THE IMPACT OF AMINOCARB ON THE ACTIVITY OF A TERRESTRIAL ANIMAL COMMUNITY

by

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ABSTRACT

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THE IMPACT OF AMINOCARB ON THE ACTIVITY OF A TERRESTRIAL ANIMAL COMMUNITY

The effects of aminocarb on the activity of an animal community were investigated using 2 sets of sand transects, 25 km apart. Changes in the ratios of animal activity between the treatment and control transects pre-spray and post-spray were used to identify impacts. Immediately following the aerial spray there was a significant decrease in Lepidopteran and Arachnid activity, and an increase in avian activity along the forest floor. The decreased Arachnid activity may have caused an increase in the activity of Chilopoda. Bufo americanus and Thamnophis s. sirtalis activity could have been adversely affected by reduced prey availability. The change in bird behaviour appears to have initiated a significant increase in Mustela erminea activity. Reductions in Blarina brevicauda and Clethrionomys gapperi activity may have been related to the increased ermine activity. A comparison of the sand transect and kill-trapping techniques demonstrated that sand tracking is the superior method for assessing the impact of insecticides on small mammal populations.

ABREGE

M.Sc. G.A. Bracher Ressources Renouvelables

L'IMPACT DE L'AMINOCARB SUR L'ACTIVITE D'UNE COMMUNAUTE ANIMALE TERRESTRE

Les effets de l'aminocarb sur l'activité animale furent examinés à l'aide de 2 transects de sable, distances de 25 km. Le rapport d'activité animale entre les transects de traitement et ceux de contrôle, avant et après l'arrosage, ont constitué les résultats de base pour établir les impacts. Immédiatement après l'arrosage aérien, nous avons constaté une baisse significative dans l'activité des lépidoptères et des arachnides alors que les oiseaux ont démontré une augmentation de l'activité sur le sol forestier. La diminution d'activité chez les arachnides fut peut-être causée par une augmentation de l'activité des chilopodes. L'activité du Bufo americanus et du Thamnophis s. sirtalis a pu être négativement affectée par une réduction des proies disponibles. La modification dans le comportement des oiseaux semble avoir produit un accroissement significatif dans l'activité des Mustela erminea. Les baisses d'activité chez Blarina brevicauda et Clethrionomys gapperi pourraient être reliées à l'accroissement de l'activité des Mustela erminea. Une comparaison des méthodes de la piste de sable et du piégeage mortel a démontré que le transect de sable constitue une méthode plus fiable pour évaluer l'impact des insecticides sur les populations de petits mammifères.

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PREFACE

The control of economically important forest pests frequently requires the use of chemical insecticides which can have an adverse effect on nontarget animals. The selection of a particular insecticide is determined by its effectiveness against the pest and the degree of effect on other organisms in the sprayed area. Therefore, it is essential to assess the environmental effects on both target and nontarget organisms for each insecticide to be applied.

Aminocarb (4-dimethylamino-m-tolyl methylcarbamate) is a nonpersistent insecticide sold under the trade name of Matacil^R by the Chemagro Chemical Corporation. It has been used with increasing frequency since 1972 for the operational control of lepidopterous defoliators in Canadian forests (Sundaram and Hopewell 1977). Despite its increased use, there was a remarkable lack of data concerning the effects of Matacil^R on populations of terrestrial nontarget animals and there had never been a full-scale field investigation performed on a total forest environment.

The purpose of this study was to determine the short- and medium-term impact of Matacil^R on a forest animal community. During the summers of 1978 and 1979, the sand transect technique (Bider 1968) was used to monitor the animal activity of 2 different areas located in forests of similar structure. The relationship between the activity of the experimental and control plots for each species crossing the transects was determined one year before the insecticide application. In June of 1979, Matacil[R] was aerially applied over the treatment site. Impacts were identified by changes in the ratios of activity between the two sets of transects from one year to the next, or between the pre-spray and post-spray activity ratios of the second summer.

The results are reported in two separate articles, the first of which deals with the over-all effects of the Matacil[R] application on the terrestrial animal community. Comprehensive descriptions of the study areas have been included in the first paper. The second article is a comparison of the sand-tracking and kill-trapping methods for assessing the impact of insecticides on small mammal populations.

SECTION I

THE EFFECTS OF MATACIL[R] ON THE ACTIVITY OF A FOREST ANIMAL COMMUNITY

ABSTRACT

Terrestrial animal activity was monitored on treatment and control transects, 25 km apart, in the Laurentians. Immediately following an aerial application of Matacil^{R} at 0.175 kg/ha there was a significant decrease in Lepidoptera and Arachnid activity, and an increase in avian activity along the forest floor. The decreased activity of Arachnida, known predators of Chilopoda, may have caused an increase in Chilopoda activity. Diplopoda activity could have increased as a result of increased food availability. The activity of Mollusca and Annelida decreased during the 2 month post-spray period. Bufo americanus were the only amphibians which appeared to be adversely affected by the insecticide application. A decrease in the activity of Thamnophis s. sirtalis could have been related to a decrease in the activity of the preferred prey types Bufo americanus and Annelida. The increased availability of avian prey at the ground level appears to have caused an increase in Mustela erminea activity 5 days after the spray. The increase in Mustela erminea activity may have resulted in a decrease in the activity of the alternate ermine prey types Clethrionomys gapperi and Blarina brevicauda.

1.1 INTRODUCTION

The nonpersistent insecticide Matacil[R] (4-dimethylamino-m-tolyl methylcarbamate (aminocarb))has been used with increasing frequency since 1972 for the control of the spruce budworm (Choristoneura fumiferana) in Canadian forests (Sundaram and Hopewell 1977). Despite its increased use, there was a remarkable paucity of studies dealing with the effects of Matacil[R] on populations of terrestrial nontarget animals and there had never been a full-scale field investigation performed on a total forest environment.

The sand transect technique (Bider 1968) simultaneously records the activity of all terrestrial animal species within a forest community. By monitoring the animal activity on treatment and control transects pre-spray and post-spray the effects of aerially applied insecticides on nontarget species can be evaluated. The objective of this study was to determine the short- and medium-term impact of Matacil[R] on the activity of a forest animal community. The work was experimental rather than operational since spruce budworm populations were not at epidemic levels in the study areas.

1.2 STUDY AREAS

Investigations were undertaken at 2 sites approximately 25 km apart in the Laurentians of southwestern Quebec. The sprayed plot was located in the St-Donat de Montcalm region (46° 13' N, 74° 10' W), 20 km southeast of the town of St-Donat. Balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*) dominated the forest overstory. Other common species were hazel (*Corylus cornuta*), cherry (*Prunus* spp.), quaking aspen (*Populus tremuloides*), red maple (*Acer rubrum*) and sugar maple (*Acer saccharum*). Major species comprising the understory were bunchberry (*Cornus canadensis*), raspberry (*Rubus* spp.), bush honeysuckle (*Diervilla lonicera*), wild lily of the valley (*Maianthenum canadense*), aster (*Aster* spp.), blueberry (*Vaccinium angustifolium*), wild sarsaparilla (*Aralia nudicaulis*) and seedlings from the overstory species. Interspersed throughout the sprayed area were small clearings colonized by grasses (Gramineae) and species common to the forest understory. A logging road and the Dufresne River passed through the treatment area. The river was sluggish and soft bottomed, about 4 m in width, and had alders (*Alnus* spp.) growing along its banks. The depth ranged from 0.9 to 1.8 m.

The control site was situated 3 km north of the village of Lac Carré (46° 09' N, 74° 29' W) and dominated by a mixed deciduous-coniferous forest more mature than that of St-Donat. The most common constituents of the overstory were sugar maple, red maple, yellow birch (*Betula lutea*), balsam fir and black spruce. The understory was largely composed of wild lily of the valley, bunchberry, wild sarsaparilla, hobblebush (*Viburnum alnifolium*), spinulose shield fern (*Dryopteris spinulosa*), blueberry, raspberry, plus seedlings from the overstory species. A fast-flowing brook 2 m wide with a gravel bottom, numerous deep pools and alder covered banks, traversed the area. The mean depth was less than 0.3 m.

Both control and treatment sites had similar soils, were within the same weather regime and at equivalent elevations. Neither of the sites had previously been treated with an insecticide. Bider (1968) and Wishart and Bider (1976) have described the topography, vegetation, climate and soils of the Lac Carré area in detail.

1.3 METHODS

1.3.1 Data Collection

Three sand transects of varying length, totalling 305 m, were constructed on the St-Donat site. An equal length from 4 different transects was used to record the animal activity at Lac Carré. Bider (1968)and Bramwell and Bider (1981) provided a description of sand transect construction and maintenance. Each crossing of a transect was defined as one unit of animal activity. Footprints on the transects were recorded from 4 to 12 times each day. The total number of daily crossings of each species at each location was then determined. Data for closely related species whose tracks could not be readily distinguished from one another were combined and considered as a single animal group, i.e. jumping mice.

For those species of animals most active during the night an activity day began and ended at noon, whereas activity days for diurnal species went from midnight to midnight.

Data were collected from 12 July to 31 August, 1978 and 1 June to 31 August, 1979.

1.3.2 Insecticide Application

On 28 June, 1979 at 19:30 hrs Matacil[R] (1.4 oil soluble concentrate) was sprayed over the forest at St-Donat by a Cessna 185 aircraft fitted with a Micronair[R] spray emission system. The application rate was 0.175 kg active ingredient in 2.24 l/ha. This dosage represents the maximum accumulation permitted within one season by Agriculture Canada (Kingsbury *et al*. 1979). The aircraft flew at a speed of 160 km per hour and sprayed approximately 150 hectares. Kromecote[R] cards placed in open areas indicated uniform coverage.

1.3.3 Analysis of Activity Data

The total activity of a species is a function of 2 main components, population size and per capital activity (Bider and Sarrazin 1972). Per capita activity is greatly influenced by weather. Precipitation increases the activity of nocturnal or crepuscular species and decreases that of diurnal species (Bider 1968, Doucet and Bider 1974, FitzGerald and Bider 1974, Stewart and Bider 1977, Vickery and Bider 1978). As a result of differences in the time and quantity of precipitation at the 2 sites, it was necessary to drop from the analysis days in which it rained significantly at one location but not at the other. Also deleted were days when transects were too wet to register prints on at least 80 percent of the total transect length at either location. In total, 8 of a possible 51 days were lost to rainfall in 1978, and 32 out of a possible 92 days were lost in 1979.

To assess the short-term effects of the Matacil^R application on animal activity an analysis of variance was conducted on data from the last 10 days of usable data prior to the spray and the first 10 days following the spray (Table 1).

Cumulative frequency histograms and activity ratios (Table 2) were used to evaluate the medium-term impact. Medium-term effects were defined as those population responses which occurred from the time of the spray until the final day of data collection. An analysis of covariance was used to determine if the changes in the ratios of activity were significantly different (Table 3). Covariance analysis is particularly useful when conducting impact assessments since it combines the principle of before and after comparisons with the use of a control. A presentation of the analysis of covariance tests used in this study may be found in Snedecor and Cochrane (1967).

For the covariance analysis to be considered reliable certain assumptions must be met. Animal activity at the control site should be correlated with that of the treatment site. In addition, the variances and slopes between the pre-spray and post-spray data sets should not be significantly different. The activity on the control plot is considered to be the independent variable and is used as a basis for adjusting the activity of the treatment transects (dependent variable). If all the assumptions of the analysis of covariance were fulfilled and the adjusted means were significantly different, then a change in activity was considered to have occurred. In the event that the covariance analysis was significant but 1 or more assumptions failed, simple chi-square contingency tables comparing the pre-spray and post-spray activity ratios of the control and treatment transects were used as back-up analysis. If the chi-square test was also significant, then a change in activity was still considered to have taken place.

In the last column of Table 3 the results of the covariance and chi-square analysis have been summarized into 3 different categories:-

a) there was an increase in activity at St-Donat relative to Lac Carré (+),

b) there was no change in activity at St-Donat relative to Lac Carré (0),

c) there was a decrease in activity at St-Donat relative to Lac Carré (-).

Animal groups crossing the tracks at low or erratic rates result in skewed and heteroscedastic data in which the variance tends to increase and decrease with the mean (Bramwell 1980). To reduce this problem, the data used in all parametric analysis were transformed by adding 1 to the observed total daily crossings and taking the natural logarithm of the sum (Snedecor and Cochrane 1967).

1.4 RESULTS

1.4.1 Overview of Animal Activity at the Two Sites

An examination of the St-Donat site was made shortly after the Matacil^R application. Numerous dead midges (Chironomidae) were found on cars and tents within minutes of the forest spray. Large numbers of spiders (Araneae), harvestmen (Opiliones), beetles (Coleoptera) and ants (Formicidae) in open areas were also immediately killed. There were no dead vertebrates found throughout the post-spray period.

During the 2 summers of data collection a total of 39 species or species groups crossed the sand transects (Table 2). These included 9 groups of invertebrates, 4 amphibians and reptiles, 23 mammals and 3 birds. Only 19 groups were sufficiently active to permit parametric analysis (Tables 1 and 3).

Differences in habitat conditions resulted in several species having consistently higher activity at one location. The maturity of

the forest at Lac Carré provided more favorable habitat for deer mice (Peromyscus maniculatus), jumping mice (Zapodidae) and porcupine (Erethizon dorsatum). Consequently, the daily activity of these species tended to be greater at Lac Carré than at St-Donat. Frogs (Rana spp.), salamanders (Urodela) and raccoons (Procyon lotor) were more active at Lac Carré due to the proximity of the stream to the transects.
The many clearings and the early stages of forest succession at St-Donat supported more snowshoe hare (Lepus americanus) and ruffed grouse (Bonasa umbellus) activity. The total invertebrate activity at both sites was approximately equal, however, shrew (Sorex spp. and Blarina brevicauda) activity was greater at St-Donat. This suggests that the extra production of arthropods at St-Donat supported a greater number of insectivores. Higher activity at St-Donat by the 2 most common terrestrial predators, the ermine (Mustela erminea) and the striped skunk (Mephitis mephitis), coincided with a greater number of small mammal and bird crossings on the treatment transects.

