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Penetration of an Area by Small Forest Rodents

[With 2 Figs. & 6 Tables]

Investigation was made of the range of penetration of three species: *Apodemus flavicollis* (Melchior, 1834), *Apodemus agrarius* (Pallas, 1771), *Clethrionomys glareolus* (Schreber, 1780). By using the stained bait method it was found that daily differences in range of penetration are not statistically significant for the above three species and that the greater part of the individual's range is revealed within one day. Discovery of stained bait in excreta made it possible to define the way in which the area was penetrated in two different types of habitat. In phytosociologically homogeneous habitats small rodents move about evenly over the whole association, but in mixed habitats, consisting of two associations, they limit their penetration to humid associations and ecotones.

I. INTRODUCTION

The use of stained bait which can be recognized in the alimentary tract or excreta makes it possible to distinguish groups of individuals without having to catch them in live-traps. This method was used to examine penetration of an area by the following species of forest rodents: *Apodemus flavicollis* (Melchior, 1834), *Apodemus agrarius* (Pallas, 1771) and *Clethrionomys glareolus* (Schreber, 1780). Particular attention was paid to the following aspects: a) the range of penetration of an area and differences in the daily range of such penetration; b) the character of penetration of an area in different habitats.

II. METHOD AND STUDY AREA

1. Preparation of Stained Bait and Rate of its Passage through the Rodents' Alimentary Tract

Yarn mixed with flour and margarine and oats stained with basic fuchsin were used alternately as bait.

The bait consisting of coloured yarn was prepared in accordance with Holišova's method (1968). The following experiment was made in order to ascertain how long bait prepared in this way remains in the alimentary tract: after feeding laboratory mice on yarn bait the animals were transferred to other cages. Two mice were killed every day, then dissected and the contents of stomach and caecum examined under a binocular microscope.

After five days the number of threads of the yarn found was negligible and the threads themselves very difficult to discover. This confirms the results obtained by Holišova (1968).

Oats were stained with basic fuchsin in accordance with the method used by Adamczyk & Ryszkowski (1968). The studies made by these authors show that after killing the rodents traces of this bait can be found in the alimentary tract up to the eighth day after ingestion.

2. Recognition of Stained Bait in Excreta

An experiment was made to establish whether or not stained bait can be recognized in excreta. Stained bait was laid out for a period of three days on four sites arranged in a line at 15 m intervals. The bait was removed after three days and four sites chosen on each side of the bait line at a distance of 15 m from it. Unstained oats were placed on sheets of paper on these sites. Mice consuming the grain left excreta on the sheets, and this was collected, placed in Petri dishes and after mixing with water examined under a binocular microscope for traces of fuchsin. Excreta was collected for a period of five days. It was found that the excreta contained traces of fuchsin up to the fourth day inclusively from the time of removing the stained bait.

As it proved possible to identify stained bait in excreta, the range of penetration of the area by rodents could be investigated without the necessity for catching or killing the animals.

3. Methods of Investigating Penetration of the Area

3.1. Methods of assessing range of penetration

Nine sites at 15 m intervals were marked out by means of numbered stakes. A second line of the same length was marked out parallel to the first line, but at a distance of 15 m from it. Stained bait was laid on each of the sites and replenished every 24 hours for three days. At the end of this time the bait was removed and two rows of spring-traps arranged vertically to both bait lines. Two traps were placed in each of the rows, which were 150 m long, at intervals of 15 m. The distance between rows was 30 m. These rows intersected the bait lines at a distance of 45 m from their ends.

On account of the shape of these areas they have been termed »cross areas« in the rest of this study, and trappings correspondingly »cross trappings«.

Two variants of this method were used: (A) removal captures immediately after the pre-baiting period; (B) removal captures delayed by one day in relation to the pre-baiting period.

Removal captures were made for three whole days. The traps were inspected every 24 hours and the number of the site recorded on which the animals were caught. When traces of bait were discovered in the alimentary tract of the animals caught then, knowing the distance between the trapping site and bait line, it was possible to determine the distance traversed by the captured animal.

