THE ROLE OF PREDATION IN THE POPULATION DYNAMICS OF THE JACK PINE SAWFLY (NEODIPRION SWAINEI MIDD.):

Small Mammal Studies 1956 - 57

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FOREST BIOLOGY LABORATORY
QUEBEC

CANADA
DEPARTMENT OF AGRICULTURE
SCIENCE SERVICE
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1. INTRODUCTION

The investigation of the role of small mammals as predators of Neodiprion swainei Midd. is one phase of a larger research program dealing with the population dynamics of this sawfly. It was undertaken after preliminary investigations in 1955 revealed that mammal predation accounted for an appreciable amount of the natural mortality in this insect (Lyons 1956). The work was carried out on the limits of the Canadian International Paper Company near Clova, Abitibi, P.Q. Field work commenced in August of 1956 and was exploratory in nature. In that year snap-traps were used to arrive at estimates of mammal populations. In 1957 live-traps were available and these were used for this purpose.

The objectives of these studies were as follows: (1) to determine the numbers and species of small mammals present in the different jackpine stands; (2) to investigate the behaviour of small mammals; and (3) to determine the degree of predation by means of cocoon analyses. In addition, observations were made on the number and kind of invertebrates in the soil samples collected for cocoon analysis, birds were collected and their gizzards examined for the presence of sawflies, and detailed vegetation analysis in the different jackpine stands was begun. Data collected on these aspects will be included in a future report.

This report does not represent a complete analysis of the data gathered to date, and is limited to a discussion of the distribution of the mammals, and some of the problems involved in arriving at population numbers. The analyses of cocoons from soil samples will be discussed in the reports of Mr. L.A. Lyons and Mr. H.A. Tripp so they will not be treated in detail here.

2. DESCRIPTION OF STUDY PLOTS

During the spring and summer of 1957 six small mammal plots were established in close proximity to areas in which entomological studies were being carried out by other research officers concerned in the jack pine sawfly project. Four of these plots were 7 chains square enclosing an area of 4.9 acres. Plot V, located between the road and a black spruce swamp was 6 by 7, and Plot VI, located between the road and the Chouart River was 4 by 7. Within the plots trap stations were set out at one-chain intervals. This type of plot was chosen to conform to those used in other small mammal studies being carried out in the Division of Forest Biology.

Detailed vegetation studies have been started on these plots but are incomplete so the following descriptions will be general in nature.

Plot I

This plot, located on the south end of an esker at Mileage 16 on the Clova road, is situated in a young stand of jack pine which regenerated after a fire in 1948. The trees are "patchy" in distribution, with a number of large thinly-treed areas interspersed by areas in which the trees are very dense. The undergrowth is generally sparse consisting chiefly of Vaccinium canadense and V. pennsylvanicum. This is characteristic of Section I shown in Figure 1. Section II has a dense growth of Comptonia perigrina. In Section III the plot encroaches on a damper area in which aspen (Populus tremuloides) becomes an important component of the vegetation. In this section the undergrowth is much denser than in Section I and includes a vigorous growth of Kalmia angustifolia. Just to the north of the plot the jack pine is more scattered, and aspen and paper birch (Betula papyrifera) become plentiful. To the east the area is bordered by a bog.

Plot II

This plot is located approximately 400 feet to the north of Plot I. The distribution of the vegetation is shown in Figure 2. Sections I, II, and IV contain scattered young jack pines interspersed with aspen, birch and wild red cherry (Prunus pennsylvanica). The undergrowth in these sections is composed chiefly of Vaccinium, Kalmia, Cornus canadensis and Aster sp. Section III is a low-lying wet area containing a dense growth of aspen, alder and cherry. The ground cover in this section is composed of various species of mosses in the wetter areas and Carex sp. in the drier sites.

Plot III

Plot III (Figure 3) is situated near Mile 36 on the Gatineau Road. The jack pines are 30-35 years old, having originated after a fire in 1923. Two types of vegetation can be recognized in this plot. In Section I the tree layer is chiefly jack pine, with a few scattered black spruce (Picea mariana). The shrub layer consists chiefly of Kalmia and Vaccinium, under which Cladonia forms the ground cover. In Section II Alnus, Betula, Populus and Prunus are common and the jack pine is much less dense than in Section I. In the ground cover Caliergon replaces Cladonia as the most common species. Herbaceous plants, such as Cornus, Linnea, Maianthemum and others are common in this section, but are lacking or rare in Section I.

The Gatineau Road runs parallel to the west side of this plot at a distance of about one chain.

Plot IV

This plot is located about 0.1 mile south of Plot III, and 2.5 chains west of the road. There are four readily recognizable vegetation types (Figure 4). Section I is a "cathedral-like" stand of mature jack-pine, and black spruce. The ground cover is chiefly needle mat with Caliergon. Scattered Kalmia and Cornus are present. Section II is a low lying wet area through which a small stream runs from west to east. This section supports a dense stand of alder under which there is a thick mat of Sphagnum and Caliergon. Section III is very similar to Section I of Plot III, but black spruce is more in evidence in the understory. Section IV is an open stand of jack pine and spruce under which there is a very dense, health-like, mat of Kalmia and Vaccinium.

Plot V

This plot is located in a 60-65 year old stand of jack pine at Mile 36 on the Chouart Road. The jack pines in this area were severely injured by N. swainei in recent years and were cut in 1956 as a salvage operation. A block about 10 chains wide and 8 chains deep located between the road and a spruce swamp, was left standing as a study area.

Boivin (1957) reported that two forest types, Kalmia-Vaccinium and Cladonia-Vaccinium, are present in this plot, the former being more common. The distribution of the two types cannot be shown satisfactorily by a diagram. Lines A and B (Figure 5) are mainly in the more humid Kalmia-Vaccinium type; C, D and E, on the face of a slope are drier and the Cladonia-Vaccinium type is more common. The traps sites in lines F and G are near the edge of, or within, a black spruce swamp.

Plot VI

This plot is just to the west of Plot V on the south side of the road. The jack pine is similar to Plot V but site is much drier. Boivin (op. cit.) has classed this area as a Caliergon-Cornus forest type.

3. SMALL MAMMALS

3.1 Field techniques

In censusing small mammal populations it is desirable to use techniques that yield results in absolute density rather than relative density. The most common techniques used by mammalogists to obtain absolute figures are: saturation trapping with live-traps or snap-traps in an effort to catch all the animals in the trapping area; the Lincoln Index method (Lincoln 1930) which involves the use of live-traps; and the removal graph method (Hayne 1949). All of these techniques require a knowledge of the range of movement of the animals, in order to determine the area that has been censused. This is usually determined by the use of live-traps but may be determined by a method devised by MacLulich (1951) through the use of snap-traps. To use MacLulich's method the small mammal population must be uniform over an area of at least one-quarter of a square mile.

In 1956 snap-traps baited with peanut butter were set out in the vicinity of entomology study plots. Fifty traps set singly at one-half chain intervals were used in each area. Where possible they were set out as two parallel lines of 25 traps each, but in most instances it was necessary to modify this in order to stay within the jack pine stands.

Each set of traps was run for a minimum of five nights. The data have been expressed on the basis of the number of individuals captured per hundred trap-nights for each species (Table I, X, and XV). This index has many weaknesses when used in comparing densities of the different species at any given time and even for comparing densities of the same species in different areas. These weaknesses are introduced by differences in response to the traps exhibited by the different species, by differences in the ranges of movement and, in this study, by differences in the pattern in which the traps were set out. In an attempt to overcome some of these differences, values for the ranges of the species involved have been taken from the literature (Buckner 1954; Holling 1956; and Blair 1940) and the number of individuals per acre calculated. Since it is well known that ranges may vary from area to area these values are at best only approximate for the Clova region.

In 1956 a grid of 36 bucket traps similar to those used by Holling (1956) was set out in Plot I. Each trap was an 18-inch length of 7-inch-diameter stove pipe sunk vertically into the ground. The holes in which these were placed were 20 to 22 inches deep, and a floor of metal screening was placed under the bottom end of the pipe, in order to prevent flooding in wet weather. Owing to the poor results produced by these traps they were not used in the other areas.

In 1957 aluminum live-traps[1] of the type developed by the Bureau of Animal Populations at Oxford, England were used (see Chitty and Kempson, 1949). These traps were set out on seven-chain -square grids and were run every fourth week in each plot. When the traps were being run they were "baited" with oats or with Purina Fox Chow pellets. On each plot the traps were run for five days and checked once each day.