1.4.2 Short- and Medium-Term Changes in Activity

1.4.2.1 Invertebrates

1.4.2.1.1 Arachnida

The activity of the group Arachnida was composed of crossings by spiders and harvestmen. The analysis of variance (Table 1) reveals that there was a decrease ($P < 0.05$) in Arachnid activity at St-Donat during the first 10 days after the Matacil[R] application. A similar change did not occur at Lac Carré.

Although there was not a significant change in Arachnid activity between 1978 and 1979 post-spray, the activity ratios (Table 2) and analysis of covariance (Table 3) indicate that there was a decrease ($P < 0.01$) in the proportion of activity at St-Donat relative to Lac Carré from 1979 pre-spray to 1979 post-spray.

1.4.2.1.2 Diplopoda

Millipede (Diplopoda) activity increased at both treatment ($P < 0.01$) and control ($P < 0.05$) sites over the short-term.

The ratio of millipede activity at St-Donat increased relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.01$), and from 1979 pre-spray to 1979 post-spray ($P < 0.01$).

1.4.2.1.3 Chilopoda

The activity of centipedes (Chilopoda) did not significantly change at either location 10 days after the forest spray.

Covariance analysis did not reveal a significant difference between the activity of the 2 years. However, centipede activity at St-Donat increased ($P < 0.01$) relative to Lac Carré from the pre- to the post-spray periods of 1979.

1.4.2.1.4 Orthoptera and Coleoptera

The tracks of Coleoptera and Orthoptera were difficult to distinguish from one another. Therefore, not much confidence should be placed in the results of the statistical tests. The only trend worth noting is that the proportion of post-spray activity at St-Donat tended to decrease relative to Lac Carré.

1.4.2.1.5 Arthropoda

To obtain a better understanding of the effects of Matacil[R] on the invertebrate community, the total daily crossings of Arachnida, Orthoptera and Coleoptera were combined and analyzed as a whole. The activity of the combined group Arthropoda did not significantly change over the short-term.

At St-Donat, Arthropoda activity decreased relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.01$), and from 1979 pre-spray to 1979 post-spray ($P < 0.01$).

1.4.2.1.6 Lepidoptera

Lepidopterous larvae activity decreased ($P < 0.01$) at St-Donat during the 10 days following the insecticide treatment. The activity on the control transects did not significantly differ during this time period.

The ratio of Lepidoptera activity between 1978 and 1979 post-spray was not significantly different. According to the analysis of covariance, the proportion of activity occurring at St-Donat decreased ($P < 0.01$) relative to Lac Carré between the pre- and post-spray periods of 1979. However, this conclusion must be rejected since the assumptions of the covariance analysis were not fulfilled and the chi-square test did not indicate a change in activity. The 1979 cumulative frequency histograms (Figure 1) reveal that the absence of a significant change in the chi-square test can be attributed to a large increase in activity at St-Donat during the final 12 days of data collection.

1.4.2.1.7 Annelida and Mollusca

The groups Annelida (earthworms) and Mollusca (slugs and snails) infrequently crossed the transects. Although the post-spray activity of both these groups decreased at St-Donat relative to Lac Carré, there was insufficient data to test the changes in activity for significance.

1.4.2.2 Amphibians and Reptiles

1.4.2.2.1 *Rana* spp.

Northern leopard frogs (*Rana pipiens*) and wood frogs (*Rana sylvatica*) were active at both sites. There was not a significant change in frog activity at either location over the short-term.

The ratio of frog activity at St-Donat remained proportional to that of Lac Carré between 1978 and 1979 post-spray, and from 1979 pre-spray to 1979 post-spray.

1.4.2.2.2 Bufo americanus

During the 10 days after the Matacil[R] application, toad (Bufo americanus) activity significantly increased ($P < 0.05$) at both sites. However, when 17 days pre-spray and post-spray were tested, the change in activity at St-Donat was no longer significant. The larger sample size is more reliable since toad activity is strongly influenced by temperature which hovers near the toad activity threshold at this time of year (FitzGerald and Bider 1974).

Although there was a reduction ($P < 0.01$) in toad activity at St-Donat relative to Lac Carré between 1978 and 1979 post-spray, the change in the ratio of activity from 1979 pre-spray to 1979 post-spray was not significant. From the 1978 cumulative frequency histograms (Figure 2) it can be seen that the sequence of activity at the 2 sites was similar until the final 19 days of data collection when the toad activity at St-Donat increased relative to Lac Carré. In contrast, the 1979 cumulative frequency curves reveal that toad activity at St-Donat was consistently less than that at Lac Carré, and that the activity at St-Donat greatly decreased relative to Lac Carré during the 2 months after the spray. This suggests that there may have been a decrease in activity at St-Donat after the insecticide treatment.

To determine whether there was a post-spray change in toad activity, the data were compared to a series of data collected at Lac Carré from 1964 to 1971 (Table 4). The 8 years of data were corrected for 305 m of transect and for the number of days represented by the pre- and post-spray periods of 1979. Activity ratios were used to adjust the activity at St-Donat. On the average over the 8 years there was 3 times as much activity during the days represented by the post-spray period, as those represented by the pre-spray period. Therefore, the expected number of crossings were obtained by multiplying the pre-spray data by 3. When the number of expected crossings was compared to the post-spray activity it was found that there were 1.98 percent more crossings than expected at Lac Carré and 39.36 percent fewer crossings than expected at St-Donat. From these latter results and the cumulative frequency histograms there appears to have been an unexpected and abnormally large decrease in toad activity at St-Donat following the forest spray.

1.4.2.2.3 Ophidia

Snakes were mainly represented by the eastern garter snake (Thamnophis s. sirtalis), although some smooth green (Opheodrys v. vernalis) and northern red-bellied (Storeris o. occipitomaculata) snakes were also present. They were not sufficiently active to permit parametric analysis, however, the activity ratios and cumulative frequency histograms (Figure 3) indicate that there was a great change in activity over the 2 years. The proportion of snake activity at St-Donat during the 2 months after the Matacil® application was half that of the 1978 pre-spray period.

1.4.2.3 Mammals

1.4.2.3.1 Sorex spp. and Blarina brevicauda

Although there was a decrease ($P < 0.05$) in the activity of both groups of shrews at Lac Carré 10 days following the insecticide spray, the activity at the treatment site did not significantly change.

At St-Donat, the activity of Sorex spp. increased relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.01$), and from the pre- to the post-spray periods of 1979 ($P < 0.01$). The activity ratios indicate that B. brevicauda activity at St-Donat decreased relative to Lac Carré between 1978 and 1979 post-spray, and from 1979 pre-spray to 1979 post-spray. However, the analysis of covariance reveals that these changes in activity were not significant. An examination of the cumulative frequency histograms (Figure 4) shows that whereas B. brevicauda activity increased at St-Donat relative to Lac Carré during the final 18 days of data collection in 1978, their activity remained constant throughout the same period in 1979. Therefore, there appears to have been a slight decrease in B. brevicauda activity over the medium-term.

1.4.2.3.2 Lepus americanus

The activity of the snowshoe hare decreased ($P < 0.01$) on the control transects 10 days after the spray, yet remained unchanged at St-Donat.

According to the analysis of covariance the proportion of hare activity at St-Donat did not significantly change during the 2 months after the Matacil^R application.

1.4.2.3.3 Tamias striatus

Chipmunks (Tamias striatus) did not demonstrate a significant short-term change in activity at either location.

At St-Donat, chipmunk activity increased relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.01$), and from 1979 pre-spray to 1979 post-spray ($P < 0.01$).

1.4.2.3.4 Tamiasciurus hudsonicus

The analysis of variance indicates that red squirrel (Tamiasciurus hudsonicus) activity increased at Lac Carré ($P < 0.01$) and St-Donat ($P < 0.01$) during the 10 days following the Matacil^R spray.

Despite the decrease in the ratio of red squirrel activity at St-Donat relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.01$), squirrel activity increased at St-Donat relative to Lac Carré from the pre- to the post-spray periods of 1979 ($P < 0.01$).

1.4.2.3.5 *Peromyscus maniculatus*

Deer mouse activity did not significantly change on either set of transects immediately following the forest spray.

In 1978, deer mice were active only at Lac Carré. The proportion of deer mouse activity at St-Donat increased ($P < 0.01$) relative to Lac Carré from 1979 pre-spray to 1979 post-spray.

1.4.2.3.6 *Clethrionomys gapperi*

During the 10 days following the Matacil^R treatment, red-backed vole (*Clethrionomys gapperi*) activity decreased ($P< 0.05$) at St-Donat. At Lac Carré, vole activity did not significantly change.

Red-backed vole activity increased ($P< 0.01$) at St-Donat relative to Lac Carré between 1978 and 1979 post-spray. However, the activity ratios between 1979 pre-spray and 1979 post-spray were not significantly different.

1.4.2.3.7 Zapodidae

The woodland jumping mouse (*Napaeozapus insignis*) was the dominant Zapodid species found. However, the meadow jumping mouse (*Zapus hudsonicus*) was also present at both sites. Although jumping mouse activity decreased ($P< 0.01$) at Lac Carré over the short-term, the activity at St-Donat did not significantly change.

Neither of the covariance tests indicate a significant medium-term change in jumping mouse activity.

1.4.2.3.8 Mustela erminea

At St-Donat, ermine increased in activity during the first 10 days after the insecticide treatment. This short-term change in activity was not statistically significant, however, by 17 days the increase in ermine activity had become significant ($P < 0.05$). Ermine were not active at the control site during either of these time periods.

The cumulative frequency histograms (Figure 5) and activity ratios indicate large differences in ermine activity between the 2 summers at the 2 sites. During 1978, ermine were active only at St-Donat. In 1979, ermine were present at both locations and were much more active than the previous summer. Ermine seldom crossed the St-Donat transects at the beginning of the tracking season, but greatly increased in activity between the fifth and eighth day after the Matacil[R] spray. The activity remained constant and high until the end of August. At Lac Carré, ermine followed a sequence of activity quite different from that of St-Donat. The first crossing did not occur until the latter half of the summer and never demonstrated any great increase in activity comparable to St-Donat. The increase in the ratio of activity at St-Donat relative to Lac Carré could not be tested for significance due to the low number of ermine crossings at Lac Carré.

1.4.2.4 Total Aves

There was an increase ($P < 0.01$) in bird activity at St-Donat during the 10 days following the insecticide spray. A similar change did not occur at Lac Carré.

Bird activity at St-Donat increased relative to Lac Carré between 1978 and 1979 post-spray ($P < 0.05$), and from the pre- to the post-spray periods of 1979 ($P < 0.01$). From the cumulative frequency histograms (Figure 6) it can be seen that avian activity at St-Donat dramatically increased for approximately 16 days after the Matacil^R treatment, then returned to a rate similar to that of the control area.

1.4.2.5 Other Species

The remaining 17 species or groups of amphibians, mammals and birds infrequently crossed the sand transects. Because of the extreme paucity of data for these less common animals it was not possible to determine the effects of Matacil^R on their activity.

1.5 DISCUSSION

The populations comprising a forest animal community are in dynamic equilibrium with each other, the plant community and the physical environment. Applications of insecticides may upset this equilibrium, thereby causing changes in animal activity. It is difficult to differentiate between changes in activity related to the direct toxic effects of an insecticide and indirect effects, such as the removal of a predator or the elimination of a competing species. Therefore, discussions on the reasons for observed changes in activity are inherently limited.

1.5.1 Invertebrates

The majority of insecticides are selective (Moore 1967). They kill species of certain large taxa and have little or no impact on the species of other taxa. The decrease in the activity of Arachnida, Lepidoptera and Mollusca can be attributed to the direct toxic effects of Matacil^{R} since this insecticide is known to be particularly lethal to these animal groups (Worthing 1979).

The increase in millipede activity at St-Donat and Lac Carré during the 10 days following the insecticide treatment corresponds to a massive hatch of young millipedes. Why the millipede activity at St-Donat increased relative to Lac Carré over the medium-term is difficult to interpret. One possible hypothesis is that their food source was enhanced by the mortality of other invertebrates either through a greater availability of carrion or a decrease in competition. Although millipedes feed mainly on plant material, they have been known to eat dead insects, molluscs and worms (Cloudsley-Thompson 1968). Environment Canada biologists working in the sprayed area reported a heavy mortality of arboreal invertebrates from balsam fir within 12 hours of the spray (Kingsbury et al. 1979). Greater food availability may have resulted in an increase in millipede numbers, thereby increasing total millipede activity.

The increased activity of Chilopoda on the treatment site during the two months after the forest spray, could have been a response to reduced predation and competition by Arachnida. In a spider removal experiment conducted by Clarke and Grant (1968) centipede numbers increased while millipedes, not taken by spiders, were unaffected. Centipedes and Arachnids are both carnivorous and may feed upon similar invertebrate prey (Cloudsley-Thompson 1968). Therefore, a reduction in the numbers of Arachnids, as suggested by the decrease in their activity, would favor an increase in centipede activity.

Part of the medium-term decrease in Arthropoda activity was due to the short- and medium-term reduction in Arachnid activity. It is possible that some species of Orthoptera and Coleoptera were adversely affected by the Matacil^{R} spray, however, the medium-term decrease in Arthropoda activity could also be related to increased predation. Birds and Sorex spp., major predators of invertebrates, increased in activity during the 2 months after the spray.

Previous investigations involving the carbamate insecticides carbaryl, carbofuran, methomyl and bufencarb have demonstrated that applications of carbamates, at dosages ranging from 0.56 to 5.00 kg/ha, frequently cause large reductions in earthworm numbers and biomass (Voronova 1968, Kring 1969, Thompson 1970, Tomlin and Gore 1974). Because the dosage of insecticide applied was only a fraction of that used in the aforementioned studies, it is unlikely that Matacil^{R} had as severe an impact on earthworms. However, the extremely low number of post-spray earthworm crossings at St-Donat is cause for concern and indicates the need for further research to elucidate the effects of Matacil^{R} on earthworm populations.