A total of 25 series of cross captures were made, which included 9 series using yarn as bait and 16 series using oats stained with basic fuchsin.

Trapping lasted from mid-June to the end of Nevember 1968, except for July.

Study areas were arranged near the Field Station at Dziekanów Leśny in the following phytosociological associations: *Carici elongatae-Alnetum, Tilio-Carpinetum, Pino-Quercetum, Pineto-Vaccinietum uliginosi.*

3.2. Methods of investigating differences in penetration of the area

Five concentric circles were marked out with radii as follows: 15, 30, 45, 60 and 75 metres. Petri dishes were arranged on the periphery of each of these circles in such a way that their number was constant per unit of periphery, that is 4, 8, 12, 16 and 20 dishes respectively.

Stained bait consisting of oats stained with basic fuchsin (cf. Fig. 2) was placed in the centre of the circle.

The experiment lasted for a total of four days. Stained bait was placed in the middle of the area on the first day. Unstained oats were placed at the same time into the Petri dishes arranged on the edge of the circles. On subsequent days the stained bait in the centre of the circle was replenished, excreta removed from the peripheral dishes, and the oats consumed by the rodents replaced.

Because of their shape these areas have been termed »circle areas« in the rest of this study.

Six such areas were marked out. To ascertain whether differences in penetration occur depending on the habitat, three of these areas were marked out in phytosociologically uniform habitats, namely: in *Carici elongatae-Alnetum, Pino-Quercetum, Pineto-Vaccinietum uliginosi,* and the three others in mixed habitats.

By mixed habitats is mean an area occupied by two phytosociological associations. Two of the areas were marked out in a space occupied by *Carici elongatae-Alnetum* and *Tilio-Carpinetum,* and the third by *Carici elongatae-Alnetum* and *Pino-Quercetum.* Areas of this type were in operation from September to the end of November 1968 near the Field Station at Dziekanów Leśny.

III. RESULTS

1. Number of Individuals Captured

A total number of 217 individuals of *A. flavicollis* were caught in the cross trappings, 33 of them with bait; 314 individuals of *C. glareolus,* 55 with bait; 167 individuals of *A. agrarius,* 39 with bait.

2. General Description of the Captured Animals

In order to ascertain whether individuals from populations of *A. flavicollis, A. agrarius* and *C. glareolus* exhibit food preferences in relation to the bait used in the experiment, comparison was made of body weight and sex ratios in the group of animals in which bait was found and in the group without bait. There were no statistically significant differences in the average body weight of individuals in which bait was found among the three species examined ($0.7 > P > 0.6$ for *A. flavicollis*, $0.9 > P > 0.8$ for *C. glareolus*, $0.4 > P > 0.3$ for *A. agrarius*) (Table 1).

Comparison of sex ratio within each species shows that individuals in which bait was found and those without bait are characterized by a similar distribution of the number of males and females (Table 2). No statistically significant differences were found between the percentage of males in the groups of animals with and without bait ($0.2 > P > 0.1$ for *A. flavicollis*, $0.3 > P > 0.2$ for *C. glareolus*, $0.1 > P > 0.05$ for *A. agrarius*).

Table 1.

Body weight of individuals caught in cross trappings.

Species	Categories of individuals	
	Containing bait	Without bait
A. flavicollis	23.3	24.1
C. glareolus	18.2	18.1
A. agrarius	17.9	18.8

Table 2.

Sex ratio of individuals caught in cross trappins.
Actual numbers of individuals caught and per cent of males (in parentheses) are given.

Species	Individuals without bait	Individuals with bait
A. flavicollis	184 (54.3)	33 (42.4)
C. glareolus	256 (49.2)	55 (41.8)
A. agrarius	128 (61.7)	38 (71.9)

The above results show that animals in which bait was found can be treated as a group representative of the whole analysed population. This applies to all three species studied.

3. Occurrence of Fuchsin and Yarn in Individuals Caught in Cross Trappings

3.1. Percentage of individuals with stained bait

The percentage of individuals with stained bait (variants A and B analysed jointly) was respectively 23.3 for *A. agrarius*, 17.6 for *C. glareolus* and 15.2 for *A. flavicollis*.