3.2 Species captured

The following species of mammals were trapped in the jack pine areas:

<u>Condylura cristata</u> - Taupe au nez étoilé - Star-nosed mole.
<u>Sorex cinereus</u> - Musaraigne commune - Cenereus shrew.
<u>Sorex palustris</u> - Musaraigne d'eau - Water shrew.
<u>Microsorex hoyi</u> - Musaraigne pygmée - Pigmy shrew.
<u>Blarina brevicauda</u> - Musaraigne à queue courte - Short-tailed shrew.
<u>Peromyscus maniculatus</u> - Souris à pattes blanches - White-footed mouse
<u>Clethrionomys gapperi</u> - Campagnol à dos roux - Red back vole.
<u>Phenacomys intermedius</u> - Phenacomys d'Ungava - Ungava Phenacomys.
<u>Microtus pennsylvanicus</u> - Campagnol des champs - Meadow vole.
<u>Synaptomys cooperi</u> - Campagnol lemming - Bog lemming.
<u>Zapus hudsonius</u> - Souris sauteuse des champs - Meadow jumping mouse.
<u>Napeozapus insignis</u> - Souris sauteuse des bois - Woodland jumping mouse.
<u>Tamias striatus</u> - Suisse - Eastern chipmunk.
<u>Tamiasciurus hudsonicus</u> - Ecureuil roux - Red squirrel.
<u>Mustela frenata</u> - Belette à queue longue - Long-tailed weasel.
<u>Mustela</u> sp. (<u>erminea</u>?) - Belette - Weasel

3.3 Mammal numbers

3.31 Mile 16, Gatineau (Plots I and II)

In 1956, fifty snap-trap stations were used to sample the mammal population in this area. Twenty-five were set in a line running west from

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1. Hereafter referred to as the Oxford traps.

the bog across the esker and 25 followed the edge of the bog on the south-east side. The traps were run for 350 trap-nights in September and 250 in October. The results are shown in Table I. Three species were captured in each of the two periods. The data show Peromyscus the most abundant in September with 0.36 animal per acre and Sorex and Clethrionomys at a slightly lower level with 0.26 and 0.28 per acre respectively. In October only one individual of each species was captured.

These snap-traps had been set out originally to see how the catch would compare with that of a grid of 36 bucket traps. Unfortunately the latter was a failure. On the first day the bucket traps were set one Microtus pennsylvanicus and two Sorex cinerus were captured. On the following day it was discovered that four of the traps had been dug up, presumably by bears. These were replaced and no further animals were captured, even though many of the traps were kept open between the trapping periods by some animal which was lifting the covers.

In 1957, two seven-chain-square grids of Oxford live-traps were set out in this area. The first (Plot I) was superimposed on the grid of bucket traps. In this plot the Oxford and bucket traps were run concurrently within one foot of one another. The second (Plot II) was set out approximately 400 feet to the north.

The number of animals captured in the Oxford and bucket traps in the different trapping periods in Plot I is shown in Table II. Peromyscus (27), Tamias (11), and Sorex (11), were the most important species. Clethrionomys, Microtis, Phenacomys, Synaptomys and Zapus were also present but not very abundant as only one individual from each of these genera was captured.

A comparison of the efficiency of these two types of traps with respect to Peromyscus and Sorex bears out the findings of Holling (1956). One difference, however, is that while he had some success in capturing Peromyscus in bucket traps, these traps did not capture any of this species in this plot. In the case of Sorex, the bucket traps appear to be much more efficient, taking 9 of the 11 individuals captured. Neither of these traps yielded any more information on Sorex than would have been gathered if snap-traps had been used, as 9 of the 11 individuals captured were dead, and the other 2 were never recaptured. The bucket traps were as ineffective in capturing Tamias as they were for Peromyscus. Eleven chipmunks were captured in the Oxford traps compared to none in the buckets. No conclusions can be drawn concerning the other species because of the small numbers involved.

The number of Peromyscus captured in this plot permits the use of the Lincoln Index for calculating population numbers. Two methods were used to calculate this index. In the first (Table III), each pair of consecutive days has been used as a separate experiment. For example, in calculating an estimate for the third day, animals captured and released on the first and second day but not captured on the third are considered as unmarked if taken in the sample on the fourth day. In sampling for the use of the index in this way the period in which the calculations can be influenced by the dilution effects of birth and immigration is reduced to 24 hours. In the second set of calculations (Table IV) the number of marked individuals has been accumulated from day to day so that the estimates are subject to the effects of dilution over the entire period. In these calculations an estimate based on the data from the last three days has been calculated in the manner proposed by Buckner (1957).

One striking feature of Table III is the high rate of recapture of the animals from day to day. This rate is so high that 9 of the 12 Lincoln indices have the same value as the sample size on which they are based. A similar situation occurs in the first trapping period in the calculations in Table IV. In the other two periods the estimates are slightly higher than the number captured. This is due chiefly to the fact that one mouse in each period avoided capture after it was released on the first day. There is a possibility that these animals did not stay on the plot.

In view of the high recapture rate it is obvious that we are not dealing with random sampling technique, so on theoretical grounds the use of the Lincoln Index or modifications of it, is not justified. From the practical viewpoint the calculations become merely an exercise in arithmetic as none of the estimates exceed the values of 10, 16, and 10 which were actually captured in each of the periods.

If the number of Peromyscus captured is accepted as indicative of the number present in a given area there is still the problem of interpreting the meaning of the figure. The high rate of turnover in small mammal populations mentioned by Hayne (1949) is well known to mammalogists, but is usually considered of no consequence during the period of about one week which is occupied in sampling. Little can be said regarding this in the present study due to the high mortality in the traps (8 of 27 in Plot I). The turnover is fairly rapid, however, as shown in Figure 6. The question is, however, how many enter and leave the plot during the sampling? On the basis of the trapping in Plot I very little emigration took place during the trapping periods (only 2 of the 27 disappeared while the traps were being run). There were also only two occasions on which an animal was known to have moved into the plot while the traps were being run. However, since the only outside source of marked mice was Plot II, immigration may have been much greater. Before this problem can be resolved much more needs to be known of the behaviour of this species.

Lincoln indices have also been calculated for Tamias in the same manner as those for Peromyscus. The results are shown in Tables V and VI where it is obvious that the chipmunk is not as readily captured as the white-footed mouse. In general the estimates based on accumulated data (Table VI) are higher than those based on a separate calculation for each pair of days. The highest estimates are obtained by aggregating the final days in each trapping period.

At present there are not enough data on Tamias to enable an evaluation of results. The variability in the estimates, and the fact that they show a decline through August, although the number captured increases, cast doubt on their validity.

In Plot II only Peromyscus, Tamias, and Sorex were captured. The numbers taken in each trapping period are shown in Table VII. Lincoln indices have been calculated for Tamias, in the period July 30 to August 3, and are presented in tables VIII and IX. These values show less variation than those for Plot I and the estimate based on the last 3 days is the same as the daily estimates calculated from the same data. Apparently the animals are not reacting to the traps in the same manner as they were in Plot I. This could be due to the presence of the larger number of Peromyscus in Plot I, if there were competition for traps.

It is not possible to make any estimate of the Sorex population in these two plots. There were no recaptures, so the Lincoln Index cannot be used, and the rate of capture was such that the removal trapping technique of Hayne (1949) was of no value. In view of the inefficiency of the Oxford traps in Plot I, the Sorex population in Plot II must have been considerably higher.

3.32 Mile 36-37, Gatineau (Plots III and IV)

In 1956, three snap-trap lines were set out in this area. Line 37-G-1 began at the edge of a side road and ran north, parallel to the main road and about two chains from it. Line 37-G-2 was set out about 4 chains to the west on the other side of the main road and ran parallel to 37-G-1. Line 37-G-3 began across the side road from 37-G-1 and ran south. A total of seven species was captured on these lines; 5 on line 37-G-1, 3 on 37-G-2 and 6 on 37-G-3. The numbers and population estimates are presented in Table X. The variation in the species composition in these three lines is surprising in view of their close proximity, but is not surprising in view of the low populations present.

In 1957, two grids of Oxford traps were set out in this area. Plot III was set out in the area occupied by line 37-G-1, and Plot IV was set out just to the south of the area of line 37-G-2. The number of animals captured in these plots is shown in tables XI and XII. In Plot III (Table XI) seven species were captured. Of these, Tamiasciurus, Blarina and Synaptomys were represented by one animal from each. Peromyscus and Sorex were the most important species on this plot. Lincoln indices cannot be calculated for any of the species because of the low number of recaptures. In the period August 13-17 only 2 of the 7 Peromyscus captured registered any recapture. This is in sharp contrast to the high recapture rate recorded in Plot I. It is possible that the Peromyscus population on this plot is a transient one, since 4 of the 13 animals were subsequently captured in Plot IV. Another was captured in October when snap-traps were reset in line 37-G-3.

Five species were captured on Plot IV. The numbers captured are shown in Table XI. The captures of Peromyscus here permit the calculation of Lincoln indices (Tables XIII and XIV). In this case the estimates are different from those in plots I and II (Tables V, VI, VIII and IX). In Plot I the estimates were the same as the number captured in many cases, while in Plot II the estimates were quite different from the number captured and the number marked. In Plot IV the estimates are close to, or coincide with, the number marked in the population. It would appear that the behaviour of *Peromyscus* is different in all four plots.

In view of high recapture rate of *Peromyscus* in Plot I, it is probably better to use the number captured as indicative of population number until nature of the differences is understood.

3.33 Mile 36, Chouart (Plots V and VI)

In 1956, three lines of snap-traps were used. Lines 36-C-1 and 36-C-2 were set out in the blocks of standing jack pine, and 36-C-3 was set out in a cut-over area between the two. The catch included *Sorex*, *Clethrionomys*, *Microtus* and *Synaptomys* on each of the lines (Table XV). *Sorex* and *Clethrionomys* were the most important species.

In 1957 Plot V was set out in the stand that contained line 36-C-1 and Plot VI in the stand that contained line 36-C-2. The number of animals captured in each period in Plot V is shown in Table XVI. This year no *Microtus* were captured but *Peromyscus* was added to the mammals known to be present in this area. The traps in Plot VI were run only in the period from August 7 to 11. Three *Sorex*, two *Peromyscus* and one *Clethrionomys* were captured in the 40 Oxford traps.

It is possible to calculate Lincoln Index estimates for the *Clethrionomys* population of Plot V. In these data the individual day calculations (Table XVII) give lower values than those in which the marked animals are accumulated (Table XVIII). On two occasions in each set of calculations it was not possible to calculate a value because no marked animals were captured. In the first and third periods the number marked in the population is the same as the Lincoln Index value calculated from the data of the final day of trapping. In the second period the estimate is larger than the number marked.

