPENDIX C. Modified Halvorson cone for handling live-trapped woodchucks (not exactly to scale).

APPENDIX D. Incisor measurements and indices of Woodchucks of known age-class. (l=length, w=width, l/w=length/width, wo=length worn back, and l/wo=total length of incisor/length worn back (Merriam 1960).)

A. Adults

l	Upper incisor				Lower incisor			
	w	l/w	wo	l/wo	l	w	l/w	l/wo
11.00	4.50	2.44	7.50	1.47	21.00	4.00	5.25	7.00
10.00	3.75	2.67	6.00	1.67	16.00	3.25	4.92	9.25
8.50	3.50	2.43	6.75	1.26	20.00	4.00	5.00	10.25
—	3.25	—	—	—	—	—	—	—
13.50	4.00	3.38	7.50	1.80	—	—	—	9.75
—	—	—	—	—	28.00	4.50	6.22	10.00
10.25	4.00	2.56	5.75	1.78	17.75	3.50	5.07	7.50
—	4.00	—	7.00	—	—	4.00	—	10.25
—	—	—	—	—	17.75	3.25	5.46	10.00
—	—	—	—	—	22.00	3.50	6.29	11.00
12.75	3.50	3.64	6.00	2.13	17.00	3.75	4.53	9.75
9.75	3.75	2.60	5.00	1.95	17.75	3.50	5.07	11.00
12.00	4.00	3.00	8.25	1.45	20.75	3.75	5.53	10.75
9.00	4.00	2.25	9.00	1.00	19.00	3.50	5.43	9.00
12.00	4.00	3.00	7.75	1.55	17.25	4.00	4.31	11.00
8.00	3.00	2.67	3.00	2.67	11.50	2.75	4.18	5.00
10.50	4.00	2.63	6.25	1.68	19.50	3.50	5.57	9.00
—	—	—	—	—	10.00	—	—	—
12.50	4.50	2.78	9.00	1.39	19.50	4.50	4.33	10.50
—	—	—	—	—	13.00	3.50	3.71	9.00
10.00	4.00	2.50	8.00	1.25	15.50	4.43	4.43	8.50
10.75	3.25	3.31	7.25	1.48	16.25	4.00	4.06	10.25
—	—	—	—	—	18.00	3.50	5.14	8.75
—	—	—	—	—	17.00	3.25	5.23	9.25
8.00	4.00	2.00	6.00	1.33	16.00	4.00	4.00	9.50
—	—	—	—	—	—	—	—	—
8.00	3.00	2.00	3.00	1.00	10.00	2.75	3.71	5.00
13.50	4.50	3.64	9.00	2.67	28.00	4.50	6.29	11.00

*Minimum measurement of index value.

†Maximum measurement of index value.

B. Juveniles

Upper incisor					Lower incisor				
I	w	l/w	wo	l/wo	I	w	l/w	wo	l/wo
6.75	3.00	2.25	3.75	1.80	12.00	2.50	4.80	4.25	2.82
6.00	3.50	1.71	6.00	1.00	16.00	3.25	4.92	8.25	1.94
11.75	3.25	3.62	8.25	1.42	15.75	3.25	4.85	10.50	1.50
8.50	3.50	2.43	5.00	1.70	8.75	3.25	2.69	5.00	1.75
6.00	3.25	1.85	3.50	1.71	12.75	3.00	4.25	5.25	2.43
7.00	3.50	2.00	5.50	1.27	14.50	2.75	5.27	5.00	2.90
7.00	3.00	2.33	5.25	1.33	13.50	3.00	4.50	7.00	1.93
8.75	3.50	2.50	7.00	1.25	15.25	3.75	4.07	9.50	1.61
9.00	3.50	2.57	4.50	2.00	15.50	2.75	5.64	9.00	1.72
—	2.50	—	3.50	—	10.00	3.00	3.33	4.00	2.50
10.00	4.50	2.22	—	—	19.00	3.50	5.43	6.00	3.17
3.25	2.25	1.44	2.75	1.18	7.50	2.00	3.75	5.25	1.43
—	—	—	1.50	—	12.25	3.00	4.08	5.50	2.23
* 3.25	2.25	1.44	1.50	1.00	7.50	2.00	2.69	4.00	1.43
+ 11.75	4.50	3.62	8.25	2.00	19.00	3.75	5.64	10.50	3.17

* Minimum measurement or index value.