No statistically significant differences were found between the percentage of individuals with stained bait in variants A and B for the species *A. flavicollis* and *A. agrarius* ($0.5 > P > 0.4$ and $0.7 > P > 0.6$). There was a statistically significant difference between variants A and B in

Table 3.

Percentage of individuals with coloured bait (yarn + fuchsin).

Variant	Categories of individuals	*A. flavicollis*	*C. glareolus*	*A. agrarius*
A+B	Total	217	314	167
	With bait	33	55	39
	% with bait	15.2	17.6	23.3
A	Total	122	160	47
	With bait	17	36	12
	% with bait	14	24.3	25.5
B	Total	95	154	120
	With bait	16	16	27
	% with bait	16.8	10.4	22.5

the case of *C. glareolus* ($P < 0.001$) (Table 3). It may be that this difference is due to the shorter time for which the bait was retained in the alimentary tract.

3.2. Comparison of yarn with fuchsin

As the bait used in studies made up to date was yarn only (Hološova, 1968) or oats stained with basic fuchsin (Adamczyk & Ryszkowski, 1968) it was decided to investigate whether these baits can be used as alternatives. For this purpose comparison was made of the percentage of individuals with yarn bait with the percentage of individuals containing fuchsin, in order to establish whether one of these baits occurs in these animals to a far greater extent than the other.

Differences in percentages between individuals in which yarn bait was found and individuals in which traces of fuchsin were found are not statistically significant ($0.4 > P > 0.3$ for *A. flavicollis*, $0.4 > P > 0.3$ for *C. glareolus*, $02 > P > 0.1$ for *A. agrarius*), which indicates that neither of the baits is preferred (Table 4). It is, however, known, that yarn remains a shorter time in the alimentary tract than fuchsin and on this account comparison was also made of the percentage of individuals with fuchsin and of those with yarn in variant A (removal trapping immediately after pre-baiting) and in variant B (removal trapping dalayed by one day in relation to the pre-baiting period). This type of comparison permits determining whether the ratio of individuals with yarn to individuals with fuchsin was similar in these two variants. Unfortunately

Table 4.

Percentage of individuals with coloured bait (yarn or fuchsin).

Species	Categories of individuals	Yarn	Fuchsin
A. flavicollis	Total	124	93
	With bait	17	16
	% with bait	13.7	17.2
C. glareolus	Total	72	242
	With bait	11	44
	% with bait	15.3	18.2
A. agrarius	Total	31	136
	With bait	10	29
	% with bait	32.3	21.3

Table 5.

Percentage of individuals with yarn and percentage of individuals with fuchsin (data for three species jointly).

Variant	Categories of individuals	Yarn	Fuchsin
A	Total	131	198
	Jointly with bait	29	39
	% of individuals with bait	22.1	20.0
B	Total	96	273
	Jointly with bait	9	50
	% of individuals with bait	9.4	18.3

in view of the small amount of data available it was necessary to consider these three species jointly. A non-significant difference was found for variant A ($0.6 > P > 0.5$) and significant difference for variant B ($0.01 > P > 0.001$). This difference is probably due to the shorter period of retention of yarn in the alimentary tract (Table 5).

4. Analysis of Trappability

The average likelihood of capture can be calculated from the formula suggested by Janion, Ryszkowski & Wierzbowska (1968):

$$E_1 k_{(x)} = \frac{q}{p} - \frac{k \cdot q^k}{1 - q^k}$$

where: $E_1 k_{(x)}$ — mean time required to catch an individual,
p — likelihood of capture,
k — number of days of removal trapping,
$1 - p = q$

The tables given in the study by the above-mentioned authors were used for these calculations.

In order to discover whether differences in trappability occur it was decided to compare:

a) likelihood of catching individuals containing stained bait, either yarn or fuchsin, with likelihood of catching individuals in which this bait was not found;

Table 6.

Likelihood of capture of individuals with and without bait.