3.4 Mammal distribution

Once the population number has been determined it is desirable to convert these figures into density. To do this it is necessary to determine the range of movement of the species concerned and add this to the dimensions of the grid used in the trapping, in order to obtain the size of the area censused. This area is made up of the grid surrounded by a strip equal in width to the cruising radius of the species.

This cruising radius can be determined by two methods:

(1) The use of live-traps to capture individual animals a sufficient number of times to trace its movements. In this the distance travelled or the area covered can be determined. The chief objections to this method are that it is time-consuming, and that the distances recorded may be larger than the distances that would be covered in a normal trapping period.

(2) The use of a technique developed by MacLulich (1951). If we have a large area with a uniform small mammal population in which it is possible to set out a trapline and a grid of traps far enough apart so that they do not interfere with one another, the ratio of the catch on one to the catch on the other will be equal to the ratio of the areas from which the animals are drawn. On this basis, MacLulich developed equations that permit the calculation of the range of movement of the animals concerned.

This method has a number of advantages: It can be carried out by using snap-traps, which involve less labour than live-traps; it does not take long to gather the data; and the range of movement calculated is for the trapping period concerned. The only source of error in calculating the range of movement by this method is connected with the assumption of uniformity of density of the mammal population in the line and grid. If an error is made by putting the line in an area of too high a density it can be detected, as credible results will not be obtained. If the error is made the other way, and the grid is in an area of higher density, reasonable results can be obtained and the error will go undetected.

In the Clova region it has not been possible to use MacLulich's method because of the heterogeneity of the areas studied. This becomes immediately obvious when we compare the numbers captured in the pairs of plots, and when we examine the distribution of the animals within the individual plots.

In Plot I the captures of Peromyscus occurred over most of the area. The scarcity of captures in sections II and III may have been because of differences in vegetation, but there is no explanation for the lack of captures in the ten traps in the southeast corner of the plot. This area does not appear to differ from the remainder of Section I.

In the case of Sorex in this plot, 7 of the 11 animals were captured in line 8, and 4 of these were captured in the trap at H-8. This distribution of Sorex may be related to the influence of the bog, which is less than one chain from H-8 and about 3 chains from A-8.

The numbers of Peromyscus, Sorex and Tamias captured in each of the sections in Plot II are shown in Table XIX. The captures of Peromyscus were concentrated in the northern half of Section I (see Figure 2). The reason for this concentration is unknown for the remainder of Section I, and sections II and III are similar to the area in which the mice were captured. There may be some difference, however, as the 2 animals which were taken in line H were apparently transients, being captured only once. One of these came from Plot I and the other was subsequently taken in that plot over a period of one month before it died in a trap.

Tamias were distributed over the 4 sections, but Sorex was confined largely to the wetter Section III.

The number of animals captured in the two sections of Plot III are shown in Table XX. Peromyscus was the only species taken in sufficient numbers to show any difference between the two. While the traps in which Peromyscus were taken, are spread over most of the plot (see Figure 3), the 5 traps which caught 4 animals in Section II represent a total of 6 captures and the 11 traps which caught 10 animals in Section I represent a total of 27 captures. It is interesting to note that none of the animals captured in Section I were taken in Section II and vice versa, though 2 of the 4 from Section II were subsequently captured in Plot IV. The status of the Peromyscus population in this plot is unknown. In the 10 trapping days in June and July only 2 juveniles and 1 subadult were captured. Two of these were later captured in Plot IV. The captures of those taken in August and September were single or intermittent. This suggests that the population is composed of transients, and immigrants. Much more extensive trapping would have to be done in this area to ascertain this. There is no explanation of why the number of traps capturing Peromyscus in line A (7), and the number of captures (22) outnumbers such traps (4) and captures (5) on lines B and C combined.

In Plot IV Peromyscus were captured in all 4 sections (see Figure 4) but the number caught in Section IV (4) is small in proportion to its area (63% of the plot - see Table XXI). It is interesting to note that the traps which captured this species were in, or close to, Section II. The animals did not wander far into the dense Kalmia and Vaccinium of Section IV and appeared to avoid penetrating very far into the bare forest floor of Section I.

In Plot V the catch of Clethrionomys (Figure 5) was confined largely to lines A and B, and F and G with the animals avoiding the traps across the center of the plot. It would appear that the lack of captures in this center area was due to an absence of the mice as only 2 of the animals captured were taken in both ends of the plot.

3.5 Discussion

The chief methods employed by mammalogists to determine the number of animals are saturation trapping, in which an effort is made to capture all the animals in an area, or capture-recapture methods such as the Lincoln Index or modifications thereof.

MacLulich (1951), Cheshire (1955), and others have concluded that all of the resident animals can be caught and have used these as estimates of population numbers. Many other authors feel that such values are unreliable and use some form of the capture-recapture technique.

In the use of the Lincoln Index, animals are captured, marked, and released. The worker now knows that there are a certain number of marked animals in the population. At some future date another sample is taken; assuming that the proportion of marked to unmarked animals in the second sample is the same as in population, it is possible to calculate the size of the population.

In order to use a capture-recapture method the following must hold (Ricker 1948):

(1) The marked animals must suffer the same natural mortality as the unmarked. That is, the population can decrease but the ratio of marked to unmarked must be maintained. In the present study it has been demonstrated that mice do leave the plots, but whether the ratio is maintained or not is unknown.

(2) The marked animals must not lose their marks. There is no evidence of marks being lost in the present study.

(3) Marked and unmarked animals must have the same probability of capture. Morris (1955) and Tanaka (1956) have presented evidence that this assumption does not hold. It also seems logical that all the animals which use a plot on which traps were set would not have the same probability of capture. Some animals which live entirely within a plot would be exposed to traps all of the time, while others whose home range is only partially in the plot would be exposed to traps only part of the time. This latter group would have the probability of their being in the plot added to the probability of capture while they are on the plot. This aspect may be responsible for the variability of the Lincoln Index estimates in this study. In many of the plots the animals were captured near the periphery and probably avoided capture by being in an area where there were no traps.

(4) The marked animals must become randomly mixed with the unmarked. If a fixed grid of traps is used in sampling, this statement does not hold up if the concept of home range is accepted. We cannot accept random wandering for one set of calculations (for determining numbers), then agree to restricted movement in the next (in determining the area censused).

(5) All marked animals must be recognized and reported.

(6) There can be only a negligible amount of recruitment to the population being sampled during the sampling period. In trapping studies this is difficult to determine and is usually accepted as correct. Immigration into the plots during the trapping in this study was detected on two occasions but there was no way of knowing the full extent to which it was taking place.

In order to arrive at the density of small mammals we have to know the area that is being censused. This involves a knowledge of the home range of the species involved. As mentioned previously this can be done by using live-traps and actually recording the movements of the animals, or by calculating it through the use of the technique developed by MacLulich (1951). Both of these have their limitations. In the present study both of them have proved impractical. The first could not be used because the plots were too small, and the second because of the heterogeneity in the distribution of the animals.

Morris (1955) has examined the techniques for assessing small mammal populations and discusses their weaknesses. He states: "A review of the literature since 1941 shows that the fundamental work necessary to the development of practical trapping methods has yet to be done". The situation has changed little since this was written and many of the assumptions underlying the available techniques are accepted because it is expedient, or statistically necessary, to do so and not because they are biologically sound.

4. PREDATION

To date the only information available on the losses of N. swainei to small mammals is that gathered through the examination of cocoons collected from a series of soil samples. These samples were collected in Plot I in the fall of 1956 and the spring of 1957, and in Plot III in the spring of 1957. Two methods were used in taking these samples in Plot I. The first involved selecting the sampling units (square links) at random from a grid of 36 milacre plots. In the second the sampling units (square links and square feet) were taken systematically at 15 foot intervals in rows situated midway between the rows of milacre plots. The results of the samples taken in Plot I in the fall of 1956 are shown in Tables XXII and XXIII. The values in these tables are based on the cocoons that have accumulated in the soil since 1948. (It is possible that some of them may have originated even before this.) The data, therefore, merely tell us that roughly 20 per cent of the cocoons in the area have been opened by small mammals. Whether these cocoons were opened at the same rate each year, or whether the bulk of them were opened during a few years of high mammal populations is not known. Unfortunately, the age of the individual cocoons cannot be determined at present. The technique developed by Holling (1956) for separating new from old cocoons of N. sertifer on the basis of colour, is of no help here, because the bulk of the over-wintering cocoons in this area have been those containing prepupae in prolonged diapause. In 1956 there was a complete failure of the larval population (Tripp 1957). This means that cocoons predated in the winter 1956-57 would all be "old" cocoons.

Since soil sampling does not provide a basis for determining the amount of predation on an annual basis cocoon plants were set out in plots I, III, and V in the fall of 1957. These plants were placed systematically near the trap sites in each of the plots. In Plot I, 4 types of plants were used to see if the practice of tying the cocoon to a tag has any influence. The results of this experiment will not be available until the summer of 1958.

Eventually it is hoped that a method can be devised to set out cocoons in a manner which approaches that in which cocoons occur naturally in the soil. At the present it appears that the best means of achieving this is to base the density and distribution (spatial and statistical) of the cocoon plants on those revealed from cocoon samples. This will be done when a method of sampling for cocoon populations has been decided on.