+ Maximum measurement or index value.

Although Merriam's (1960) samples of adult and juvenile age-classes showed discrete ranges for upper incisor width and length-worn-back measurements, he suggested larger sample sizes may reveal range overlap. Data from roadkilled Queensway Woodchucks demonstrate overlapping ranges for all incisor measurements and indices; these cannot be used independently as a reliable method of age-class discrimination.

Merriam, H. G. 1960. Problems in Woodchuck population ecology and a plan for telemetric study. Ph.D. thesis, Cornell University.

APPENDIX E. Discussion of the home-range concept as it applies to
Woodchucks studied at Queensway interchanges.

The concept of mammalian home range is well entrenched in ecology. Burt's (1943) definition, "the area, usually around the home site, over which [an] animal normally travels in search of food," is a classic concept. Godfrey's (1954) definition of "range", "that area traversed by an animal in its normal activities of food-gathering, mating, and caring for young," takes into consideration a more realistic set of an animal's activities and requirements. Allen's (1946) "individual range" includes occasional sallies out of a home range. Scott (1943) included in home range all the area of ecological significance to the Red Foxes he studied. Herein, "range", in reference to Queensway Woodchucks, includes all locations at which an individual was seen during the 1981 season, for reasons that will become apparent. "Home range" refers to concepts existing in the literature.

Many problems are associated with the quantification of home range and with what constitutes a home-range movement. The problems and influences associated with the repeated use of traps in revealing normal activity (Linsdale 1946, Hayne 1949, Godfrey 1954, Flyger 1960, Adams and Davis 1967) are not pertinent to this research for my Woodchucks were individually marked, permitting observation of their normal activities including movements without subsequent trapping.

The numbers of records or observations necessary to determine the limits of an animal's home range are discussed by Haugen (1942), Hayne

(1949), Godfrey (1954), and Sanderson (1966). Godfrey (1954) found that the average range length reached a plateau with 19 observations yet the minimum area continued to increase for Field Voles, Microtus agrestis, which move over a restricted area. Haugen (1942) found that no mean home-range size could be calculated for adult Eastern Cottontails because the area increased with each additional capture. Merriam (1966) stressed the importance of observation effort being "applied uniformly in space, in time, and among individuals", in reference to Woodchucks. The Woodchucks used in my range comparison analyses were observed an average of 3.83 h (range=0.95-11.98) plus 5 spottings (range=1-12), and over an average of 12 separate days (range=4-24). Different trapping dates, loss of fur-dye markings after moult, and different above-ground activity levels of individuals resulted in an unavoidably wide range of observation effort for Queensway Woodchucks. I suspect that even for the individuals observed most frequently, my measurements did not reach the limits of their 1981 ranges, particularly for range areas.

Chitty (1937) and Stickel (1954) suggested that animals may range farther than expected and that these movements explain unsuspected homing and orientation abilities. I observed some Woodchucks retreat almost directly to burrow entrances at which they had not previously been observed and up to 47.5 m from their most frequently used burrow system.

Burt (1943), Godfrey (1954), and Stickel (1954) stated that sallies should not be included in home range quantification. Smith

(1973) found that 67% of his 48 Oldfield Mice, Peromyscus polionotus, were found in burrows outside their calculated home ranges. Blair (1943) and Storer et al. (1944) observed adult small mammals making distant trips and subsequently returning to their initial home ranges. Such occasional sallies are less likely to be observed but do constitute part of a Queensway Woodchuck's range. Flyger (1960) found that dispersal events could not be discerned from movements within the home ranges of Gray Squirrels, Sciurus carolinensis. This difficulty also arose when I was analysing Queensway Woodchuck movement data.

Although it seems safe to assume that the movement of Mel2²j (Fig. 15) was a dispersal event, most Woodchuck movements are not so easily distinguished. Michener and Michener (1977) found that it was impossible to state that movement over a certain distance implied dispersal in Richardson's Ground Squirrels. They arbitrarily defined "dispersal" as any movement greater than 250 m.

Whether movements are exploratory in nature, part of a dispersal event, or otherwise infrequently made, I think they should be included when considering an animal's range. Theoretically, if the areas visited were preferable to the animal's existing range, they would be used more frequently. By omitting these temporary range extensions, an arbitrary and biased limit of the intensity of use of an area is applied.