Species	Individuals with bait		Individuals without bait	
	yarn	fuchsin	yarn	fuchsin
A. flavicollis	0.84	0.80	0.60	0.62
C. glareolus	0.73	0.57	0.61	0.66
A. agrarius	0.91	0.77	0.55	0.60

b) likelihood of catching individuals in which yarn was found with likelihood of catching individuals containing fuchsin;

c) likelihood of catching individuals in which bait was not found but which were caught in trapping series in which yarn was used as bait, with likelihood of catching individuals in which no bait was found, but which were caught in trappings when the bait used was fuchsin.

Analysis made in this way permitted on the one hand grasping of differences in the trappability of individuals with and without bait, and on the other hand of defining the degree of differentiation of the populations.

Individuals containing yarn are characterized by a greater likelihood of capture than individuals not containing stained bait. The trappability of individuals containing traces of fuchsin in the alimentary tract is greater (*A. agrarius*) or similar (*A. flavicollis* and *C. glareolus*) to the trappability of individuals not containing stained bait.

Among individuals in which stained bait was discovered the individuals containing yarn are more likely to be caught than those with fuchsin. This high degree of likelihood of catching individuals with yarn appears to be connected with under-estimation of the number of animals on the second and third day of removal trapping (see discussion).

Differences in likelihood of capture between series containing yarn and series with fuchsin do not appear to be significant in the case of individuals in which coloured bait was not found (Table 6).

5. Analysis of Range of Penetration

The mean distance at which individuals were caught from the bait line was respectively for *C. glareolus*, *A. flavicollis*, *A. agrarius* in variant A (removal trapping immediately after pre-baiting) 38, 69 and 34 m and

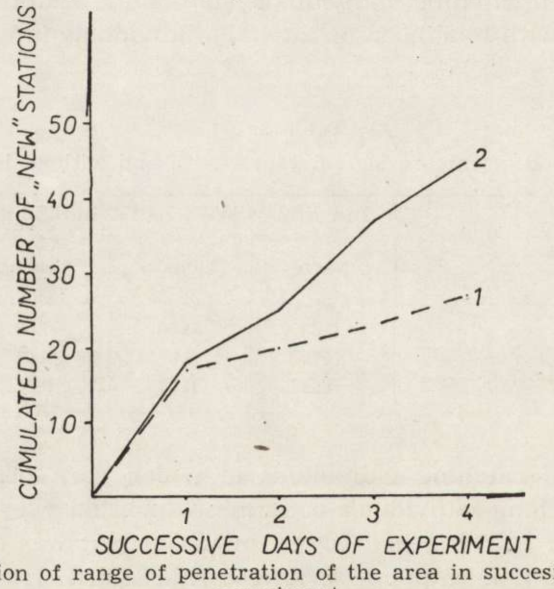

Fig. 1. Extension of range of penetration of the area in succesive days of the experiment.
1 — mixed habitats; 2 — uniform habitats.

in variant B (removal trapping delayed by one day) 60, 83 and 56 m. It was found that at the 5% level of significance the differences between the various species are not statistically significant when the two variants are compared. Nevertheless in variant B the mean distances are greater than in variant A. This probably indicates that a larger part of the range is revealed as early as the first day of the experiment. On the following day the range of penetration is only slightly extended.

6. Evaluation of the Character of Penetration Area

Investigations made in three phytosociologically homogeneous associations (*Carici elongatae-Alnetum, Pino-Quercetum, Pineto-Vaccinietum uliginosi*) and in three mixed associations (*Carici elongatae-Alnetum* and *Tilio-Carpinetum, Carici elongatae-Alnetum* and *Pino-Quercetum, Carici elongatae-Alnetum* and *Tilio-Carpinetum)* would appear to show that