To date, only one other study has attempted to determine the impact of Matacil^{R} on litter dwelling invertebrates. Varty (1978a). found that the total catch of spiders, beetles, millipedes and other invertebrates in pitfall traps was 19 percent lower on an area treated with Matacil^{R} in 1977 and irregularly with fenitrothion in previous years, than at a similar forest which had never been sprayed.

1.5.2 Amphibians and Reptiles

The absence of a significant change in activity indicates that the spraying of the forest with Matacil^{R} did not have a negative impact on frogs.

The decrease in toad activity during the 2 months after the insecticide treatment was probably related to reduced prey availability. The combined effects of the Matacil^{R}-induced mortality of invertebrates in the sprayed area, plus increased competition by birds and other insectivores for the remaining arthropods may have made foraging difficult for toads. Matacil[R] has a residual toxicity lasting from only 5 to 10 days (Nigam 1975). If toads received a lethal dose of the insecticide, it does not seem likely that they would have increased their activity over the short-term.

Examination of *T. sirtalis* gut contents by several investigators, including Hamilton (1951), Carpenter (1952), Fitch (1965) and Gregory (1978), has shown that amphibians and earthworms form the bulk of the garter snake's diet. Consequently, the reduced earthworm and toad activity during the post-spray period may have had a limiting influence on garter snake activity.

Weary (1969) noted that in the Quebec Laurentians, snakes come out of their woodland hillside hibernacula and slowly move into open fields on the valley floor, as the trees begin to leaf and block the sun's rays. They bear their young near the end of July, then continue to feed until the third week of August when a rapid migration back to the winter hibernacula begins. The 1979 cumulative frequency histograms (Figure 3) reveal that from about the end of July until the third week of August snake activity at St-Donat was very low, then increased during the final week of data collection. These changes in activity suggest the following scenario. Snakes migrated into the area as they normally would. After fulfilling their parental duties and finding foraging difficult they left the study site. In the last week of August, snakes from areas outside the sprayed plot migrated through the area on their way back to the winter hibernacula. Therefore, snakes could have been adversely affected by the Matacil[R] spray through their response to reduced prey availability.

1.5.3 Mammals

In most instances, mammals did not appear to be unfavorably affected by the Matacil[R] spray. With few exceptions the activity of nearly all groups or species of mammals increased or did not significantly change over the short- and medium-term.

The reduction in the ratio of red squirrel activity at St-Donat relative to Lac Carré between 1978 and 1979 post-spray can be attributed to yearly variation. In 1978, red squirrel activity at Lac Carré was the lowest on record in 15 years. Because squirrel activity was extremely low at Lac Carré, yet was higher in other areas i.e. St-Donat, it is not surprising that there was an increase in activity at Lac Carré during 1979. This caused the change in the ratio of activity at Lac Carré to be greater than that of St-Donat. The significant short-term increase in activity at both treatment and control sites, and the increase in activity at St-Donat relative to Lac Carré from 1979 pre-spray to 1979 post-spray suggests that red squirrels were not affected by the insecticide application.

It is unlikely that the significant short-term decrease in red-backed vole activity and the non-significant medium-term decrease in *B. brevicauda* activity were a result of the direct toxic effects of Matacil[R]. Both the short-tailed shrew and red-backed vole are primarily active during the night (Banfield 1974). In early evening at the time of the forest spray, these small mammals were probably underground in burrows. The probability of appreciable quantities of insecticide droplets penetrating a burrow are remote, particularly since the forest floor is not a major site for deposition of insecticide aerosol droplets (Armstrong 1975).

A more plausible route of entry into the small mammal complex is the consumption of contaminated invertebrates and vegetation. However, laboratory experiments conducted by Buckner *et al*. (1977) have demonstrated that small mammals will not readily feed on poisoned food sources. Although mammals could have come into contact with the insecticide by other means, such as walking through contaminated vegetation or drinking contaminated water, it would still not account for the medium-term decrease in *B. brevicauda* activity. Matacil[R] is a low-persistence insecticide and breaks down rapidly in animal tissues (Varty 1976). Therefore, there was little likelihood of delayed toxicity. If *B. brevicauda* had come into contact with lethal quantities of Matacil[R], its impact should have materialized as a short-term response.

The reductions in short-tailed shrew and red-backed vole activity were probably related to increased predation by ermine, as suggested by the large post-spray increase in ermine activity at St-Donat.

Reduced prey availability may have also had a negative impact on *B. brevicauda* activity. *Blarina brevicauda* are particularly vulnerable to forest sprays since with their high metabolism, insectivorous feeding and large food consumption they could starve to death before insect populations recover.

1.5.4 Invertebrate-Bird-Ermine Food Chain

Most aerosol droplets from an insectivide spray cloud are intercepted by the upper forest canopy. The remainder filter through the lower canopies resulting in a gradient of deposit from the top of the tree to the lower branches (Armstrong 1975, Varty 1978b). Presumably, this would have a differential effect on invertebrates. Arthropods in the upper forest crown would suffer greater mortality than those inhabiting the mid or lower crown. The majority of birds are primarily insectivorous in early summer (Martin *et al*. 1951). Therefore, any change in invertebrate numbers at the various forest strata should be reflected by avian activity.

A reduction of canopy foraging birds has been reported after some Matacil[R] applications (McLeod *et al*. 1975, Sarrazin 1978), but not after others (Buckner *et al*. 1973, Pearce *et al*. 1976, Buckner and McLeod 1977, Baird *et al*. 1978, Sarrazin 1978, Germain and Morin 1979, Germain 1980). Environment Canada biologists working at the St-Donat site did not observe a reduction in canopy foraging birds following the Matacil[R] spray (Kingsbury et al. 1979). The increase in avian activity recorded on the sand transects could indicate that canopy foraging birds responded to the reduced availability of arthropods by foraging along the ground. Personnel from the Quebec Ministry of Energy and Resources mist netted birds on treatment and control plots at St-Donat from 29 June to 9 July (Ouellet Pers. comm.). Greater numbers of birds in breeding condition, including canopy and shrub dwellers, were captured near the ground level on the sprayed plot. This behavioural change contradicts the hypothesis put foreword by several investigators (Giles 1970, Doane and Schaefer 1971, Chambers 1972, Moulding 1976) who hypothesized that insecticide-induced food shortages resulted in opportunistic feeding outside the sprayed area. Perhaps, the increased activity at the ground level might reduce detectability. Therefore, in cases where there was a decrease in canopy dwellers it is possible that there had not been a loss of birds, but rather they were not detected with the census techniques used.

At the time of the insecticide application, nesting was well in progress. Consequently, breeding birds were bound to the sprayed area by their parental duties and probably could not move elsewhere.

The short-term increase in avian activity at the ground level may have been partially a result of birds foraging on invertebrates killed by the forest spray. However, since Matacil[R] is lethal to invertebrates for only up to 10 days (Nigam 1975), there would have been an insufficient supply of carrion to sustain the high level of avian activity observed during the first 16 tracking days after the forest spray.

The increased availability of birds at the ground strata in addition to mice, shrews, voles, etc. would have resulted in high prey density and may account for the high level of ermine activity noted during the post-spray period. Ermine and other small mustelids have high metabolic rates (Scholander et al. 1950, Brown and Lasiewski 1972, Iversen 1972, Casey and Casey 1979) and consequently, must capture large quantities of prey to satisfy their energy requirements. If there had not been an increase in prey availability it seems unlikely that there would have been an increase in ermine activity.

According to Novikov (1962), Stroganov (1969) and Banfield (1974) ermine are mainly nocturnal in activity. However, Table 5 reveals that 60.00 percent of the 1979 pre-spray ermine activity at St-Donat occurred during daylight hours. Diurnal ermine activity increased to 80.58 percent during the first month after the spray and decreased to 30.45 percent throughout the month of August. This suggests that ermine changed their diel distribution of activity to take advantage of the increased availability of diurnal prey immediately following the Matacil[R] application. At the treatment site during daylight hours, ermine were repeatedly observed trying to prey upon birds trapped in a mist net (Ouellet Pers. comm.).

Ermine activity did not increase until 5 days after the spray. Presumably it took this length of time for the predators to respond to the increased prey availability in the treatment area. In this experimental application only 150 hectares were sprayed, a relatively small area compared to operational forest sprays. Ermine from neighbouring unsprayed areas could have directed their hunting activity to the sprayed plot and thus have contributed to an increase in activity. Stroganov (1969) claims that ermine are capable of traveling from 10 to 15 km in a single night.

Although ermine prey mainly upon small rodents, alternative prey types include birds, shrews and lagomorphs (Hamilton 1933, Klimov 1940, Aldous and Manweiler 1942, Novikov 1962, Day 1968, Potts and Vickerman 1974, Tapper 1976, FitzGerald 1977, Simms 1978, Simms 1979, Erlinge 1981). Models on optimal food selection proposed by Emlen (1966), Rapport (1971), Estabrook and Dunham (1976) and Stenseth and Hansson (1979) postulate that relative abundance can have an influence on an animal's optimal diet and a non-preferred prey type can be included in the diet by becoming relatively plentiful. Therefore, the greater the number of birds feeding at the ground level the greater the impact of predation by ermine that can be expected.

1.5.5 Long-Term Impact

At least one additional year of post-spray data should have been collected before attempting to determine the long-term effects of the Matacil^{R} application. Unfortunately, this was prevented by constraints of time and budget. The available activity data does not provide evidence of a long-term impact on the forest animal community. As a result of Matacil^{R}'s nonpersistence and short residual toxicity, the toxic effects of this insecticide are not expected to be long-term in nature.

The reproductive potential of most species of invertebrates is extremely high, thus arthropod numbers on the treatment site are expected to rapidly return to pre-spray levels. On account of the small area sprayed, the vacancies left by poisoned individuals would probably be quickly filled by mobile invertebrates from areas surrounding the treatment site. Past studies have shown invertebrate populations are quite resilient to occasional insecticide applications. Freitag and Poulter (1970), and Carter and Brown (1973) investigated the long-term impact of the low-persistance organophosphate insecticides fenitrothion and phosphamidon on predacious litter dwelling arthropods. Both investigations reported a reduction in spider, harvestmen and beetle numbers in the year of the spray, but recuperation of populations resumed in the following year.

The majority of short- and medium-term changes in amphibian, snake and mammalian activity can be directly or indirectly attributed to the mortality of invertebrates in the sprayed area. In view of the expected rapid recovery of invertebrate populations, it is unlikely that these changes in activity would persist over the long-term.

1.5.6 Probable Impact of an Operational Matacil[R] Spray Program

The major differences between the experimental application of Matacil[R] and an operational spray program include the dosage applied, the size of the treatment area, and the sudden elimination of large numbers of spruce budworm larvae.

Under operational conditions hundreds of thousands of hectares are frequently sprayed. Although the reintroduction of invertebrates from neighboring unsprayed areas could be hindered by the large size of an operational spray block, the dosage used in operational programs is much less than that applied in the experimental forest spray. Therefore, the direct toxic effects of Matacil[R] on nontarget arthropods and other animal groups would be less. In Quebec 2 applications of Matacil[R] at an emitted dosage of 0.052 kg/ha, 5 days apart, are normally used to control budworm outbreaks.

In an operational forest spray increased predation of birds might begin soon after the spray, however, there probably would be a rapid decline in ermine predation with time as avian activity returned to normal and the predators found other easy food resources. The impact of ermine predation might not be too severe since ermine could not respond numerically in spring at the time of spray operations, and the impact would be spread over a greater area.

Although examination of stomach contents by Mitchell (1952) revealed that when at epidemic levels spruce budworm make up approximately

40 percent of the diet of birds, the majority of insectivorous birds are facultative feeders preying upon a great variety of available prey opportunistically (Otvos 1979). Presumably, the mortality of spruce budworm following an operational Matacil[R] spray would cause insectivorous birds to switch to other abundant alternate prey species.

The effects of a sudden elimination of a large proportion of a spruce budworm population on mammals and predacious terrestrial invertebrates may not be too great. With the exception of squirrels, the mammals in a fir-spruce forest are more terrestrial than arboreal. The only time spruce budworm are available to terrestrial animals is when populations are at epidemic levels and the subsequent loss of foliage causes many larvae to drop from the trees (Morris _et al_. 1958). This takes place only during severe outbreaks and for a limited time period in late June and early July. Therefore, spruce budworm populations probably have a negligible influence on terrestrial animals.

1.6 CONCLUSIONS

Arachnid and Lepidopteran activity decreased immediately following the experimental application of Matacil[R]. The decreased Arachnid activity appears to have initiated an increase in Chilopoda activity over the medium-term. An increase in food availability may have resulted in an increase in the activity of Diplopoda. Annelida and Mollusca activity decreased during the 2 months after the insecticide application. Toad and garter snake activity could have been adversely affected by a decrease in prey availability. It appears that there was a direct relationship between an increase in prey availability at the ground level and an increase in ermine activity. Animal activity data suggests that canopy feeding birds were forced to forage along the forest floor after their invertebrate food resources were reduced by the Matacil[R] spray. The increase in ermine activity may have caused a decrease in the alternate prey species *B. brevicauda* and *C. gapperi*.

SECTION II

TRACKING AND TRAPPING, A COMPARISON OF TWO TECHNIQUES FOR ASSESSING THE IMPACT OF INSECTICIDES ON SMALL MAMMAL POPULATIONS

ABSTRACT

The results of the sand transect and kill-trapping techniques for assessing the effects of insecticides on populations of small mammals were compared following an experimental application of Matacil[R]. Data obtained by both methods indicate that the small mammal complex was not adversely affected by the aerial spray. The sand transect technique had several advantages over kill-trapping. It yielded a greater volume of data for each species and supplied information on all species within the forest animal community. The relation between animal activity and trapping success varied among the species studied. This variation may have been due to differences in above ground activity and the amount of activity involved in foraging. Inadequate trapping effort resulted in a low capture rate during the pre-spray period. Since kill-trapping creates a vacuum which can be rapidly filled with animals from outside the sprayed area it is not an appropriate technique.