It has been shown in connection with studies on other sawflies that it is possible to determine whether a cocoon had been predated by a rodent or a shrew by the type of hole in it. In order to determine the appearance of predated cocoons of N. swainei, healthy cocoons were presented to various species of mammals in the laboratory. The results, samples of which are shown, figures 7 and 8, indicate that it should be very easy to determine the predator, even to species. However, when cocoons from the soil samples are examined the situation is not so clear cut. Attempts to segregate the cocoons into those preyed on by rodents and by shrews have not been satisfactory. It is possible that the marks left on a cocoon by a predator vary depending on its condition. This is suggested by the cocoons on pins B and C in Figure 7, which were all opened by the same animal. The former were recently spun cocoons and the latter were 2 to 3 months old. In spite of this difficulty the shrew, Sorex cinereus, appears to be the most important, though the author would hesitate to quote figures at the present time.

5. SUMMARY

A study of the small mammal populations was commenced in the summer of 1956 in the vicinity of Clova, Abitibi, P.Q. In that year snap-traps were used to estimate populations in three areas in which entomological studies were being carried out. In general, populations were low with estimates all below one animal per acre for the individual species in 2 of the 3 areas. In the younger stands of jack pine (8 to 10 years and 30 to 35 years) Sorex cinereus and Peromyscus maniculatus are the most abundant, while in the older stand (60 to 65 years) S. cinereus and Clethrionomys gapperi are the most numerous.

In 1957 live-traps were used to capture the mammals. The data gathered by the use of these have been used to calculate Lincoln Index estimates of population numbers. These estimates behave differently in the different plots used. It is suggested that this is due to the behaviour of the animals. In plots where the activities of the animals are concentrated near the periphery the results are more variable than when the animals are within the plot. It would appear that animals whose activities are limited to the plot have a different probability of capture than those whose activities are not so limited. In view of this it has been concluded, with the distribution and population levels encountered in this region, that the assumptions necessary for the use of the Lincoln Index cannot be accepted.

In the case of Peromyscus it appears that the number of animals captured in a five day period is a valid estimate of the number present. For the other species the data are insufficient to draw any conclusions.

Home range, or range of movement, values have not been calculated for any of the species. The majority of the animals were taken in traps at the periphery of the plots, so complete ranges were not revealed. The distribution of the animals in the three areas studied was such that the MacLulich method for determining range of movement could not be used with any confidence.

The analysis of cocoons recovered from soil samples in the Mile 16 (Plot I) area indicates that about 20 per cent have been chewed by small mammals over the period in which the cocoons have accumulated in the soil. Since the cocoons could not be aged, cocoon plants were set out in 1957 in an attempt to obtain a value for a single year.

6. RECOMMENDATIONS

The data gathered through the use of live-traps at Clova indicate that the study plots are not large enough to properly assess the populations of small mammals. Many of the individuals captured were involved in the edges of the plots and others appeared to be transients. In view of this a complete analysis has been deferred until more information is gathered.

In 1958 plots I and II will be enlarged to study the effects of the different vegetation types on the distribution of the species concerned, and an additional plot will be set out in a more homogeneous area for comparison.

One aspect that is very important in determining small mammal populations is the concept of home range. This range is defined as the area over which an adult mammal normally travels in search of food and in the other normal functions of life. In theory this applies to animals which have established themselves in an area, but in practice it is usually applied to all the individuals captured. The enlarged areas to be used in 1958 may make it possible to calculate home ranges and to clarify the situation regarding transients.

Cocoon planting will be continued as a means of determining the effect of predation on this stage of the sawfly. Efforts will be made to obtain parasite-free cocoons and to develop techniques for obtaining known parasitized cocoons for studies on the selectivity of the small mammals. The object of these studies will be to determine whether selectivity, if present, occurs throughout the life cycle of the parasite.

7. ACKNOWLEDGMENTS

The author would like to acknowledge the co-operation of the members of the staff of the Field Station at Clova.

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TABLE I. Population indices for Mile 16 Gatineau in September and October, 1956

Species	Period	Cruising radius (Chains)	Area (Acres)	Number caught	Number per acre	Number per 100 trap nights
<u>Sorex</u>	September	2.11	11.7	3	0.26	0.9
	October			1	0.09	0.4
<u>Peromyscus</u>	September	2.02	11.2	4	0.36	1.1
	October			1	0.09	0.4
<u>Clethrionomys</u>	September	1.35	7.2	2	0.28	0.6
	October			1	0.14	0.4
Total	September				0.90	
	October				0.32	

TABLE II. Animals captured in Oxford and Bucket Traps in Plot I (Mile 16) Clova, 1957

Date	Trap	No. of Individuals Captured			
		Peromyscus	Tamias	Sorex	Others
June 5-8	O	2	0	0	0
	B	0	0	0	0
July 2-6	O	10	0	1	0
	B	0	0	5	2
July 30-Aug. 4	O	16	8	0	0
	B	0	0	1	3
Aug. 27-Aug. 31	O	10	10	1	0
	B	0	0	3	0
Total Individuals	O	27 *	11 *	2	0
	B	0	0	9	5

* Some individuals captured in more than one trapping period.

TABLE III. Population estimates for *Peromyscus* in Plot I, 1957, using pairs of consecutive days

Date	m	x	n	T	Dead	Pop. Estimate.
July 2	-	-	2	4	1	5
3	1	1	4	7	0	7
4	4	4	7	8	0	8
5	7	7	8	8	1	9
6	7	7	8	-	0	-
July 30	-	-	4	10.6	0	11
31	4	3	8	10.	0	10
Aug. 1	8	8	10	12.2	0	12
2	10	9	11	13.	2	15
3	9	9	13	-	2	-
Aug. 27	-	-	5	11.6	0	12
28	5	3	7	6	2	8
29	5	5	6	5	1*	5
30	5	5	5	7	0	7
31	6	6	7	-	1	-

* One animal taken to laboratory in weakened condition, returned to plot on Aug. 30.

m = number marked in population

n = number in sample

x = number marked in sample

$$T = m \frac{n}{x}$$

TABLE IV. Lincoln Index Estimates for *Peromyscus* in Plot I, 1957, accumulating marked animals from day to day

Date	m	x	n	T	Dead
July 2	-	-	2	4	1
3	1	1	4	7	0
4	4	4	7	8	0
5	7	7	8	8	1
6	7	7	8	-	0
Last 3 days	7	18	23	8.9 (7.7-12.5)	
July 30	-	-	4	10.6	0
31	4	3	8	11.3	0
Aug. 1	9	8	10	13.4	0
2	11	9	11	14.3	2
3	11	10	13	-	2
Last 3 days	11	27	34	13.8 (12-17)	
Aug. 27	-	-	5	11.6	0
28	5	3	7	7	2
29	7	6	6	6	1*
30	6	5	5	8.2	0
31	7	6	7	-	1
Last 3 days	7	17	18	7.4 (7-13)	

* See Table III

TABLE V. Lincoln Index Estimates for *Tamias* in Plot I, 1957, using pairs of consecutive days

Date	m	x	n	T	Dead
July 30	0	0	0	-	-
31	0	0	0	-	-
Aug. 1	0	0	1	6	0
2	1	1	6	12	0
3	6	2	4	-	0
Aug. 27	-	-	3	2	1
28	2	2	2	-	1
29	1	0	4	9	1
30	3	1	3	6	0
31	3	2	4	-	-

TABLE VI. Lincoln Index Estimates of *Tamias* population in Plot I, 1957, accumulating marked individuals from day to day

Date	m	x	n	T	Dead
July 30	-	-	0	0	
31	0	0	0	0	
Aug. 1	0	0	1	6	
2	1	1	6	14	
3	7	2	4	-	
2 days est.	7	3	10	23.3 (11-116)	
Aug. 27	-	-	3	2	1
28	2	2	2	-	1
29	1	0	4	12	1
30	4	1	3	8	
31	6	3	4	-	
Last 3 days	6	4	11	16.5 (8-67)	

TABLE VII. Animals captured in Oxford Traps in Plot II (Mile 16) Clova, 1957

Date	Peromyscus	Tamias	Sorex
June 5-8	2	0	0
July 2-6	5	2	1
July 3-Aug. 4	6	12	7
Total Individuals	11 *	12 *	8

*Some individuals captured in more than one trapping period.

TABLE VIII. Lincoln Index Estimates for Tamias in Plot II, 1957, using pairs of consecutive days

Date	m	x	n	T	Remarks
July 30	-	-	3	8	1 dead
31	2	1	4	10	
Aug. 1	4	2	5	10.5	1 left Plot, 1 dead
2	3	2	7	14	1 left Plot
3	7	3	6	-	

TABLE IX. Lincoln Index Estimates for Tamias in Plot II, 1957 accumulating marked mice from day to day.