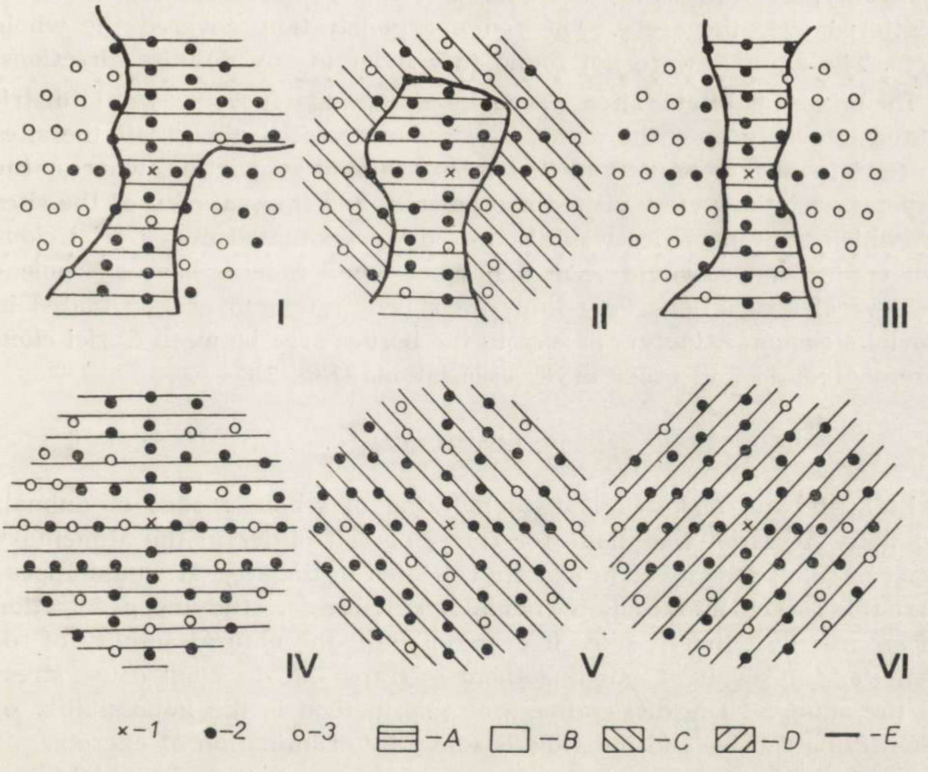

Fig. 2. Penetration of area by forest rodents in different habitats.
I, II, III — mixed habitats; IV, V, VI — homogeneous habitats; 1 — site on which coloured bait was laid; 2 — sites on which coloured bait was discovered; 3 — sites on which coloured bait was discovered; A — *Carici elongate-Alnetum*; B — *Tilio Carpinetum*; C — *Pino-Quercetum*; D — *Pineto-Vaccinietum uliginosi*; E — boundary of habitats.

there is a different type of penetration of the area by rodents in homogeneous and mixed habitats. Fig. 1 illustrates the changes in number of new sites visited by rodents on successive days of the experiments. On the first day the number of sites on which the presence of rodents was found was similar in both types of area. All sites on which the presence of rodents were discovered were treated as new ones.

One the second day seven new sites were found on which the presence of mice had not hitherto been discovered. Only three new sites were found in mixed habitats. On the third and fourth day these differences in the number of new sites were maintained, with 12 and 8 new sites in homogeneous habitats, and 3 and 4 in mixed habitats.

In study areas in homogeneous habitats, that is, in *Carici elongatae-Alnetum* only, in *Pineto-Vaccinietum uliginosi* only and in *Pino-Querce-tum* only, sites on which the excreta collected contained fuchsin were scattered over the areas. The rodents' penetration covered the whole area. The animals were not found to wander in any definite directions.

In mixed habitats sites excreta containing fuchsin were distributed unevenly over the areas. The rodents visited almost all the sites in *Carici elongatae-Alnetum*, that is, in a humid association, whereas the dryer associations were visited sporadically and the majority of the sites on which their presence was discovered were situated near *Carici elongatae-Alnetum*. It would seem that when small rodents have a »choice« of several associations they limit their penetration to areas situated in *Carici elongatae-Alnetum* or else to the border area between *Carici elongatae-Alnetum* and other dryer associations (Fig. 2).