2.1 INTRODUCTION

The majority of small mammals are nocturnal and secretive in their habits. Therefore, assessing the ecological impact of aerially applied insecticides on the small mammal complex is extremely difficult. The simplest and most commonly used technique for censusing small mammal populations during impact studies involves kill-trapping. However, trapping would seem to be less than satisfactory. At the time of spray operations, 15 May to 20 June, small mammal populations are extremely low and the samples taken are too small to give significant results. The object of this investigation was to compare the results of kill-trapping with those of an alternate method, the sand transect technique (Bider 1968), following an experimental forest application of Matacil^{R}.

2.2 STUDY SITES

Sand tracking data were collected at two locations 25 km apart in southwestern Quebec. Both sites were at similar elevations and within the same weather regime. The Matacil^{R} treated area was located in the St-Donat de Montcalm region (46^{o}13' N, 74^{o}10' W) and consisted of a balsam fir (Abies balsamea) and black spruce (Picea mariana) forest. A comprehensive habitat description can be found on pages 2 and 3 of the first section. The control transects were situated 3 km north of the village of Lac Carré (46°09' N, 74°29' W) and ran through a mixed deciduous-coniferous forest dominated by sugar maple (_Acer saccharum_), red maple (_Acer rubrum_), yellow birch (_Betula lutea_), balsam fir and black spruce. The vegetation, climate and topography of the control area have been described by Bider (1968) and Wishart and Bider (1976).

Trapping was conducted by biologists from the Forest Pest Management Institute, Sault Ste-Marie, on control and treatment plots in the St-Donat area.

2.3 METHODS

2.3.1 Sand Transect Technique

Animal activity was monitored on a total of 305 m of sand transect at each site. Detailed descriptions of the construction and maintenance of sand transects can be found in Bider (1968) and Bramwell and Bider (1981). Each crossing of a transect was defined as one unit of animal activity. Daily activity totals were used, although transects were read from 4 to 12 times daily throughout the study. For nocturnal mammals an activity day began and ended at noon, whereas activity days for diurnal species ran from midnight to midnight. Data for closely related species whose tracks could not be be readily distinguished were combined and considered as a single animal group, i.e. jumping mice.

The sand transects were in operation for 2 summers. In 1978 data collection commenced 12 July and ended 31 August, whereas the 1979 field season went from 1 June to 31 August.

2.3.2 Kill-trapping Technique

Kingsbury et al. (1979) sampled small mammal populations using standard snap-back traps (Victor 4-way^R) baited with a mixture of rolled oats, peanut butter and bacon fat. Trapping was carried out during the 5 days immediately prior to the spray, a 6 day period immediately after the insecticide application, and during a 10 day period 23 days after the treatment.

2.3.3 Data Analysis

To determine if there was a relationship between animal activity and the number of animals captured, simple linear correlation coefficients were calculated and tested for significance. Because different control plots were used in the 2 investigations, only the trapping and animal activity data obtained from the treatment site could be compared.

The correlation coefficients for the meadow vole (Microtus pennsylvanicus) and the star-nosed mole (Condylura cristata) were not determined as there was insufficient data on which to base the analysis. Also deleted were the days from 1 July to 3 July during the immediate post-spray period since excessive rainfall rendered the sand transects inoperable.

2.3.4 Insecticide Application

Matacil^{R} (4-dimethylamino-m-tolyl methylcarbamate (aminocarb)) was sprayed over 150 hectares of forest at St-Donat on 28 June, 1979 at 19:30 hrs by a Cessna 185 aircraft fitted with a Micronair^{R} spray emission system. The spray was emitted at the rate of 0.175 kg active ingredient in 2.24 l/ha.

2.4 RESULTS

The kill-trapping program on the treatment site resulted in the capture of 6 different animal groups. These included shrews (Sorex spp. and Blarina brevicauda), boreal red-backed voles (Clethrionomys gapperi), deer mice (Peromyscus maniculatus), jumping mice (Zapodidae), a meadow vole and a star-nosed mole. The number of daily captures per 100 traps and the corresponding activity data for each species have been summarized in Table 6.

From Table 7 it can be seen that the relation between the daily capture rate and animal activity was not the same for each species. Although the correlation coefficients calculated for Sorex spp. ($r = 0.766$) and P. maniculatus ($r = 0.695$) were significant at the 0.01 level, those of C. gapperi ($r = -0.096$) and Zapodidae ($r = 0.193$) were not significant. In contrast, the correlation coefficient for B. brevicauda ($r = -0.473$) was negative and significant at the 0.05 level.

2.5 DISCUSSION

2.5.1 Relation Between Activity and Trapping Data

The significant positive correlation coefficients calculated for P. maniculatus and Sorex spp. reveal that similar results were obtained for both these species. As the number of shrews and deer mice crossing the transects increased there was a corresponding increase in the number of individuals captured. Sarrazin and Bider (1973), and O'Neil (1976) noted a similar relation between the activity of the masked shrew (Sorex cinereus) and the number of captures in unbaited pitfall traps. An inverse relation was indicated by the negative correlation coefficient determined for B. brevicauda. The number of short-tailed shrews captured decreased as activity increased. There was no relationship found between the number of C. gapperi or Zapodidae taken and their activity. This is in direct contrast to O'Neil (1976) who reported a positive correlation between activity and the number of captures of the woodland jumping mouse (Napaeozapus insignis), yet agrees with the findings of Pellerin (1969) who found no such relationship among jumping mice.

The major problem with Zapodidae is that they change their rate of activity at different locations under different weather conditions. On nights without precipitation jumping mice are active near streams (Thibault 1969), whereas on rainy evenings they are active away from the streams (Bider 1968, Pellerin 1969). Therefore, weather and the location of trap sites are extremely important, and one should not expect a correlation between tracking and trapping data unless the work is carried out at the same site as in O'Neil (1976).

In general it can be assumed that an animal has a poor likelihood of being trapped when it is not active. However, it does not follow that animals which are active should be captured if baited traps are used since not all activity is directed towards feeding. When the relation between total numbers captured and total activity for each species is compared (Figure 7) one notices that there is a tendency for free ranging animals such as Zapodidae, to have a small number of captures relative to the number of crossings. This suggests that Zapodidae spend more of their overground activity exploring, searching for mates or exercising, rather than foraging. On the other hand, the small number of crossings and the large number of captures reveal that the more fossorial rodent C. gapperi probably does little else than search for food when above the ground. The significant positive correlation between Sorex spp. activity and bait or pitfall trapping is a good indication that the greatest part of their overground activity is involved in food searching.

The small number of captures and the relatively low activity makes it difficult to determine what might have happened in the cases of *B. brevicauda* and *P. maniculatus*. It is possible that the small number of *B. brevicauda* captured resulted in an inaccurate representation of the relationship between animal activity and trapping success. Because *B. brevicauda* and *Sorex* spp. are both insectivores with high metabolic rates both must spend a great deal of time foraging (Banfield 1974). Therefore, it seems unlikely that an increase in activity should result in a decrease in the number of *B. brevicauda* captured, while the opposite occurred for *Sorex* spp. *Peromyscus maniculatus* falls between *C. gapperi* and *Zapodidae* in their tendency to run overground. Consequently, there was a more linear correlation between bait trapping and activity.

2.5.2 Trapping Effort

The trapping success of Kingsbury *et al*. (1979) was high compared to that obtained in other studies investigating the impact of Matacil^R on populations of small mammals (Buckner *et al*. 1973, Buckner *et al*. 1974, Buckner *et al*. 1975). However, the number of individuals captured, particularly during the pre-spray period, was still too small to yield significant results.

Figure 8 shows the relation between the activity of *Sorex* spp. and the success of kill-trapping. From the regression line ($y = 0.0227x - 1.0883$) it can be seen that when there is little *Sorex* spp. activity the number of expected captures is also low. In fact, the relation shows that one should not expect a capture when there is less than 92 crossings/305 m of transect/day. Since the average number of crossings per day was 148 during the pre- and immediate post-spray periods it is not surprising that there were few shrews captured. The least animal activity tends to occur in early summer when small mammal populations are extremely low. Therefore, the trapping effort should be greatest at the beginning of the summer and may be reduced throughout the summer as populations increase. Despite this, Kingsbury *et al*. (1979) did just the opposite. The fewest number of traps (75) were used during the 5 day pre-spray trapping period and subsequently increased to 103 and 230 traps during the 6 and 10 day post-spray trapping periods. This probably accounted for the scarcity of data during the pre-spray period.

Mammal populations and animal activity can vary widely even on plots of land a few meters apart. Bider and Sarrazin (1972) noted that *S. cinereus* activity data, corrected for variances in transect length, was twice as high on one sand transect as on 2 others only a few meters away. Therefore, it is necessary to determine if the animal activity between 2 areas is similar before using one as a control. Throughout the 2 summers of data collection Bider and Bracher (1980) found that *P. maniculatus* and Zapodidae activity was consistently higher on the control transects, yet the activity of shrews (*B. brevicauda* and *Sorex* spp.) was always greater on the treatment site. To overcome the problems of the differences between the two sites Bider and Bracher (1980) based the impact assessment of the insecticide on changes in the ratios of activity pre-spray and post-spray. The 5 day pre-spray trapping period was an inadequate length of time to detect any difference in small mammal populations. A significant improvement in experimental design would have been to trap the summer prior to the forest spray to determine if the small mammal complex of the treatment and control areas were similar, and if there were differences to compare the ratios of trapping success pre-spray and post-spray.

2.5.3 Comparison of Results

Although the results of the studies done by Bider and Bracher (1980) and Kingsbury *et al.* (1979) both indicated that Matacil[R] did not have a severe impact on populations of small mammals, there were changes noted by the sand transect technique that were not recorded by trapping data. A significant decrease in *C. gapperi* activity 10 days after the insecticide application and a non-significant drop in *B. brevicauda* activity during the 2 months after the spray were reported by Bider and Bracher (1980). These reductions in activity may have been a result of the Matacil[R] spray but were more probably due to predation by ermine (*Mustela erminea*). The kill-trapping method may not have detected these short-term changes because of the small number of mammals captured during the experimental period.

2.5.4 Advantages of Tracking

In this study the sand transect technique had several advantages over kill-trapping. It permitted each individual in the population to be sampled many times instead of just once as in kill-trapping, and with minimal disturbance to the population. Consequently, there was a much larger data base on which to base the impact assessment. Because kill-trapping creates a vacuum which can be rapidly filled when animals are active it is not an appropriate technique.

As a result of the low number of mammals captured, the trapping results of all species were combined and the impact of Matacil[R] determined on the small mammal complex as a whole. Unfortunately, the susceptibility of animals to a toxin can vary widely, even for closely related species (Tucker and Crabtree 1970, Pimentel and Goodman 1974, Matsumura 1975). The examination of combined trapping results could mask the impact of an insecticide on a particular small mammal population.

When using trapping as a means of censusing small mammal populations the size and type of trap, and the bait used will influence the size range and species of animals captured. The trapping results of Kingsbury *et al.*(1979) indicate that the snap-back traps used in their investigation were capable of taking up to chipmunk-size (*Tamias striatus*) mammals. However, animals of this size are frequently capable of triggering common snap-back traps and avoiding capture. The springing of traps by escaping animals, falling leaves, wind, etc. may result in a substantial loss of data in trapping studies. In contrast the sand transect technique yields data on all mammals independent of their size, and simultaneously samples not only populations of mammals but all terrestrial species within the community (Bider 1968, Bramwell 1980, Bider and Bracher 1980). This provides the investigator with information on prey-predator interactions and is useful in determining the secondary effects of an insecticide application.

The inclusion of data from nonresident mammals is a problem common to both methods. There is no way of differentiating between mammals originating in or outside the treatment block. The kill-trapping method however, may be more subject to this source of error. The removal of animals from the sprayed area encourages the immigration of others to fill the vacancies left by trapped individuals. Mammals such as the woodland jumping mouse and the masked shrew are highly mobile and will rapidly reinvade vacant habitat (Sarrazin and Bider 1973, O'Neil 1976). Also, when trapping is done near the border of the treatment site, as in this experiment, there is the increased chance of catching animals from outside the sprayed area. Data for the animal activity study was gathered in the center of the sprayed block. If data from nonresident mammals are included in data analysis, then the impact of an insecticide on the small mammal complex may not be detected.

2.6 CONCLUSIONS

Although both kill-trapping and animal activity data reveal that the spraying of the forest with Matacil[R] did not cause a drastic reduction in small mammal populations, greater confidence can be placed in the results of the sand transect technique. The animal activity study yielded a greater volume of data for each species and provided information on all terrestrial animal species within the community. Because of poor trapping success, the data for all trapped species were combined and analyzed as a single group, thus masking the impact of the insecticide on any one species. Also, the kill-trapping study was more subject to the inclusion of nonresident individuals in data analysis. Differences in the relation between trapping success and animal activity among the species studied appear to be a result of variation in above ground activity and the degree of activity spent searching for food. To obtain a better representation of pre-spray population levels the trapping effort should have been increased, and the treatment and control plots should have been checked for similarities in small mammal populations the summer before the spray.

SUMMARY AND CONCLUSIONS

During the summers of 1978 and 1979, the sand transect technique was used to record the daily activity of a terrestrial animal community on two sites, 25 km apart. In June of 1979, an experimental application of Matacil^R at 0.175 kg/ha occurred over 150 hectares of forest on the treatment area. Changes in the ratios of activity between the experimental and control plots pre-spray and post-spray were used to identify impacts.