Date	m	x	n	T	Remarks
July 30	-	-	3	8	1
31	2	1	4	12.5	
Aug. 1	5	2	5	17.5	1 dead, 1 left Plot
2	5	2	7	18	1 left Plot
3	9	3	6	-	
Last 3 days	9	9	18	18 (12-33)	

TABLE X. Population Indices for Mile 36-37 Gatineau in August and September, 1956

Line	Species	Period	Cruising radius (Chains)	Area (Acres)	Number Caught	Number per acre	Number per 100 trap nights
37-G-1	Sorex	August	2.11	11.7	0	0	0
		September			2	0.17	0.8
	Blarina	August	2.02	11.2	3	0.27	1.2
		September			0	0	0
	Clethrionomys	August	1.35	7.2	1	0.14	0.4
		September			0	0	0
	Microtus	August	1.10	5.8	2	0.34	0.8
		September			0	0	0
	Condylura	August	?	-	1	-	0.4
37-G-2	Sorex	August	2.11	8.1	3	0.37	1.2
		September			1	0.12	0.4
	Clethrionomys	August	1.35	5.3	0	0	0
		September			1	0.19	0.4
	Synaptomys	August	?	-	4	-	1.6
		September			2	-	0.8
37-G-3	Sorex	August	2.11	10.6	0	0	0
		September			7	0.66	3.11
	Blarina	August	2.02	10.2	3	0.29	1.33
		September			3	0.29	1.33
	Peromyscus	August	2.02	10.2	1	0.10	0.44
		September			1	0.10	0.44
	Napaeozapus	August	?	-	3	-	1.33
		September			0	0	0
	Microtus	August	1.10	5.2	1	0.19	0.44
		September			2	0.38	0.89
	Synaptomys	August	?	-	0	0	0
		September			1	-	0.44

TABLE XI. Animals captured in Oxford Traps in Plot III, 1957

Date	Peromyscus	Tamias	Sorex	Microtus	Others
June 20-24	1	0	0	2	1
July 17-21	2	0	2	1	0
Aug. 13-17	8	3	5	0	2
Sept. 3-7	6	0	2	0	0
Total individuals	14*	3	9	3	3

*Some individuals captured in more than one trapping period.

TABLE XII. Animals captured in Oxford Traps in Plot IV, 1957

Date	Peromyscus	Tamias	Sorex	Clethrionomys	Blarina
Aug. 13-17	14	3	3	0	0
Sept. 3-7	7	3	3	3	1
Total individuals	15*	5*	6	3	1

*Some individuals captured in both trapping periods.

TABLE XIII. Lincoln Index Estimates for Peromyscus on Plot IV, 1957, using pairs of consecutive days

Date	m	x	n	T	Remarks
Aug. 13	-	-	6	10	1 left Plot
14	5	3	6	12.6	1 dead
15	7	5	9	7.5	3 dead
16	6	4	5	7.5	
17	5	4	6	-	
Sept. 3	-	-	4	6	
4	4	4	6	10	1 from Plot III
5	6	3	5	6.7	1 dead
6	4	3	5	4	1 dead
7	4	3	3	-	

TABLE XIV. Lincoln Index Estimates for Peromyscus on Plot IV, 1957, accumulating marked animals from day to day

Date	m	x	n	T	Remarks
Aug. 13	-	-	6	10	1 left Plot
14	5	3	6	12	1 dead
15	8	6	9	10	3 dead
16	8	4	5	10.8	
17	9	5	6	-	
Last 3 days	9	15	20	12 (10-16)	
Sept 3	-	-	4	6	
4	4	4	6	7.5	1 from Plot III
5	6	4	5	6	1 dead
6	6	5	5	6	1 dead
7	6	3	3	-	
Last 3 days	6	12	13	6.5 (6-100)	

TABLE XV. Population Indices for Mile 36 Chouart, October, 1956

Line	Species	Cruising radius (Chains)	Area (Acres)	Number caught	Number per acre	Number per 100 trap nights
36-C-1	Sorex	2.11	7.2	15	2.08	6.0
	Clethrionomys	1.35	4.8	5	1.04	2.0
	Microtus	1.10	4.1	1	0.24	0.4
	Synaptomys	?	-	2	-	0.8
36-C-2	Sorex	2.11	6.3	2	0.32	0.8
	Clethrionomys	1.35	4.0	3	0.75	1.2
	Microstus	1.10	3.4	1	0.29	0.4
	Synaptomys	?	-	2	-	0.8
36-C-3	Sorex	2.11	7.6	3	0.39	1.2
	Clethrionomys	1.35	4.9	10	2.04	4.0
	Microtus	1.10	4.1	3	0.73	1.2
	Synaptomys	?	-	5	-	2.0

TABLE XVI. Animals captured in Oxford Traps in Plot V, 1957

Date	Clethrionomys	Sorex	Peromyscus	Synaptomys
July 9-13	13	9	0	2
Aug. 7-11	8	7	2	0
Sept. 10-14	7	2	1	0
Total individuals	22*	18	3	2

* Some individuals captured in more than one trapping period.

TABLE XVII. Lincoln Index Estimates for Clethrionomys on Plot V, 1957, using pairs of consecutive days

Date	m	x	n	T	Remarks
July 9	-	-	2	-	
10	2	0	3	21	
11	3	1	7	11	
12	7	7	11	9	2 dead
13	9	8	8	-	
Aug. 7	-	-	2	4	
8	2	1	2	-	1 dead
9	1	0	2	6	
10	2	1	3	6	
11	3	2	4	-	1 dead
Sept. 10	-	-	3	7.5	
11	3	2	5	10	
12	5	1	2	4	
13	2	1	2	2	
14	2	1	1	-	

TABLE XVIII. Lincoln Index Estimates for *Clethrionomys* on Plot V, 1957, accumulating the marked animals from day to day

Date	m	x	n	T	Remarks
July 9	-	-	2	-	
10	2	0	3	11.6	
11	5	3	7	14.1	
12	9	7	11	11	2 dead
13	11	8	8	-	
Last 3 days	11	18	26	15.8 (15-22)	
Aug. 7	-	-	2	4	
8	2	1	2	-	1 dead
9	2	0	2	6	
10	4	2	3	10	
11	5	2	4	-	1 dead
Last 3 days	5	4	9	11.2 (6-38)	
Sept. 10	-	-	3	7.5	
11	3	2	5	12	
12	6	1	2	7	
13	7	2	2	7	
14	7	1	1	-	

TABLE XIX. Number of mammals in each section of Plot II Mile 16 Clova, P.Q. during summer of 1957

Section	No. of traps	Approx. % of total area	Peromyscus	Tamias	Sorex
I	23	32	9	9	1*
II	6	6	0	1	1*
III	6	25	1	1	5
IV	29	37	3	11	1*

*Captured in traps near edge of Section III.

TABLE XX. Number of animals taken in the two sections of Plot III (Mile 36 Gatineau) in 1957

Section	Approx. % of total area	Peromyscus	Tamias	Sorex	Microtus	Synaptomys
I	39	10	0	3	1	0
II	61	4	2	5	0	1

Peromyscus taken in one section were never taken in the other.

TABLE XXI. Number of animals taken in each section of Plot IV (Mile 36 Gatineau) in 1957

Section	Approx % of total area	Peromyscus	Tamias	Sorex	Clethrionomys	Blarina
I	8.1	4	0	0	1	0
II	18.1	10	0	0	2	0
III	10.2	4	3	0	0	0
IV	63.2	4	1	6	1	1

TABLE XXII. Analysis of square link soil samples - Mile 16 Gatineau, September 8-15, 1956. N = 100

Row	Total cocoons	Sound cocoons	Parasitized	Mammal predated	Insect predated	Emerged	Dead	Cocoons per sample	% Parasitized	% Mammal predated	% Insect	% Emerged	% Dead
1	178	38	52	34	6	28	20	7.4	29.21	19.10			
2	144	28	44	26	7	11	28	6.9	30.55	18.06			
3	126	25	40	21	0	24	16	10.5	31.74	16.67			
4	79	17	13	26*	3	11	9	6.1	16.46	32.91*			
5	67	12	25	9	3	7	11	6.1	37.31	13.43			
6	37	13	3	9	2	0	10	1.9	8.11	24.32			
Total	631	133	177	125	21	81	94	6.3	28.05	19.83	3.3	12.8	14.9

*15 of the mammal predated cocoons from one sample

1.33 sound cocoons per sample

TABLE XXIII. Analysis of square link soil samples - Mile 16 Gatineau, October 21-22, 1956. N= 123.

Row	Total cocoons	Sound cocoons	Parasitized	Mammal predated	Insect predated	Emerged	Dead	Cocoons per sample	% Parasitized	% Mammal predated	% Insect	% Emerged	% Dead
1	80	14	17	33*	2	2	3	3.3	21.25	41.25*			
2	118	42	29	16	2	15	6	4.5	24.57	13.56			
3	82	35	17	10	0	15	3	3.4	20.73	12.19			
4	149	45	39	13	6	21	14	6.2	26.17	8.72			
5	101	32	24	20	4	8	9	4.0	23.76	19.80			
Total	530	168	126	92	14	61	35	4.3	23.77	17.35	2.6	11.5	6.6