Seasonal changes in home ranges occur in Gray Squirrels (Flyger 1960), Eastern Cottontails (Haugen 1942), and various smaller mammals (Stickel 1954). de Vos and Gillespie (1960) reported that Woodchucks

may shift their home ranges over a season and Merriam (1971) observed individuals practising burrow exchange at a high rate. My marked Woodchucks were observed between April and October; however, no obvious trends in movement frequency or location were apparent throughout this observation period. Monthly mortality data (mostly involving unmarked Woodchucks), however, indicate adults move more often in May and June, whereas juveniles most frequently cross roads in June, July, and August.

The major weakness in quantifying home range is its method of delineation. The minimum area method has been used to estimate home ranges for a wide variety of mammalian species, including Woodchucks (Bronson 1964), Gray Squirrels (Flyger 1960, Pack et al. 1967), Field Voles (Godfrey 1954), Oldfield Mice (Smith 1973), Eastern Cottontails (Haugen 1942), and Red Foxes (Storm 1965). When the outlying points at which an animal was observed are joined, the resulting polygon conservatively estimates the home range, for the animal is known to have been within this enclosed area (Hayne 1949). Unfortunately, plotted animal movement is usually amoeboid in appearance and polygons give a false impression of actual area and precision (Burt 1943, Linsdale 1946, Stickel 1954). Queensway Woodchuck movement-tracks are irregular in shape. When I used the minimum area method, relatively large areas of paved surface, bridge, and/or creek were included in the range area measured (e. g., #10♂Ad (Fig. 13) and Mel2♀j (Fig. 15)). Because Queensway interchanges provide a Man-made heterogeneous environment, areal quantification of the Woodchucks' ranges must be interpreted with reservations.

Home ranges are rarely 2-dimensional, nor are they a permanent attribute of an animal (Linsdale 1946). Three-dimensionality of range is shown by the Queensway Woodchucks' use of slopes, stumps, raised manholes, and culverts. In 1980, 2 juveniles at Pinecrest SW were seen on a branch of a White Elm, about 5 m above ground level. Data on Woodchucks observed over only a short term such as a week would give a more biased view of range dimensionality, for the probability of observing the full spectrum of movements undertaken by an individual over a season is low. Minimum area polygons and measurements taken from 2-dimensional contour maps produce data which lack third-dimension information. This underestimates the surface area used by animals moving along slopes, while areal quantification for those ranging on essentially flat areas produces more accurate measures.

Differential intensity of use of the habitat is inevitable in an animal's home range (Hayne 1949, Stickel 1954, Flyger 1960, Sanderson 1966). The line drawn to enclose an animal's movements is an abstraction of ours, having little meaning to the animal itself (Linsdale 1946). For an individual whose range is relatively compact and repeatedly travelled, such as Whiteye?Ad (Fig. 11) on Pinecrest SW, the minimum area method seems reasonable. However, for virtually all other individuals, Mel2+j (Fig. 15) at Pinecrest being a highly exaggerated example, this method overestimates the area of ecological importance to a Woodchuck.

To attempt to assign a specific geometric design to a species'

home range, as done by Stumpf and Mohr (1962), Frantz (1972), Metzgar (1972), Koepl et al. (1975), and Van Winkle (1975), has little ecological utility. The topography of an area, however, may encourage a certain utilization pattern by resident animals. Sanderson (1966) and Stumpf and Mohr (1962) commented on how mammals associated with watercourses often exhibit linear home ranges, as do birds living along roadsides (Linsdale 1929). Shape may be of ecological interest, but only when qualified by its probable causes.

Composite home ranges (Mohr 1965, Mohr and Stumpf 1966, Metzgar 1972) may falsely assume that within a species, movements do not vary significantly. This method must assume the "animals" used in analysis come from similarly homogeneous habitats. Environmental homogeneity we perceive may be quite different from a particular animal's perception.

"Biologists should lose some of their preoccupation with shape and size of home range Movement patterns are established and regulated by the density of the species, food supply, reproductive activity, the quality and physiographic arrangement of the habitat, and no doubt many other factors No doubt the home range can be reduced to some unknown minimum size. Therefore, perhaps investigators should be studying what each animal needs under each set of circumstances" (Sanderson 1966).

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