Immediately following the aerial forest spray there was a decrease in Arachnid and Lepidopteran activity, and an increase in avian activity at the ground level which continued for 16 days. Chilopoda, known prey of Arachnida, may have increased their activity in response to the drop in Arachnid activity. An increase in food availability could have resulted in an increase in Diplopoda activity. During the 2 months following the Matacil^R spray Mollusca and earthworm activity decreased. Toads were the only amphibians which appear to have been affected by the insecticide application. Garter snakes, predators of toads and earthworms, may have been adversely affected by reduced prey availability. The change in avian behaviour seems to have initiated an increase in ermine activity 5 days post-spray. The activity of Blarina brevicauda and Clethrionomys gapperi, alternate ermine prey types, appears to have been lowered by increased ermine activity.

The changes in animal activity noted by the sand transect technique did not provide conclusive evidence of insecticide-related impacts. However, they did reveal several areas in which further research is required by indicating which species and food chains in the terrestrial animal community may have been affected by the Matacil[R] application.

A comparison of the sand transect and kill-trapping techniques for assessing the impact of insecticides on small mammal populations demonstrated that sand tracking is a superior method. Removal of individuals by kill-trapping creates a vacuum which can be rapidly filled with animals from outside the sprayed area. Although the results of both methods indicate that small mammal populations were not severely affected by the forest spray, greater confidence can be placed in the results of the animal activity study. The sand transect technique provided a much greater volume of data on which to base the impact assessment. As a result of inadequate trapping effort, particularly during the pre-spray period, few mammals of any one species were captured. Consequently, the trapping data of all species were combined and analyzed as a whole, thereby masking the impact on any one species. The relation between tracking and trapping data was not the same among all species examined. This variation appears to be the result of differences in aboveground activity and the degree of activity spent foraging.

Although the experimental Matacil® application appears to have had an impact on several species of nontarget animals, there was no evidence that an operational forest spray program would have a more severe effect on the animal community.

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Table 1. Logarithm of mean activity for 10 day periods before and after Matacil^{R} application

Species	Lac Carré			St-Donat		
	Mean			Mean		
	Pre-spray	Post-spray	F	Pre-spray	Post-spray	F
Arachnida	4.6244	4.4630	0.1566	6.0604	5.3002	7.5664*
Diplopoda	1.4439	2.6683	6.6218*	0.3807	2.1147	13.4899**
Chilopoda	0.8090	0.6174	0.3707	1.1204	1.1772	0.0199
Orthoptera	5.0450	4.5648	2.0613	4.0883	4.0468	0.0084
Coleoptera	6.4239	6.7875	0.5938	5.7224	5.4949	0.8227
Arthropoda [Ψ]	6.9644	6.9875	0.0049	6.7067	6.2385	3.0981
Lepidoptera	2.3437	2.4562	0.1091	3.4650	2.7816	12.3839**
Rana spp.	1.3683	2.2525	3.1471	0.8605	1.8951	4.3135
Bufo americanus	1.9590	3.2456	5.5409*	0.9492	2.1669	4.5840*
Bufo americanus [o]	2.2438	3.3589	6.5769*	1.6464	2.4904	3.0969

cont'd.

Table 1. Cont'd

Species	Lac Carré			St-Donat		
	Mean			Mean		
	Pre-spray	Post-spray	F	Pre-spray	Post-spray	F
Sorex spp.	4.2209	3.9099	5.1645*	4.8457	4.5050	4.0559
Blarina brevicauda	1.9134	1.1601	5.4475*	3.3991	2.9185	2.7170
Lepus americanus	2.6203	1.3836	11.7743**	5.1994	5.2937	0.4795
Tamias striatus	4.7462	4.6546	0.3191	3.6167	3.6686	0.0213
Tamiasciurus hudsonicus	3.2888	4.1771	12.2067**	2.9128	3.5588	10.5651**
Peromyscus maniculatus	3.6263	3.4058	1.8866	2.9805	3.0259	0.0202
Clethrionomys gapperi	1.8382	1.6927	0.1703	3.0476	2.5789	5.9202*
Zapodidae	4.9556	4.3670	8.3465**	4.1186	3.5051	4.5546
Mustela erminea				0.7203	1.4558	1.4324
Mustela erminea[o]				0.6753	1.5750	4.9487*
Total Aves	5.6810	5.4313	3.0077	4.7366	5.8251	34.2591**

ψ Arthropoda includes Arachnida, Orthoptera and Coleoptera   * $p < 0.05$

o Logarithm of mean activity of 17 days before and after spray   ** $p < 0.01$

Table 2. Number of crossings and ratios of activity between Lac Carré and St-Donat sites

Species	1978	1979	
		Pre-spray	Post-spray
Mollusca			
Lac Carré	23(1)	14(1)(0.78)	111(1)(1.41)
St-Donat	40(1.74)	18(1.29)(1)	79(0.71)(1)
Annelida			
∇ Lac Carré	319(2.90)	?	239(15.93)
St-Donat	110(1)	10	15(1)
Arachnida			
Lac Carré	8376(1)	2814(1)	3958(1)
St-Donat	14610(1.74)	8637(3.07)	6064(1.53)
Diplopoda			
Lac Carré	668(2.04)	106(1.28)	721(0.48)(1)
St-Donat	328(1)	83(1)	1517(1)(2.10)
Chilopoda			
Lac Carré	135(1)	50(1)(1.02)	68(1)(0.08)
St-Donat	719(5.33)	49(0.98)(1)	855(12.57)(1)
Orthoptera			
Lac Carré	6164(1)	3132(1)(2.08)	6827(1)(1.00)
St-Donat	11671(1.89)	1505(0.48)(1)	6854(1.00)(1)
Coleoptera			
Lac Carré	17990(2.76)	14212(2.72)	21898(2.10)
St-Donat	6529(1)	5225(1)	10452(1)
Arthropoda[1]			
Lac Carré	32530(2.76)	20158(1)(1.31)	32683(1)(1.40)
St-Donat	32810(1.01)	15367(0.76)(1)	23370(0.72)(1)
Lepidoptera			
Lac Carré	464(1)	482(1)	605(1)
St-Donat	559(1.20)	652(1.35)	746(1.23)
Rana spp.			
Lac Carré	707(1.72)	138(1.53)	488(1.45)
St-Donat	411(1)	90(1)	337(1)
Bufo americanus			
Lac Carré	3238(1)	392(1)(1.46)	1530(1)(2.46)
St-Donat	4085(1.26)	268(0.68)(1)	622(0.41)(1)
°Urodela			
Lac Carré	327	297	213
St-Donat	5	6	8
Ophidia			
Lac Carré	31(1)	6(1)	28(1)
St-Donat	283(9.13)	35(5.83)	129(4.61)

cont'd.

Table 2 Cont'd

Species	1978	1979 Pre-spray	1979 Post-spray
Sorex spp.			
Lac Carré	2516(1)	1016(1)	2660(1)
St-Donat	4470(1.78)	1826(1.80)	7680(2.89)
Blarina brevicauda			
Lac Carré	391(1)	102(1)	389(1)
St-Donat	765(1.96)	425(4.17)	706(1.81)
°Talpidae			
Lac Carré	241	22	127
St-Donat	1	0	30
Lepus americanus			
Lac Carré	99(1)	233(1)	221(1)
St-Donat	8595(86.82)	2885(12.38)	8127(36.77)
Tamias striatus			
Lac Carré	2249(1.37)	1584(2.32)	2720(1.14)
St-Donat	1638(1)	684(1)	2382(1)
°*Marmota monax*			
Lac Carré	0	9	72
St-Donat	0	0	60
°*Sciurus carolinensis*			
Lac Carré	0	0	0
St-Donat	0	0	77
Tamiasciurus hudsonicus			
Lac Carré	668(1)	455(1)(1.29)	1915(1)(0.67)
St-Donat	1620(2.43)	353(0.78)(1)	2864(1.50)(1)
Glaucomys sabrinus volans			
Lac Carré	48(1.78)	11(0.92)(1)	98(0.79)(1)
St-Donat	27(1)	12(1)(1.09)	124(1)(1.27)
Peromyscus maniculatus			
Lac Carré	1064	641(2.65)	2606(1.23)
St-Donat	0	242(1)	2121(1)
Clethrionomys gapperi			
Lac Carré	1173(4.64)	141(0.41)(1)	576(0.49)(1)
St-Donat	253(1)	346(1)(2.45)	1181(1)(2.05)
°*Rattus norvegicus*			
Lac Carré	0	0	17
St-Donat	8	0	0
Zapodidae			
Lac Carré	10705(2.09)	2403(2.26)	9641(1.86)
St-Donat	5121(1)	1062(1)	5179(1)

cont'd

Table 2 Cont'd

Species	1978	1979	
		Pre-spray	Post-spray
Erethizon dorsatum			
Lac Carré	22	40	0
St-Donat	0	0	0
[o]*Canis domestica*			
Lac Carré	0	14	36
St-Donat	0	0	4
Vulpes fulva			
Lac Carré	0	0	0
St-Donat	7	0	0
[o]*Ursus americanus*			
Lac Carré	0	1	0
St-Donat	0	0	7
[o]*Procyon lotor*			
Lac Carré	155	44	56
St-Donat	17	0	0
Mustela erminea			
Lac Carré	0	0	73
St-Donat	83	33	434
[o]*Mustela vison*			
Lac Carré	0	1	1
St-Donat	0	0	0
Mephitis mephitis			
Lac Carré	32(1)	73(1)	76(1)
St-Donat	49(1.53)	53(0.73)	244(3.21)
Felis domestica			
Lac Carré	154	9	191
St-Donat	0	0	0
[o]*Alces alces*			
Lac Carré	0	1	0
St-Donat	0	0	0

Cont'd.

Table 2 Cont'd.

Species	1978	1979 Pre-spray	1979 Post-spray
Bonasa umbellus			
Lac Carré	26(1)	23(1)	54(1)
St-Donat	169(6.50)	92(4.00)	225(4.17)
°Philohela minor			
Lac Carré	1	0	0
St-Donat	0	0	5
Total Aves			
Lac Carré	6131(1)	3874(1)(2.32)	7465(1)(0.60)
St-Donat	7556(1.23)	1669(0.43)(1)	12342(1.65)(1)

Δ - activity of Annelida was only recorded after 6 July in 1979

1 - includes Arachnida, Orthoptera and Coleoptera

o - activity for these groups was recorded on all days. i.e. 51 days in 1978 and 92 days in 1979; for other species there were 43 days in 1978 and 61 days in 1979.

Table 3. Covariance and Chi-square analysis

REGRESSION LINE COMPARISONS

Animal Group	Pre-spray	Post-spray	TEST OF ASSUMPTIONS: r_{pre}	r_{post}	σ^2pre=σ^2post	Slope	TRANSFORMED ACTIVITY MEANS (ADJUSTED) PRE-SPRAY: Lac Carré	St-Donat	POST-SPRAY: Lac Carré	St-Donat	Position	χ^2	Change
Arachnida	1978	1979	0.3309*	0.4451**	*	(ns)	5.4117	5.2436	4.3228	4.9522	(ns)	**	0
	1979	1979	0.7156**	0.4451**	(ns)	(ns)	4.7160	5.9849	4.3228	4.7308	**	**	-
Diplopoda	1978	1979	0.3472*	0.1904(ns)	(ns)	(ns)	2.7687	1.7452	2.5656	3.1829	**	**	+
	1979	1979	0.7671**	0.1904(ns)		**	1.6860	1.2065	2.5656	3.1517	**	**	+
Chilopoda	1978	1979	0.1854(ns)	-0.0157(ns)	(ns)	(ns)	1.2935	2.1514	0.7651	2.5320	(ns)	**	0
	1979	1979	-0.2451(ns)	-0.0157(ns)	(ns)	(ns)	0.9984	0.9503	0.7651	2.4766	**	**	+
Orthoptera	1978	1979	0.3098*	0.6288**	(ns)	**	4.8891	5.6494	4.9392	4.7720	**	**	-
	1979	1979	0.2166(ns)	0.6288**	*	**	4.3693	4.2178	4.9392	4.7363	*	**	-
Coleoptera	1978	1979	0.2580(ns)	0.6451**	**	(ns)	6.1770	4.8538	5.8969	5.4002	**	**	+
	1979	1979	0.4743(ns)	0.6451**	**	(ns)	6.3007	4.8600	5.8969	5.3952	(ns)	**	0
Arthropoda[Δ]	1978	1979	0.2612(ns)	0.6437**	*	(ns)	6.7621	6.5802	6.4463	6.2514	**	**	-
	1979	1979	0.7863**	0.6437**	(ns)	(ns)	6.8112	6.5255	6.4463	6.2325	**	**	-
Lepidoptera	1978	1979	0.0974(ns)	-0.0030(ns)	(ns)	(ns)	2.3351	2.5616	2.5696	2.6928	(ns)	(ns)	0
	1979	1979	0.6698**	-0.0030(ns)	(ns)	(ns)	2.9076	3.5742	2.5696	2.7114	**	(ns)	0
<u>Rana</u> spp.	1978	1979	0.6498**	0.6287**	(ns)	(ns)	1.2660	2.1420	2.0233	1.5679	(ns)	(ns)	0
	1979	1979	0.6932**	0.6287**	(ns)	(ns)	1.6076	1.3678	2.0233	1.4394	(ns)	(ns)	0
<u>Bufo americanus</u>	1978	1979	0.8175**	0.7471**	(ns)	*	3.5304	3.9329	3.1565	2.2750	**	**	-
	1979	1979	0.7651**	0.7471**	*	(ns)	2.1850	2.2278	3.1565	1.9443	(ns)	**	0
<u>Sorex</u> spp.	1978	1979	0.7378**	0.2811(ns)	(ns)	**	3.9491	4.5203	3.9785	5.0516	**	**	+
	1979	1979	0.6351**	0.2811(ns)	(ns)	(ns)	3.6451	4.5689	3.9785	5.0370	**	**	+
<u>Blarina brevicauda</u>	1978	1979	0.1514(ns)	0.1292(ns)	**	(ns)	1.9389	2.5843	2.0621	2.7035	(ns)	(ns)	0
	1979	1979	0.5270*	0.1292(ns)	*	*	1.7182	3.0052	2.0621	2.6910	(ns)	**	0
<u>Lepus americanus</u>	1978	1979	0.0552(ns)	0.0252(ns)	**	(ns)	0.8088	5.1838	1.4790	5.1416	(ns)	**	0
	1979	1979	-0.0486(ns)	0.0252(ns)	(ns)	(ns)	2.4475	5.0269	1.4790	5.1512	(ns)	**	0
<u>Tamias striatus</u>	1978	1979	0.2255(ns)	0.0907(ns)	(ns)	(ns)	3.8972	3.5372	3.9320	3.8685	**	**	+
	1979	1979	0.5000(ns)	0.0907(ns)	**	*	4.4500	3.0295	3.9320	3.9087	**	**	+
<u>Tamiasciurus hudsonicus</u>	1978	1979	0.5276**	-0.4229**	**	**	2.6638	3.3286	3.5983	3.9372	**	**	-
	1979	1979	-0.1694(ns)	-0.4229**	(ns)	(ns)	3.2986	2.9936	3.5983	4.0516	**	**	+

Cont'd.