IV. DISCUSSION

Stained baits make immediate marking of whole groups of animals possible. A search was made for traces of bait either in the alimentary tract of small rodents or in excreta collected in the area. It would appear that this second method is particularly suitable for studying penetration of an area by animals, since it does not limit the natural activity of rodents as the result of catching them in traps and does not cause stress in the animals. The disadvantage of this method is the impossibility of identifying species and individuals solely by examination of excreta.

In view of the absence of differences in respect of body weight and sex ratio between individuals with and without bait which were caught in »cross trappings« there would appear to be no objection to treating animals in which bait was found as a group fully represented for each of the species examined.

Within the species differences in the percentage of individuals containing bait connected with the introduction of a one-day interval after the pre-baiting period for *A. flavicollis* and *A. agrarius* are not significant. The marked predominance of individuals containing bait in variant A and small number of animals in variant B in the case of *C. glareolus* is very difficult to interpret. It may be that bait is retained for a shorter time in the alimentary tract of this species.

Both yarn and fuchsin are thus equally satisfactory baits for the purpose of marking small rodents. Attention must, however, be drawn to the fact that yarn remains in the alimentary tract up to the fifth day and consequently the possibility of using it as bait is limited to short-term experiments. This five-day period of retention of bait in the alimentary tract may in fact provide the explanation of the difference between the percentage of individuals with fuchsin and those with yarn. As removal trapping in this variant was delayed by one day in relation to pre-baiting the total period of the experiment for this variant was seven days (three days of pre-baiting plus one day interval plus three days of trapping). Thus in animals which consumed bait during the first day of prebaiting it was possible to establish with complete certainty that traces of the bait were present in their alimentary tract, if such individuals were caught on the first day of trapping. Discovery of yarn in animals caught on the second and third day of removal trapping is less certain, despite the fact that the bait had been eaten. On this account it is impossible to rule out the fact that the number of animals containing yarn bait is slightly underestimated for the second, and particularly the third day of removal trapping in variant B. There are no doubts of this kind when fuchsin bait is used, as this can be discovered in the alimentary tract up to the eighth day inclusively.

If we accept that the number of animals containing yarn bait is underestimated during the second and third day, this would explain the greater likelihood of catching rodents containing yarn than of rodents in which traces of fuchsin were found. The decrease in the number of animals caught on successive days of removal trapping is greater for individuals with yarn than for those with fuchsin.

The studies made on the »cross areas« were not intended to determine the absolute range of penetration, and in fact the use of the methods employed in this study, in view of the particular intensification of migration during the summer and autumn period found by Ilenko & Zubčaninova (1963), that is, during the period the present studies were made, would make assessment of this kind impossible. On the other hand it is known from the studies by Ilenko & Zubčaninova (1963) and Nikitina (1961) that the maximum distances over which small rodents wander greatly exceed the recording capacity of the areas used in this study. The study made by Adamczyk & Ryszkowski (1968) shows that the values obtained for range of penetration depend on the size of the cross areas themselves, and even when using the cross arrangement, in which length of rows may be as much as 300 m, the full range of penetration is not obtained.

In the present study attention has been concentrated on examination of differences in daily ranges of penetration. The differences in mean distances for the species examined in variants A and B were not found to be significant, except that in variant B the mean distances from the bait line were greater than in variant A. This points to the fact that a considerable part of the range of penetration is revealed on the first day, and that range is only slightly extended on subsequent days.

Data collected from the circle areas indicates that the area is evenly penetrated in phytosociologically homogeneous habitats, but not in mixed habitats. In the latter the rodents move about either within the bounds of humid associations or in the area of contact with other associations. At the same time the number of new sites in which the presence of marked rodents was found increases with the passage of time in homogeneous habitats, whereas in mixed habitats this tendency to extend the range of penetration is not strongly marked.

It would appear that hitherto sufficient importance has not been attached to the reciprocal connections between the character of the habitat and the way and range of penetration of the area by small rodents. There are few studies, apart from Olszewski's (1968), concerned with the directions in which animals move about within the habitats in which they live or with the influence of the habitat itself on the shape of this range.