* 2/3 of the mammal predated cocoons from one sample

1.36 sound cocoons per sample

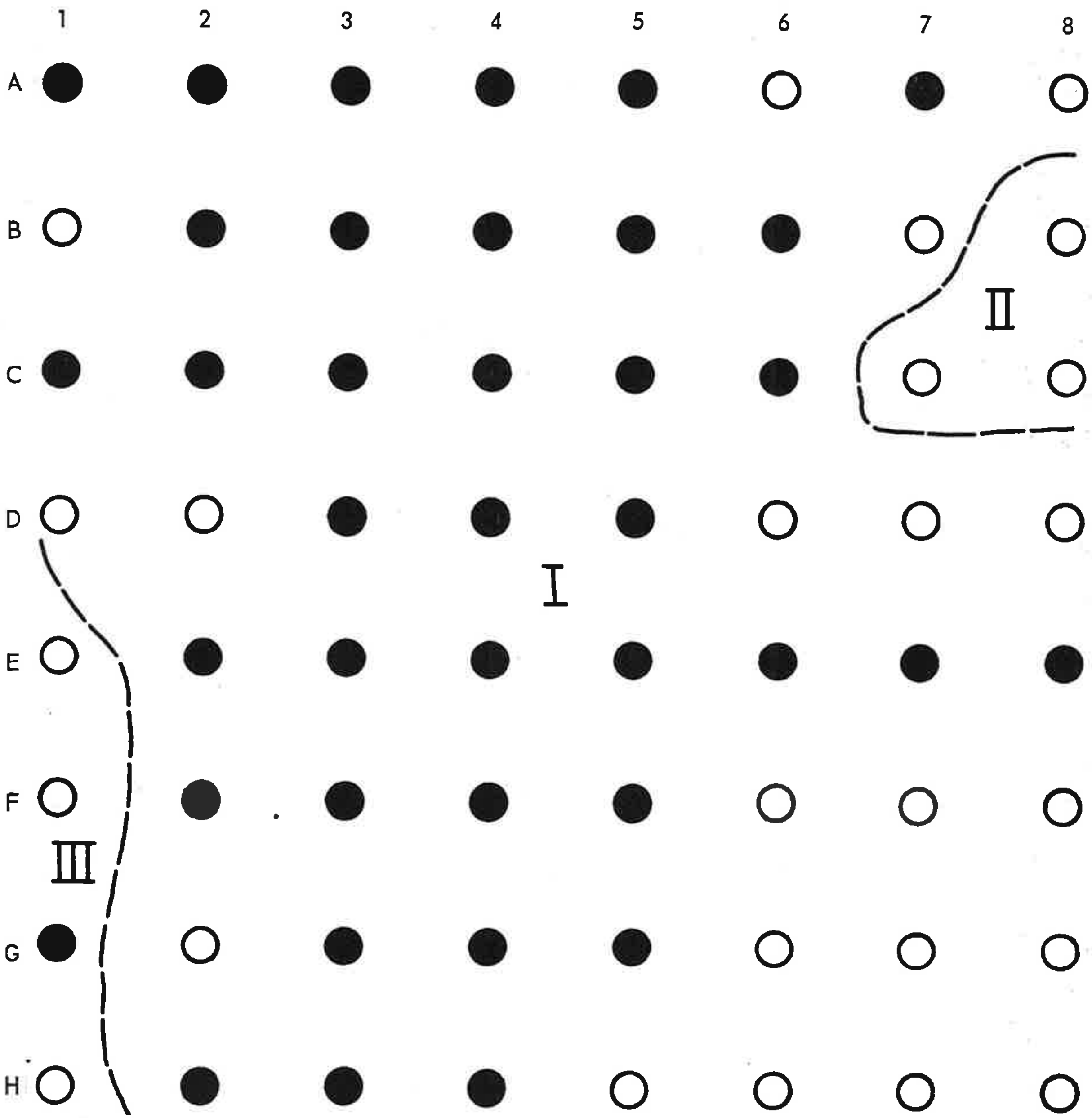

Figure 1. Distribution of vegetation and catch of *Peromyscus* in Plot I. Solid circles indicate traps in which animals were captured.

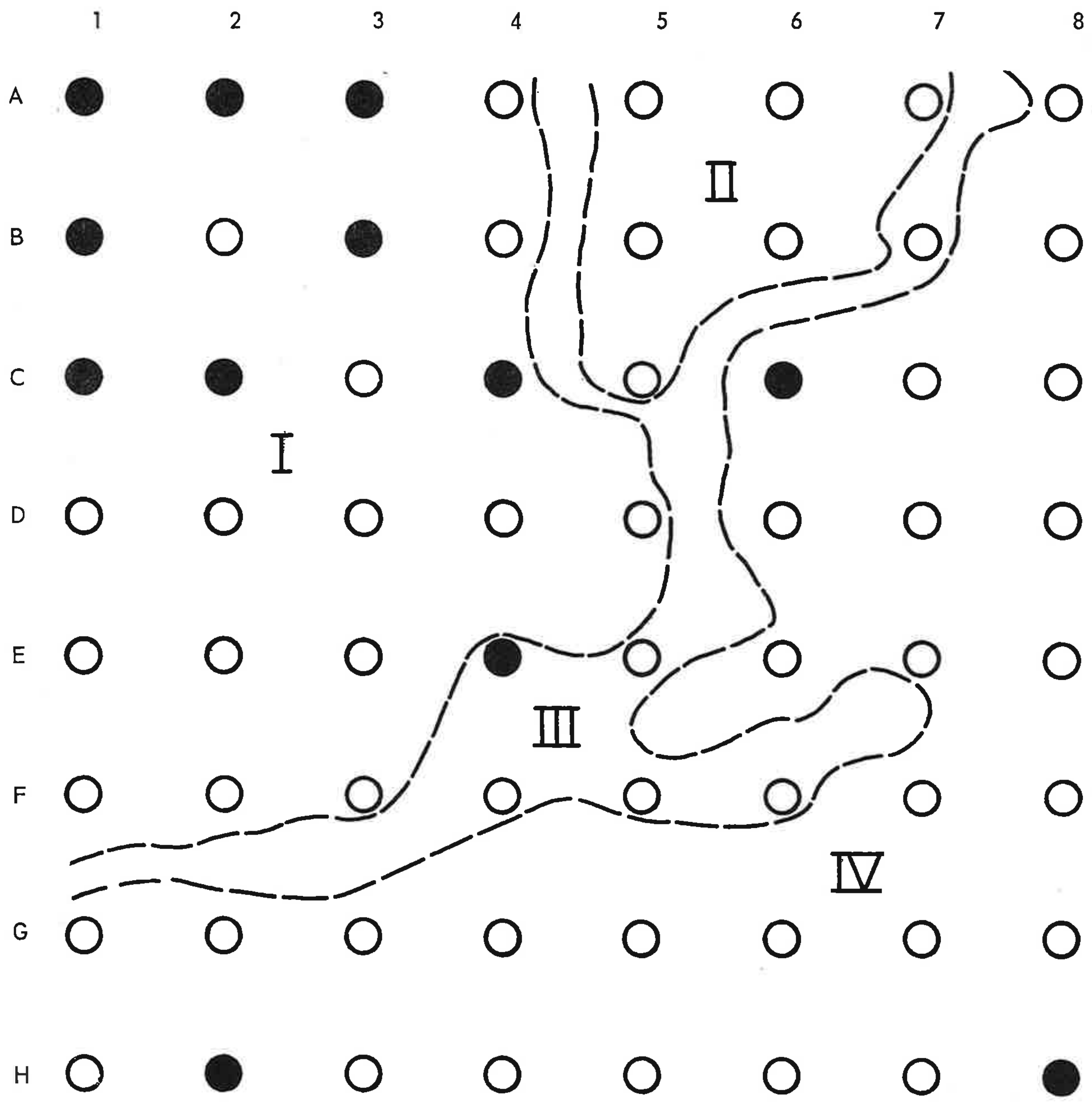

Figure 2. Distribution of vegetation and catch of *Peromyscus* in Plot II. Solid circles indicate traps in which animals were captured.