Table 3. Cont'd.

Animal Group	Pre-spray	Post-spray	REGRESSION LINE COMPARISONS: TEST OF ASSUMPTIONS: r_{pre}	r_{post}	$\sigma^2 pre=\sigma^2 post$	Slope	TRANSFORMED ACTIVITY MEANS (ADJUSTED): PRE-SPRAY: Lac Carré	St-Donat	POST-SPRAY: Lac Carré	St-Donat	Position	χ^2	Change
<u>Peromyscus maniculatus</u>	1978	1979	0.6214**	0.4838**	*	*	3.5332	2.4807	3.9540	3.6259	**	**	+
<u>Clethrionomys gapperi</u>	1978	1979	0.0642(ns)	0.0529(ns)	(ns)	(ns)	3.1735	1.4849	2.3372	3.0230	**	*	+
	1979	1979	0.6404**	0.0529(ns)	(ns)	(ns)	1.8196	2.9149	2.3372	2.9609	(ns)	(ns)	0
Zapodidae	1978	1979	0.5721**	0.6137**	(ns)	(ns)	5.3462	4.4333	5.2083	4.4879	(ns)	**	0
	1979	1979	0.6257**	0.6137**	(ns)	(ns)	4.7750	4.3027	5.2083	4.3379	(ns)	**	0
Total Birds	1978	1979	0.6005**	0.5266**	(ns)	(ns)	4.7180	5.0927	5.0353	5.3641	*	**	+
	1979	1979	0.2992(ns)	0.5266**	(ns)	*	5.4211	4.5211	5.0353	5.5004	**	**	+

* - $p<0.05$.

** - $p<0.01$.

r - correlation coefficient

σ^2 - variance

Δ - includes Arachnida, Orthoptera and Coleoptera

χ^2 - chi-square

Table 4. Bufo americanus activity at Lac Carré from 1964 to 1971.

	1 June to 27 June		28 June to 31 August
Year	Daily crossings per 305 M	Year	Daily crossings per 305 M
1964	1041.83	1964	3874.79
1965	517.39	1965	2428.15
1966	189.18	1966	1316.09
1967	787.15	1967	2077.61
1968	796.00	1968	1315.95
1969	318.17	1969	2252.42
1970	998.28	1970	1525.33
1971	422.78	1971	723.22
Average	633.85	Average	1939.20

	Pre-spray	Post-spray	Expected Post-spray	Percent difference
Lac Carré	633.85(1.46)	1939.20(2.46)	1901.55	+ 1.98
St-Donat	433.35(1)	788.35(1)	1300.05	-39.36

Table 5. Diel distribution of ermine activity.

	Percent diurnal activity (5:00 to 21:00 hrs)	percent nocturnal activity (21:00 to 5:00 hrs)	Total number of Crossings per 305 M
<u>Pre-spray</u>			
(1 June to 27 June)	60.00	40.00	33
<u>Post-spray</u>			
(28 June to 31 July)	80.59	19.41	238
(1 August to 31 August)	30.45	69.55	196

Table 6. Daily Activity Totals and Trapping Success.

		Daily captures per 100 traps							Daily crossings per 305 M						
	Date	Sc	Bb	Cg	Pm	Zp	Mi	Cc	Sc	Bb	Cg	Pm	Zp	Mi	Cc
	24 June	0	0	0	0	0	0	0	135	26	19	10	43	0	0
	25 June	0	0	1.33	0	0	0	0	149	36	30	10	39	0	0
Pre-spray	26 June	1.33	0	0	0	0	0	0	143	27	13	26	46	0	0
	27 June	4.00	0	0	0	0	0	0	150	88	24	9	63	0	0
	28 June	0	0	9.33	0	1.33	0	0	100	23	18	2	59	0	0
	29 June	0.97	0	0.97	0	0	0	0	162	29	10	17	36	0	0
	30 June	0.97	0	0.97	0	0.97	0	0	205	58	39	50	104	0	0
Immediate	1 July[o]	0	0	2.91	0	0	0	0	-	-	-	-	-	-	-
Post-spray	2 July[o]	0	1.94	2.91	0	0.97	0	0	-	-	-	-	-	-	-
	3 July[o]	0	0	1.94	0	0.97	0	0	-	-	-	-	-	-	-
	4 July	2.91	0	2.91	0	0	0	0	131	6	31	23	23	0	0
	22 July	1.30	0.43	2.17	0.43	0	0.43	0	142	18	28	58	39	0	2
	23 July	1.30	0.43	3.04	0.87	0.87	0	0	146	23	35	37	53	0	0
	24 July	6.09	0.87	1.30	0.87	0	0	0	130	14	27	77	27	0	0
	25 July	3.48	0.87	1.30	0.87	0.87	0	0	138	17	17	76	76	0	0
Second Post-spray	26 July	4.78	0	1.30	0	0	0	0.43	174	17	61	28	113	0	0
	27 July	5.65	1.74	0.87	1.30	0.87	0	0	206	13	27	37	79	0	0
	28 July	7.39	0.87	2.61	1.74	0.87	0	0	346	20	73	85	339	0	1
	29 July	9.13	1.74	1.30	0.87	0	0	0	451	10	40	129	174	0	0
	30 July	5.65	1.30	0.43	0.87	2.17	0	0	328	9	38	51	91	0	0
	31 July	5.22	0.87	0.43	0.87	0.43	0	0	274	24	86	78	211	0	3
Total per 1800 trap nights		60.17	9.12	30.36	8.69	8.38	0.43	0.43	3516	458	618	803	1715	0	6

Sc = *Sorex* spp.

Bb = *Blarina brevicauda*

Cg = *Clethrionomys gapperi*

Pm = *Peromyscus maniculatus*

Zp = Zapodidae

Mi = *Microtus pennsylvanicus*

Cc = *Condylura cristata*

[o] 1 July to 3 July not included in totals

Table 7. Correlation Coefficients

SPECIES	CORRELATION COEFFICIENT
Sorex spp.	0.766**
Blarina brevicauda	-0.473*
Clethrionomys gapperi	-0.096(ns)
Peromyscus maniculatus	0.695**
Zapodidae	0.193(ns)

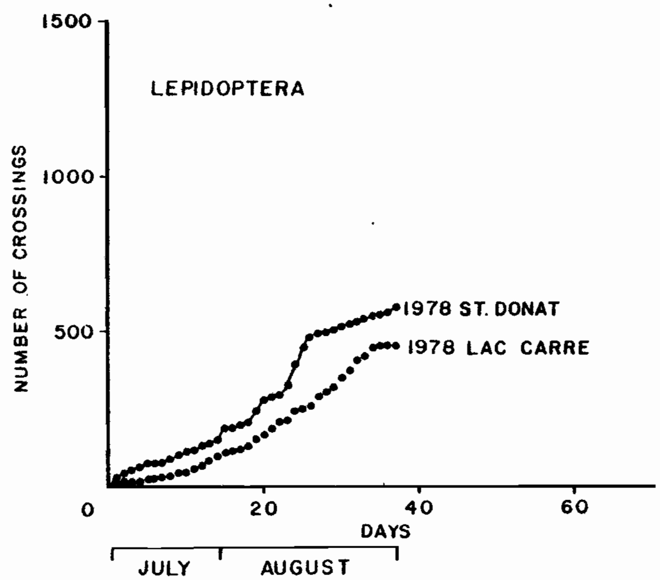
* - $p < 0.05$

** - $p < 0.01$

ns - not significant

Figure 1. Cumulative frequency of Lepidopteran activity in 1978 and 1979 at Lac Carré and St-Donat.

The arrow indicates the day of the Matacil[R] spray.


1500
1000
500
0
LEPIDOPTERA
NUMBER OF CROSSINGS
1978 ST. DONAT
1978 LAC CARRE
20
40
60
DAYS
JULY
AUGUST

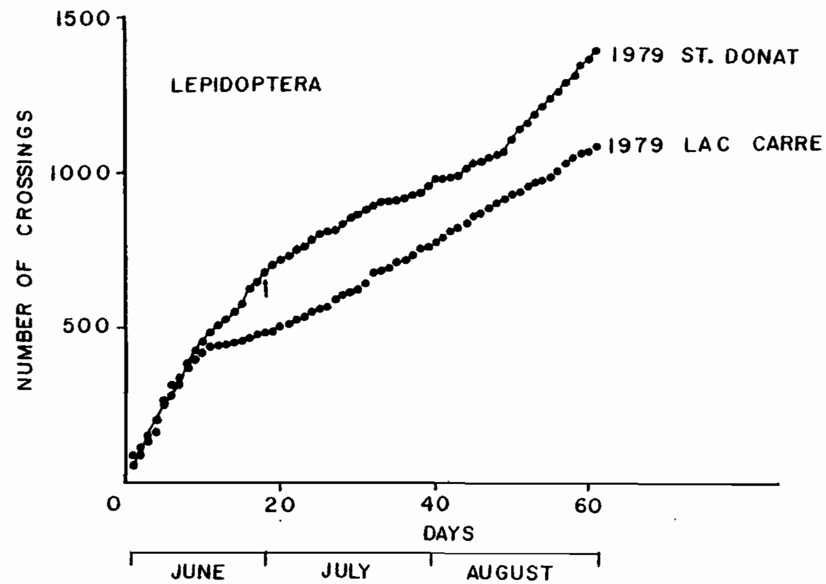
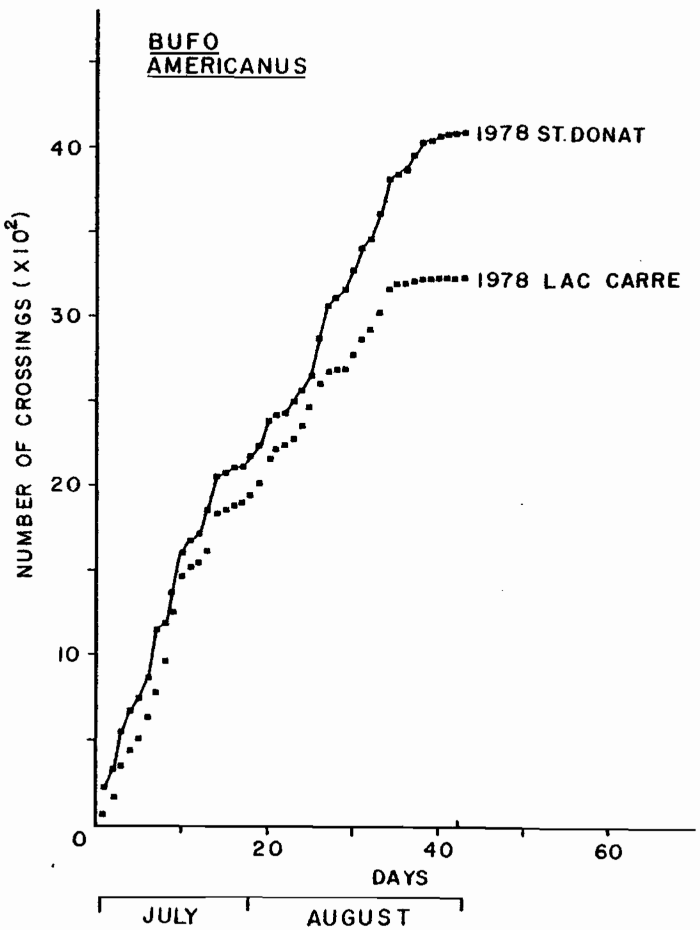

1500
1000
500
0
LEPIDOPTERA
NUMBER OF CROSSINGS
1979 ST. DONAT
1979 LAC CARRE
20
40
60
DAYS
JUNE
JULY
AUGUST

Figure 2. Cumulative frequency of toad (Bufo americanus) activity in 1978 and 1979 at Lac Carré and St-Donat.
The arrow indicates the day of the Matacil[R] spray.