In view of the differences found in this study in the character of penetration of an area, depending on the habitat, it becomes necessary when investigating individual ranges, migrations and density of small rodents, to examine the ways in which the animals penetrate the area in different habitats.

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PENETRACJA TERENU PRZEZ DROBNE GRYZONIE LEŚNE

Streszczenie

Badając dobowe zasięgi penetracji terenu stosowano następujące powierzchnie odłowne. Dwie linie z przynętami o długości 120 m każda przecięto prostopadłymi do nich rzędami pułapek zabijających o długości 150 metrów. W każdym rzędzie ustawiono po 2 pułapki co 15 metrów. Okres przynęcania trwał 3 dni. Jako przynętę stosowano owies barwiony fuksyną zasadową która utrzymuje się w przewodzie pokarmowym do ósmego dnia od momentu spożycia lub włóczkę zmieszaną z margaryną i mąką którą można wykryć do piątego dnia od momentu podania. Stosowano dwa warianty wyłowu: *A* — wyłów bezpośredni po przynęcaniu, *B* — wyłów opóźniony o jedną dobę w porównaniu z wariantem *A*.

Brak istotnych statystycznie różnic między znakowanymi i nie znakowanymi zwierzętami pozwala traktować zwierzęta, u których wykryto barwną przynętę jako grupę reprezentatywną dla danej populacji. Wydaje się, że żadna z używanych przynęt nie jest preferowana. Wiadomo jednak, że włóczka utrzymuje się krócej w przewodzie pokarmowym niż fuksyna i możliwość jej stosowania ogranicza się do eksperymentów krótkoterminowych.

Średnia odległość złowienia osobników od linii przynęcania wynosi dla gatunków *A. flavicollis*, *A. agrarius* i *C. glareolus* w wariancie *A* odpowiednio: 69, 34, 38 metrów a w wariancie *B*: 83, 56, 60 metrów. Różnice między wariantem *A* i *B* a więc dobowe różnice w zasięgu penetracji nie są istotne statystycznie, mimo że średnie odległości w wariancie *B* są większe. Wskazuje to na fakt ujawniania większej części rewiru już pierwszego dnia.

Stwierdzono, że w kale można wykryć ślady barwnej przynęty do czwartego dnia od momentu jej podania. Wykorzystując ten fakt zbadano przyżyciowo penetrację terenu przez drobne gryzonie w różnych środowiskach. Centralny punkt w którym

podawano barwną przynętę był otoczony kołami o promieniach kolejno: 15, 30, 45, 60, 75 metrów na których rozmieszczono punkty przynęcania. Liczba tych punktów była stała na jednostkę obwodu koła. W tych wyznaczonych punktach na szalkach Petriego wyłożono niezabarwiony owies. Zwierzęta wyjadając przynętę zostawiały kał, który zbierano i oglądano pod binokularem szukając śladów przynęty.

Trzy powierzchnie tego typu założono w środowiskach jednorodnych a mianowicie: w olsie (*Carici elongatae-Alnetum*), w borze mieszanym (*Pino-Quercetum*), i w borze bagiennym (*Pineto-Vaccinietum uliginosi*), trzy pozostałe w środowiskach mieszanych. Dwie z tych trzech powierzchni założono na terenie zajętym przez ols i grąd (*Carici elongatae-Alnetum* i *Tilio-Carpinetum*) trzecią na obszarze olsu i boru mieszanego (*Carici elongatae-Alnetum* i *Pino-Quercetum*). Otrzymane wyniki wskazują na równomierną penetrację terenu w środowiskach jednorodnych i zróżnicowanie penetracji w środowiskach mieszanych. W obrębie tych ostatnich gryzonie poruszają się po zespołach wilgotnych i po styku zespołu. Jednocześnie w środowiskach jednorodnych w kolejnych dniach eksperymentu obserwuje się rozszerzenie zasięgu penetracji podczas gdy w środowiskach mieszanych to rozszerzenie w kolejnych dniach jest niewielkie.