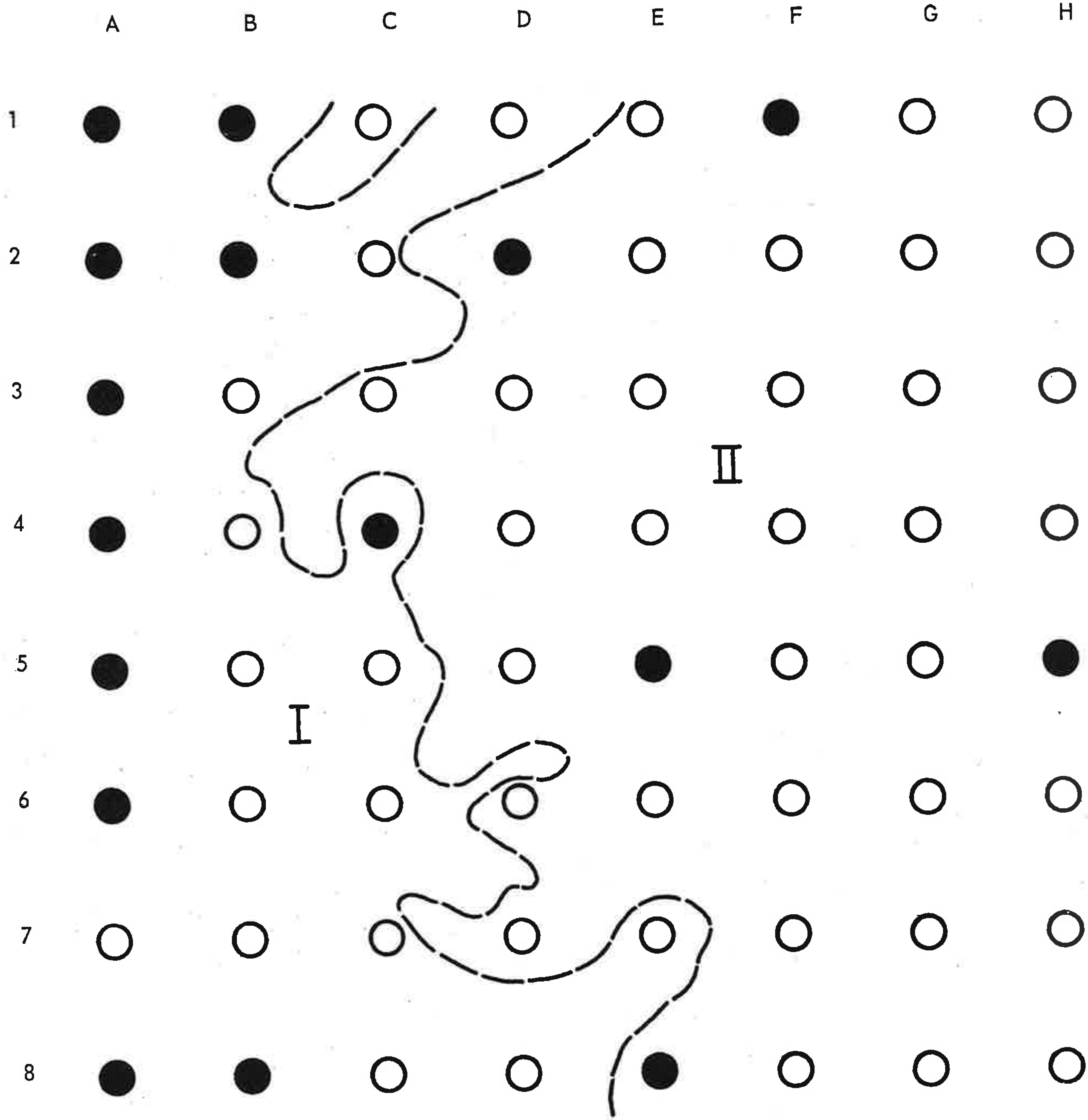

Figure 3. Distribution of vegetation and catch of *Peromyscus* in Plot III. Solid circles indicate traps in which animals were captured.

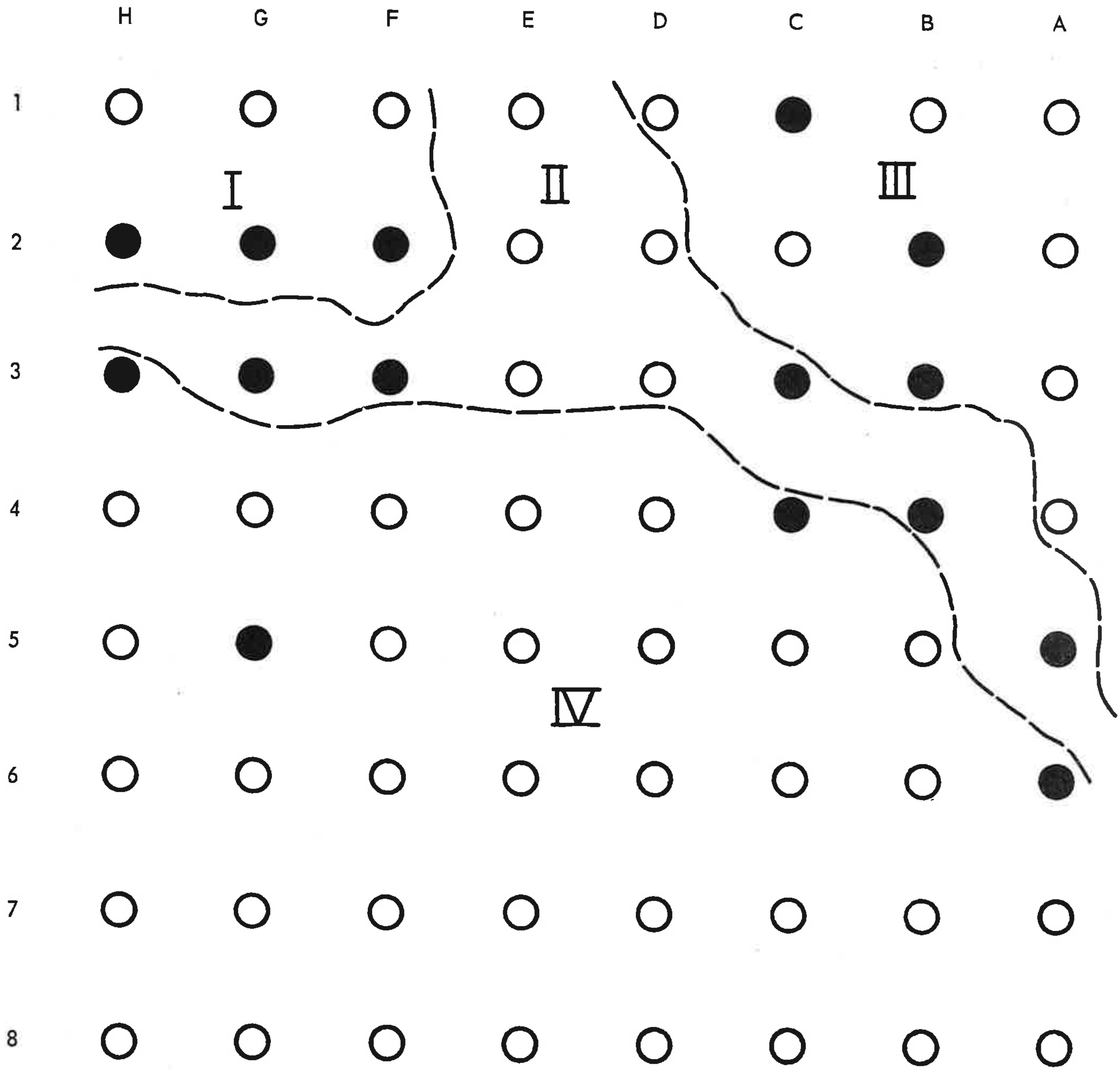

Figure 4. Distribution of vegetation and catch of *Peromyscus* in Plot IV. Solid circles indicate traps in which animals were captured.

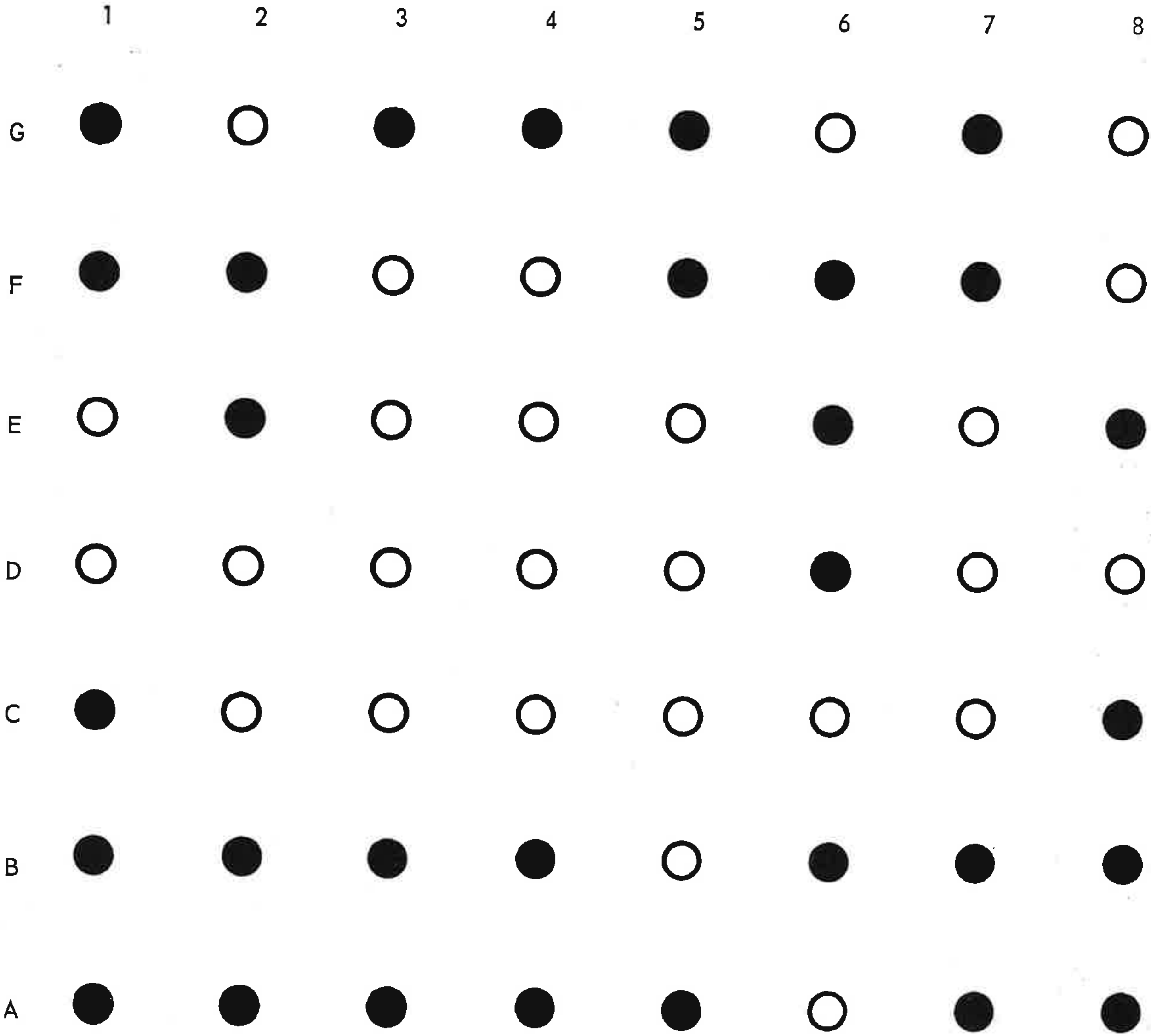

Figure 5. Distribution of the catch of *Clethrionomys* in Plot V. Solid circles indicate traps in which animals were captured.