BUFO
AMERICANUS
1978 ST. DONAT
1978 LAC CARRE
NUMBER OF CROSSINGS (X 10²)
0
10
20
30
40
60
DAYS
JULY
AUGUST

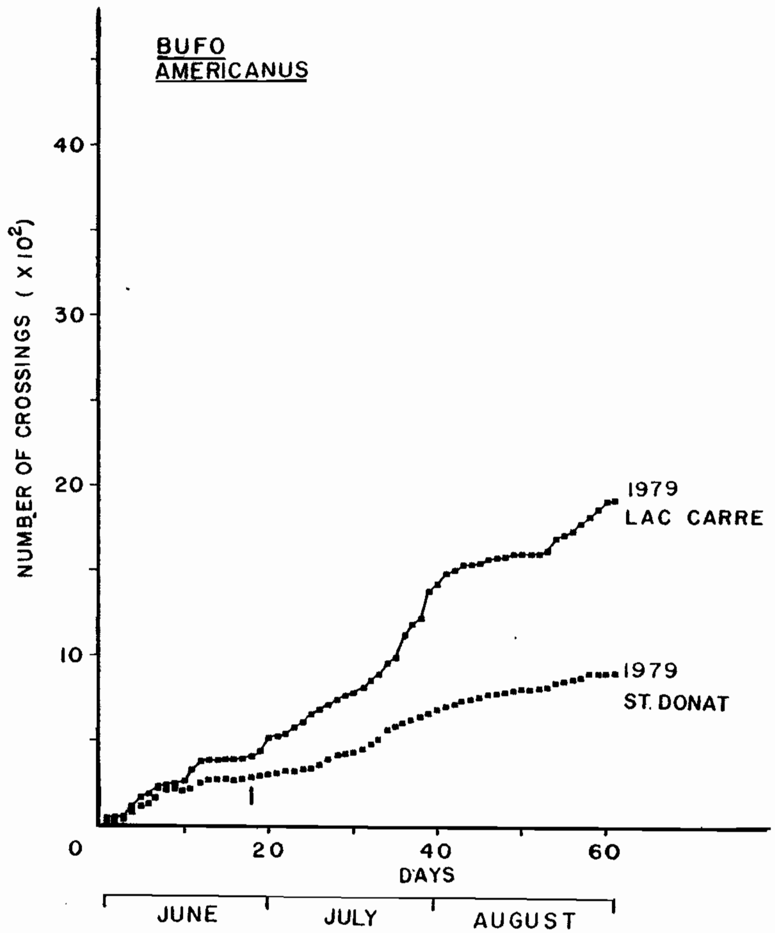
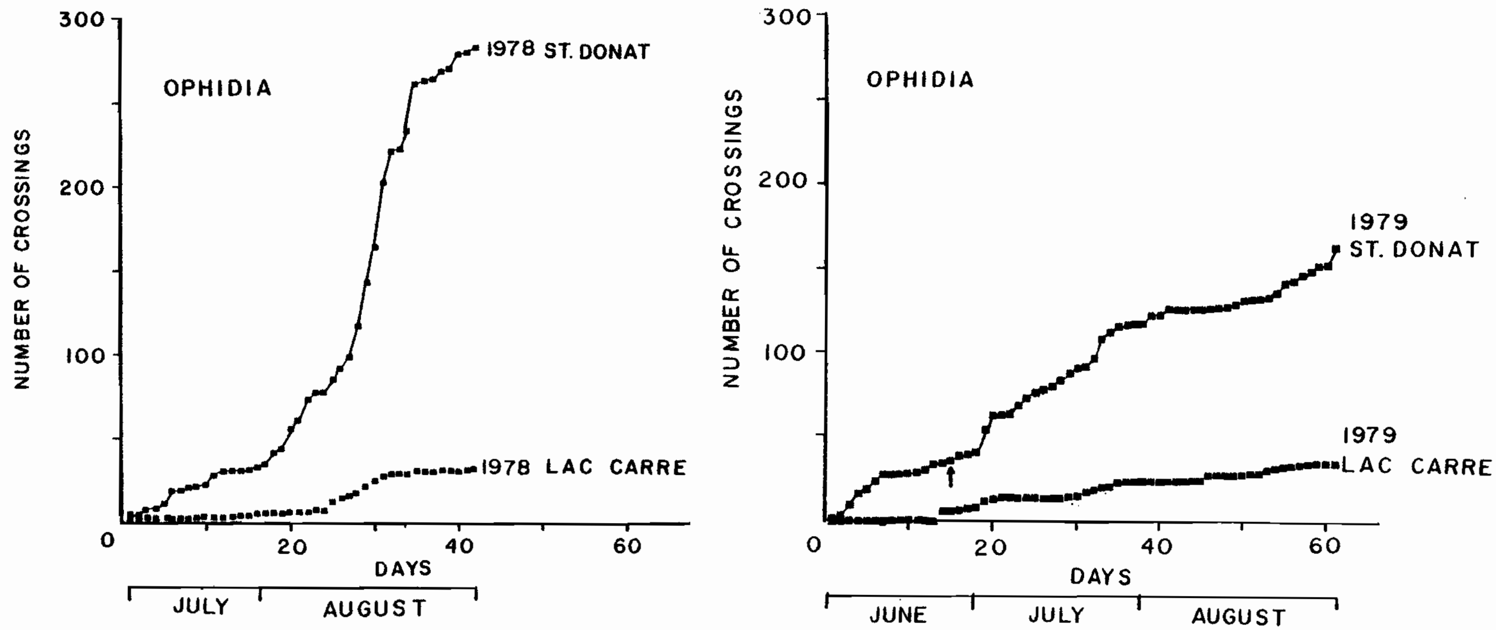

BUFO
AMERICANUS
1979
LAC CARRE
1979
ST. DONAT
NUMBER OF CROSSINGS (X 10²)
0
10
20
30
40
60
DAYS
JUNE
JULY
AUGUST

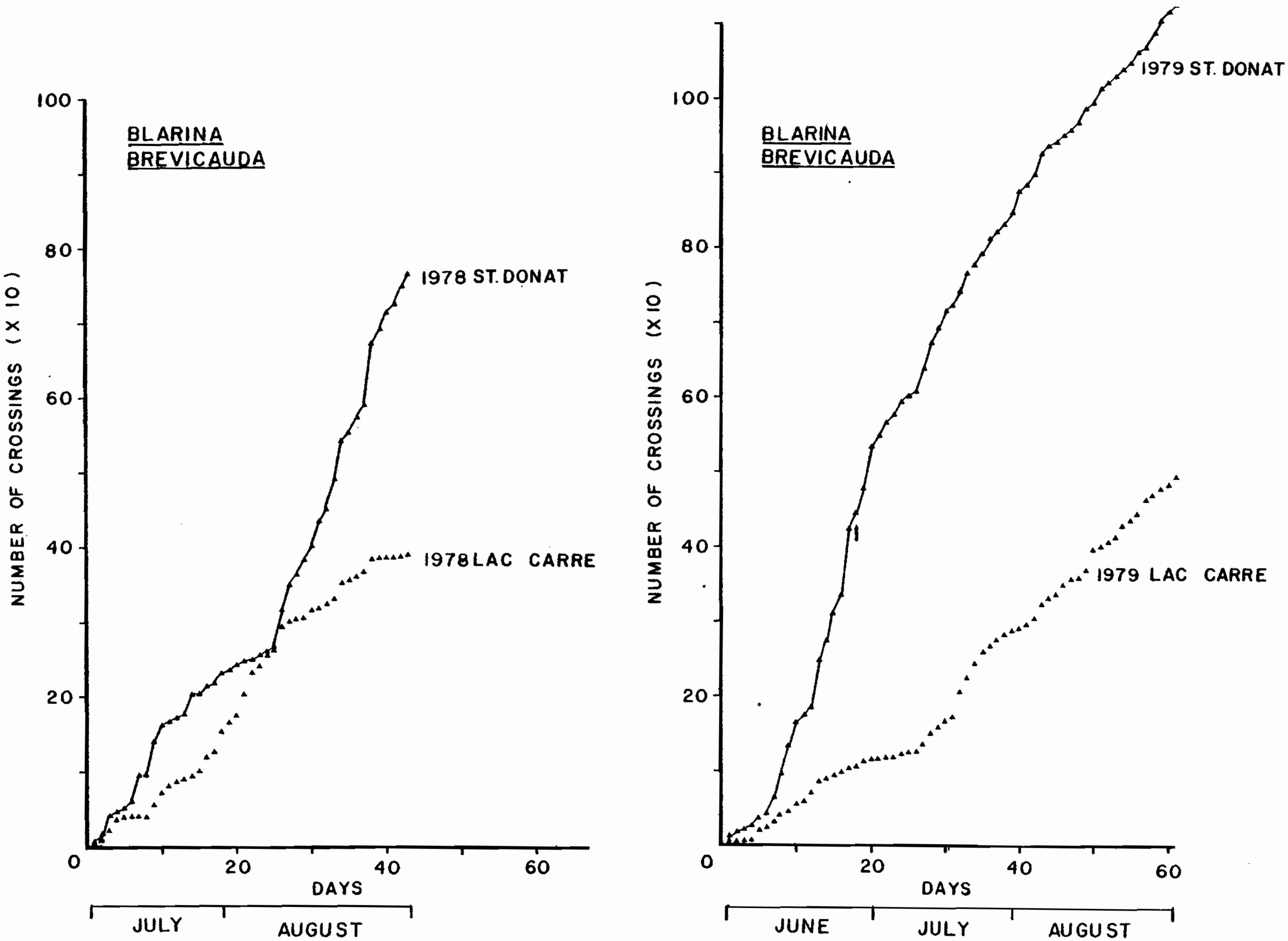
Figure 3. Cumulative frequency of snake (Ophidia) activity in 1978 and 1979 at Lac Carré and St-Donat. The arrow indicates the day of the Matacil[R] spray.



OPHIDIA
NUMBER OF CROSSINGS
300
200
100
0
20
40
60
DAYS
1978 ST. DONAT
1978 LAC CARRE
JULY
AUGUST
OPHIDIA
NUMBER OF CROSSINGS
300
200
100
0
20
40
60
DAYS
1979
ST. DONAT
1979
LAC CARRE
JUNE
JULY
AUGUST

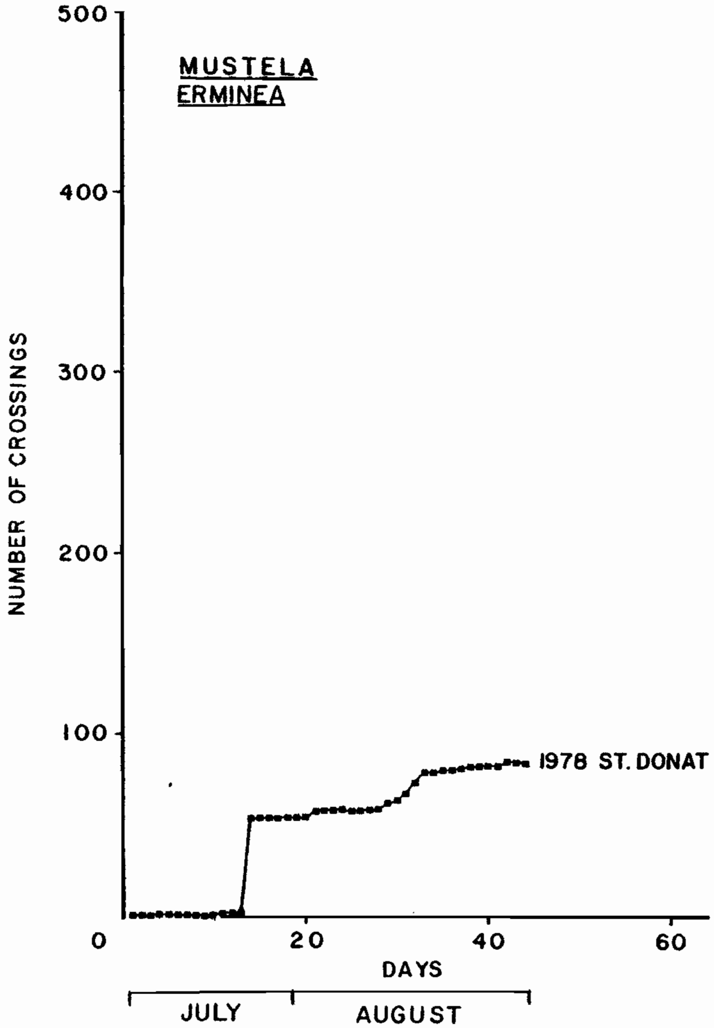
Figure 4. Cumulative frequency of short-tailed shrew (*Blarina brevicauda*) activity in 1978 and 1979 at Lac Carré and St-Donat.

The arrow indicates the day of the Matacil^{R} spray.

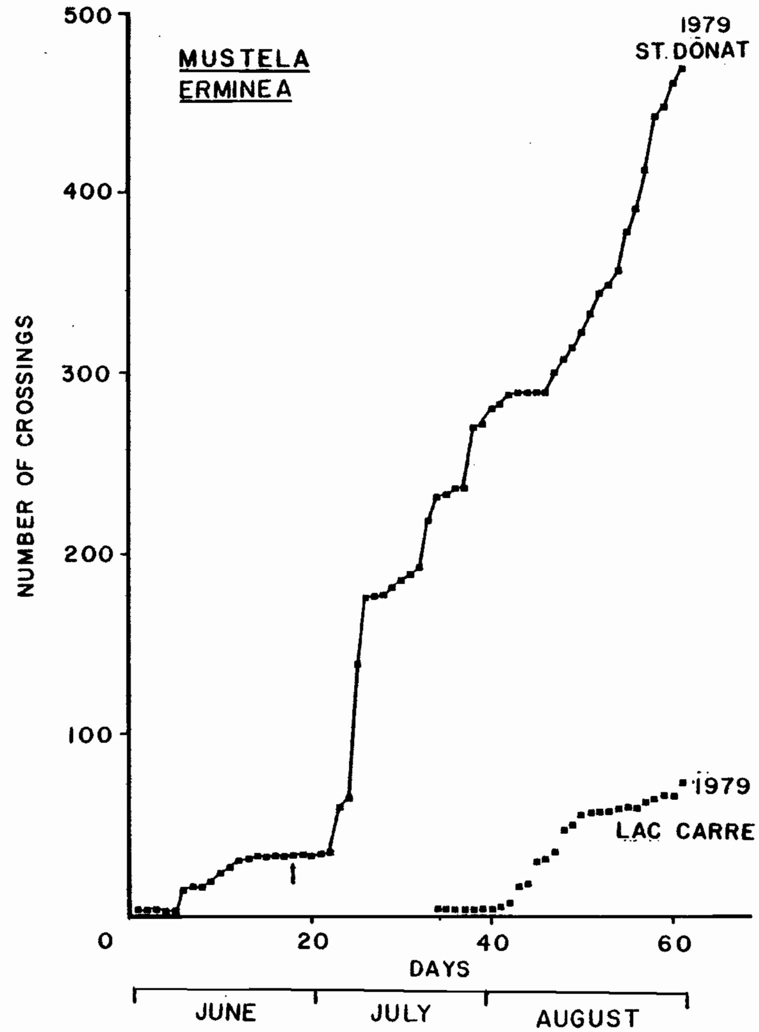


BLARINA BREVICAUDA
NUMBER OF CROSSINGS (X 10)
100
80
60
40
20
0
20
40
60
DAYS
1978 ST. DONAT
1978 LAC CARRE
JULY
AUGUST
BLARINA BREVICAUDA
NUMBER OF CROSSINGS (X 10)
100
80
60
40
20
0
20
40
60
DAYS
1979 ST. DONAT
1979 LAC CARRE
JUNE
JULY
AUGUST

Figure 5. Cumulative frequency of ermine (*Mustela erminea*) activity in 1978 and 1979 at Lac Carré and St-Donat.
The arrow indicates the day of the Matacil[R] spray.

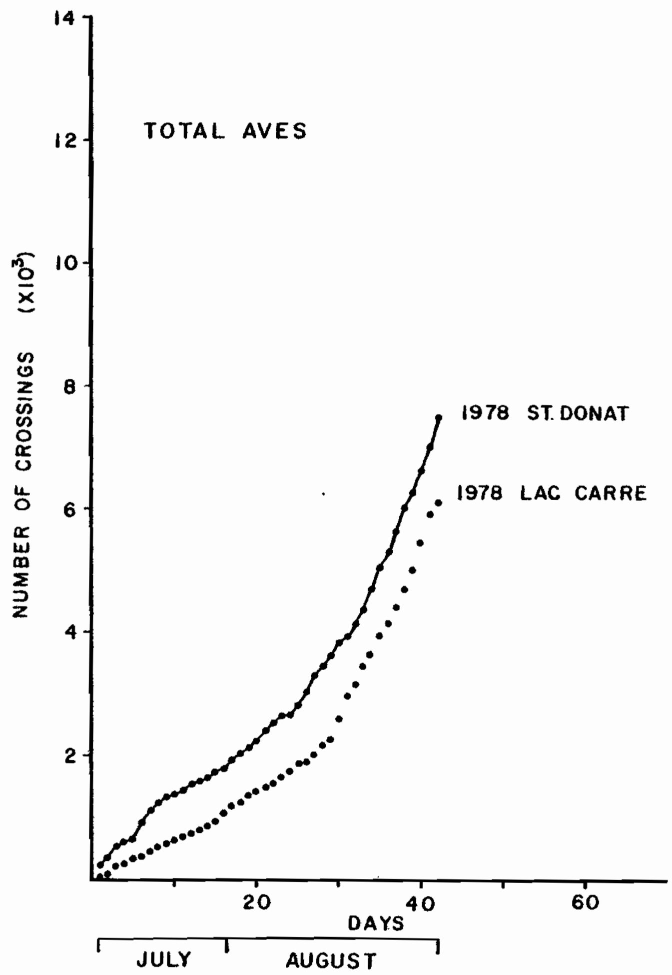


MUSTELA ERMINEA
NUMBER OF CROSSINGS
500
400
300
200
100
0
20
40
60
DAYS
1978 ST. DONAT
JULY
AUGUST

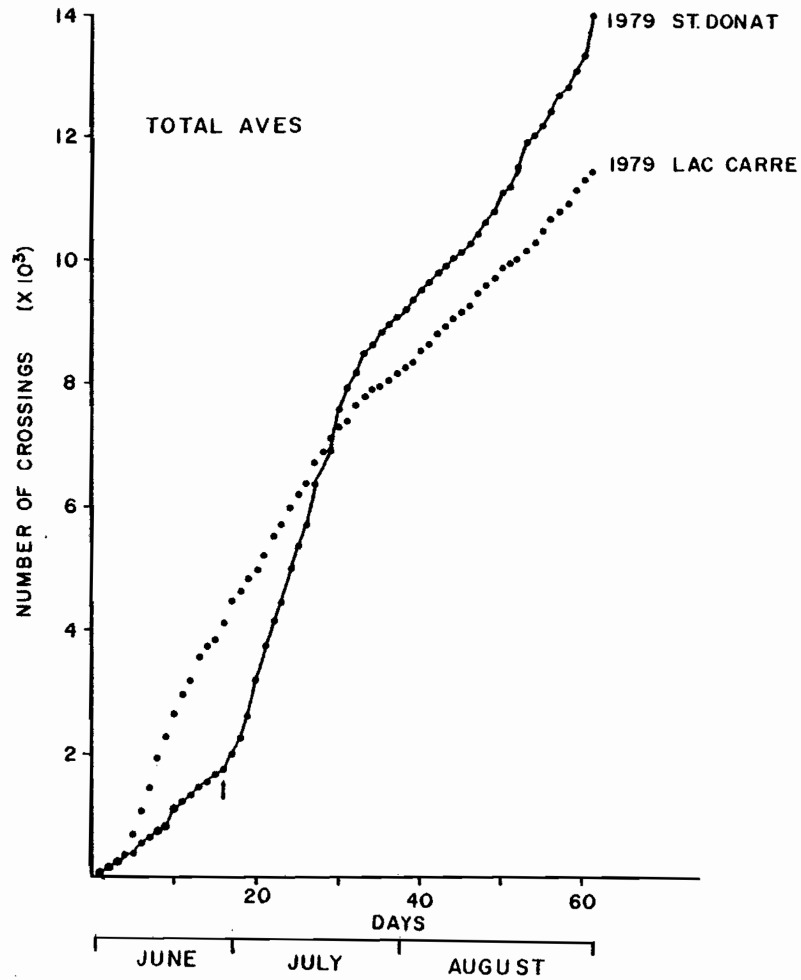


MUSTELA ERMINEA
NUMBER OF CROSSINGS
500
400
300
200
100
0
20
40
60
DAYS
1979 ST. DONAT
1979 LAC CARRE
JUNE
JULY
AUGUST

Figure 6. Cumulative frequency of total Aves activity in 1978 and 1979 at Lac Carré and St-Donat.
The arrow indicates the day of the Matacil^{R} spray.



TOTAL AVES
NUMBER OF CROSSINGS (X10^3)
14
12
10
8
6
4
2
20
40
60
DAYS
1978 ST. DONAT
1978 LAC CARRE
JULY
AUGUST



TOTAL AVES
NUMBER OF CROSSINGS (X 10^3)
14
12
10
8
6
4
2
20
40
60
DAYS
1979 ST. DONAT
1979 LAC CARRE
JUNE
JULY
AUGUST

Figure 7. Relation between the total mammals trapped for 1800 trap nights and the total number of crossings per 305 m of sand transect during the same time period.

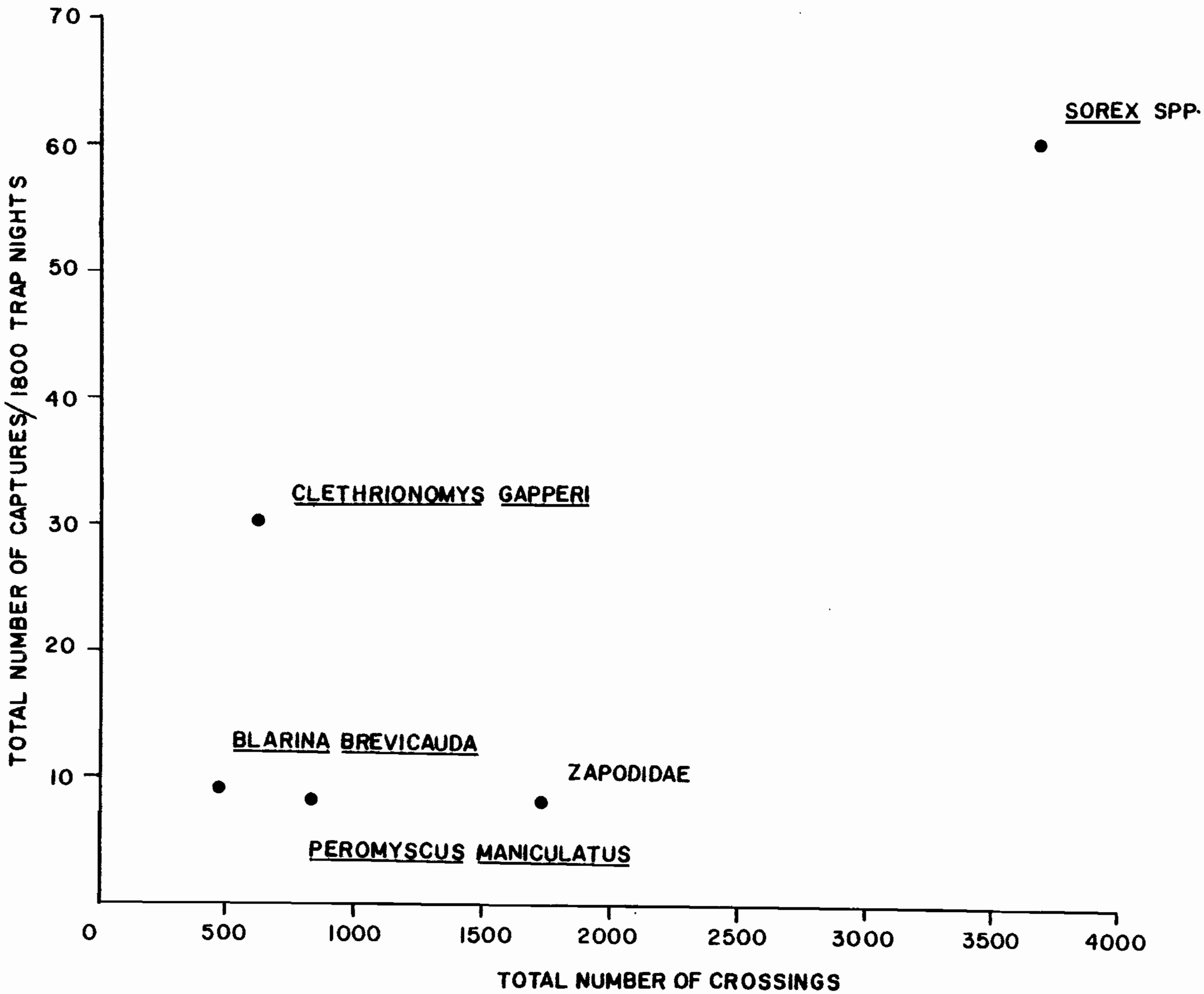
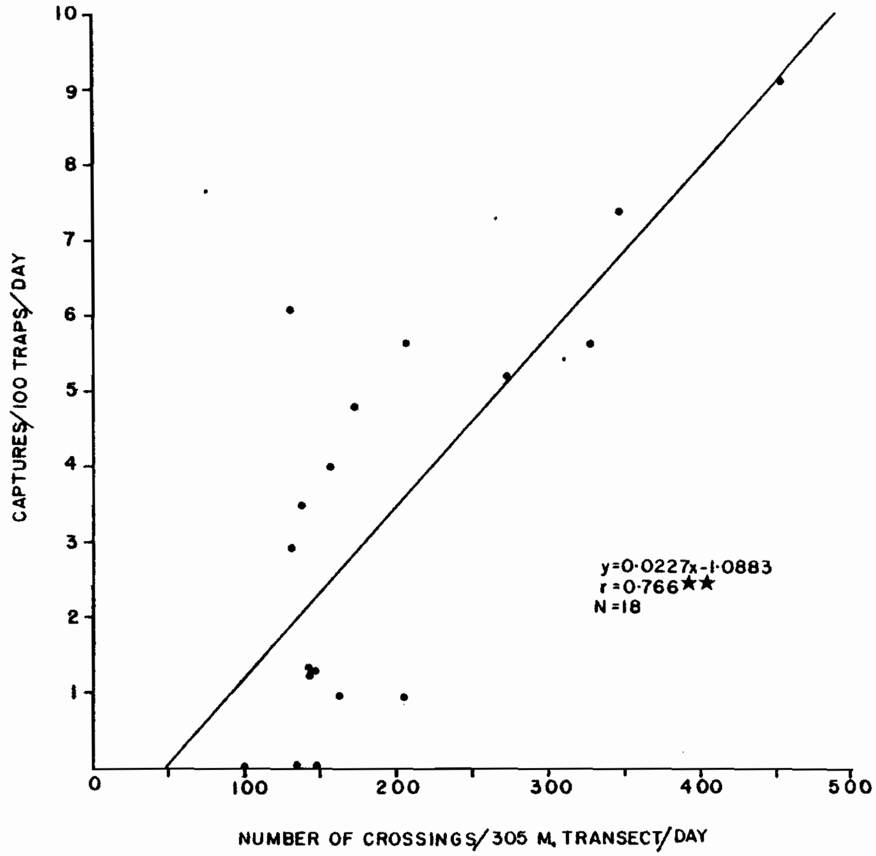

SOREX SPP.
CLETHRIONOMYS GAPPERI
BLARINA BREVICAUDA
ZAPODIDAE
PEROMYSCUS MANICULATUS
TOTAL NUMBER OF CAPTURES/1800 TRAP NIGHTS
TOTAL NUMBER OF CROSSINGS
70
60
50
40
30
20
10
0
500
1000
1500
2000
2500
3000
3500
4000

Figure 8. Relation between the number of *Sorex* spp. captured per 100 traps per day and the number of crossings on 305 m of sand transect per day.

** $p < 0.01$



CAPTURES/100 TRAPS/DAY
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
NUMBER OF CROSSINGS/305 M. TRANSECT/DAY
y=0·0227x-1·0883
r=0·766★★
N=18