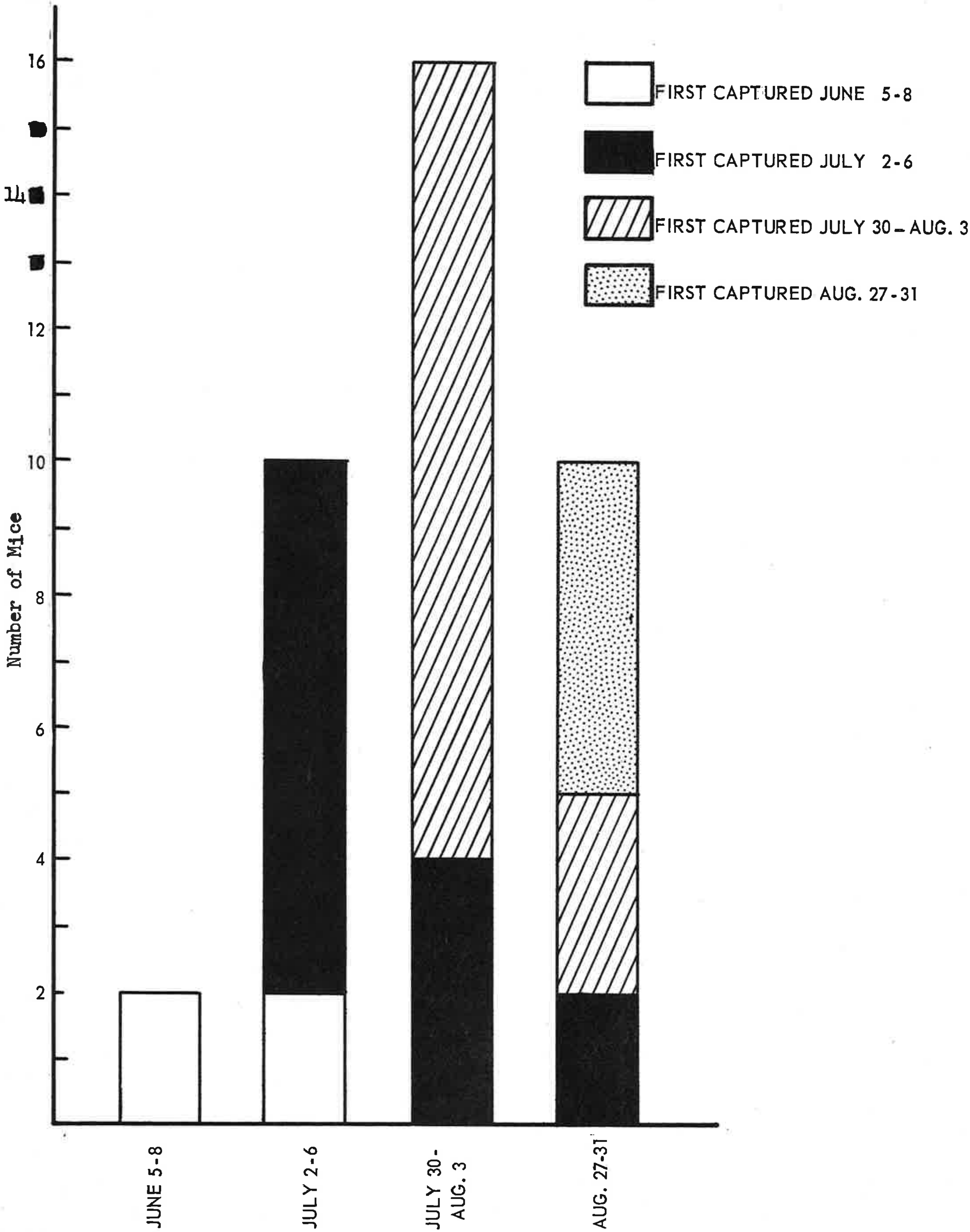

Figure 6. Turnover in *Peromyscus* population on Plot I, 1957.

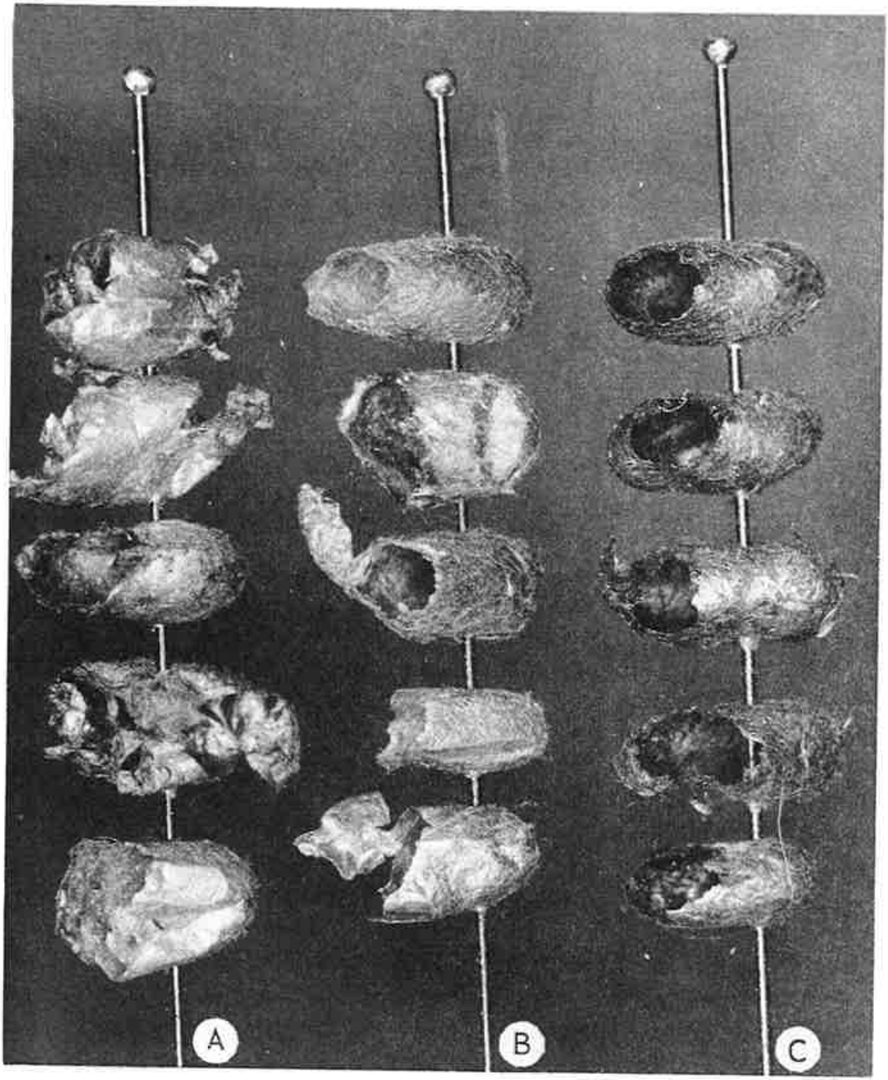

Figure 7. Cocoons of *N. swainei* predated by mammals. A – *Blarina brevicauda;* B – recently spun cocoons predated by *Clethrionomys gapperi;* C – older cocoons predated by *C. gapperi.*

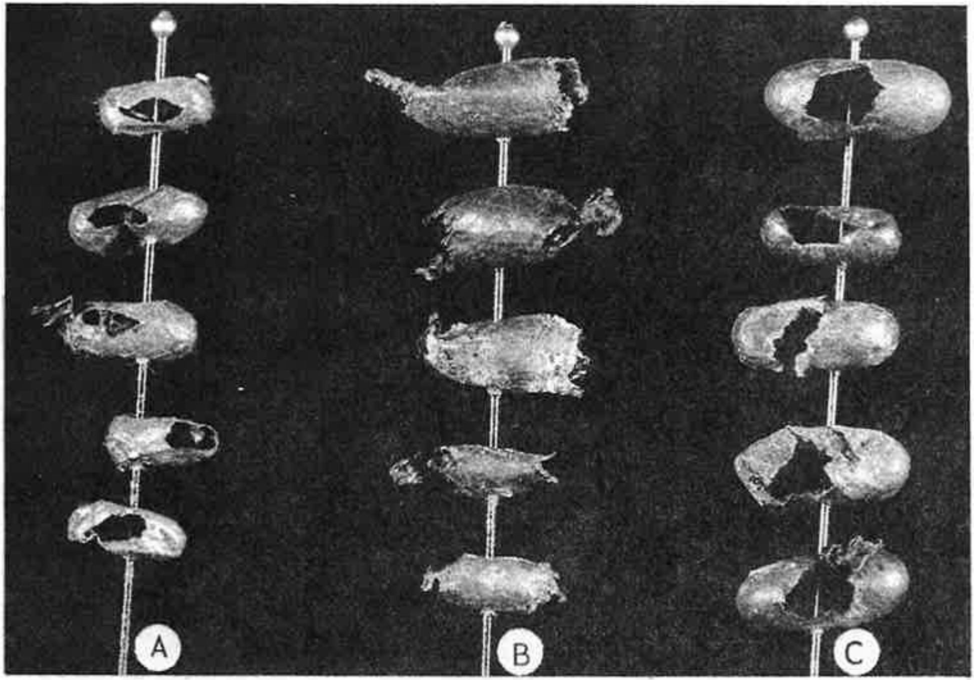

Figure 8. Cocoons of *N. swainei* predated by mammals. A – *Zapus hudsonius;* B – *Sorex cinereus;* C – *Peromyscus maniculatus.*