A C T A T H E R I O L O G I C A

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Estimation of Rodent Numbers by Means of Prebaiting and Intensive Removal [1])

[With 6 Tables and 6 Figs.]

The aim of investigations was to elaborate an accurate and labour-saving method of estimating the numbers of small rodents. Each of 8 two-week series of captures consisted of: (1) a seven-day period of prebaiting the rodents on an area of 5.76 ha, over which a grid of 256 points with bait was arranged and (2) a seven-day period of intensive removal of rodents by means of snap-traps, two of which were set on each point. No correlation was found between the number of baits consumed and the number of rodents on a given point. From 78—100 per cent of all rodents captured over a seven-day period were removed by the fifth day. Differences were found in the rate of removal of different species of rodents and of marked and unmarked individuals of the same species. Estimate of population numbers was made by the regression method, obtaining satisfactory results in 17 cases out of 18 possibles. This method is recommended, but it is suggested that the prebaiting and removal periods should be shortened to five days each.

I. INTRODUCTION

The aim of the investigations was to elaborate a method which would be both exact and economical (not too laborius) for estimating the numbers of small rodents. The studies were the result of co-operation in research work for the International Biological Programme in Poland, carried out by the Department of Animal Genetics and Organic Evolution, Jagiellonian University in Cracow, the Institute of Ecology, Polish Academy of Sciences, Warsaw and the Mammals Research Institute, Polish Academy of Sciences, Białowieża.

Members of the scientific staff of the Mammals Research Institute, J. Olszewski and Z. Pucek, and technical workers W. Bajko, S. Buszko, L. Siemieniuk and M. Szuma carried out captures in the Białowieża National Park (B.N.P.) $\varphi = 52°42'N$, $\lambda = 23°51'E$. The capture area was covered by a wood of the

[1]) This study was carried out under the Rodent Project of the International Biological Programme in Poland.

Querco-Carpinetum medioeuropeum association. Three series of captures were made: autumn 1964 (October 14—29) within section 343 of B.N.P.; spring 1965 (May 3—17) in the same place as the preceding captures; autumn 1965 (October 13—27) within section 345 of B.N.P.

Members of the staff of the Department of Animals Genetics and Organic Evolution, A. Drożdż, A. Górecki and W. Grodziński carried out investigations in the Jamki gorge situated in the Ojców National Park ($\varphi = 50°13'$N, $\lambda = 19°40'$E). The capture area was situated in a beech wood of the *Fagetum carpaticum* association, which was represented by a poorer variant of this association, with *Asperula odorata* and *Majenthemum bifolium*. Captures were made twice in 1965: in spring (April 13—28) and autumn (September 27 — October 11).

Members of the staff of the Institute of Ecology, K. Adamczyk, H. Chełkowska, M. Janion and L. Ryszkowski — carried out captures in the Kampinos National Park in the area around Dziekanów Leśny ($\varphi = 52°20'$N, $\lambda = 20°50'$E). Two series of captures in spring (April 23 — May 6) and autumn 1965 (September 14—28) were made in an area covered by forest consisting of the following associations: *Pino-Quercetum, Vaccinio myrtilli-Pinetum subass. molinietosum, Tilio-Carpinetum, Carici elongatae-Alnetum*. A third series of captures (Sept. 2—15, 1965) were made in a meadow surrounded by wooded land, forming a complex of the following associations: *Glyceriaetum maximae, Caricetum elatae, Carici (Canescentis)-Agrostetum, Stellarie-Deschampsietum.*

The material was worked out by all authors, but the manuscript was prepared by one of us (L. R.).

II. METHODS

A full series (cycle) of captures termed "Standard-Minimum" [2]) lasted two weeks, the rodents being prebaited in the first week, followed by their intensive removal in the second. Captures were made within a quadrangular section, the sides of which measured 240 m (area — 5.76 ha), divided into 16 rows and 16 lines perpendicular to them, with 15 m × 15 m spacing. This "grid" connected 256 points at which the lines intersect the rows. Each of these points was permanently marked in the area, and a small piece of cardboard measuring 8 × 8 cm was placed on each and secured by means of a special pin.

During the prebaiting week scores of oat grains were put on to the pieces of cardboard. Bait consumption was inspected every morning. When inspection was made on the seventh day the oats were removed from the cardboards and two snap-traps were set by each of them. A total of 512 traps were thus set in the area (256 × 2). A cotton wick fried in oil with slightly browned wheat flour was used as bait in the traps. Capture of rodents was continued for the following seven days, during which time the traps were inspected twice daily, in the morning and evening.

The captures made in the autumn of 1964 at Białowieża differed from the above standard method, in that the experimental area was 6.076 ha and the traps were arranged in 15 rows and 18 lines, also spaced 15 × 15 m. Three live-traps were placed on each of the 270 points of intersection of rows and lines. For the first two days captures of rodents were made without prebaiting, the animals being marked and released on the place of capture. The rodents were next prebaited for six days

[2]) The authors are very grateful to Dr. R. Andrzejewski (Warszawa) for elaborating the final instructions for "Standard-Minimum" captures.

with oats placed in open traps, and the seventh day capture, marking and release were again carried out. In the final stage of the experiment, lasting 9 days — intensive removal of rodents took place, first inspecting the traps every 4 hours, and later every 8 hours. As captures with release and prebaiting of the rodents were taken as corresponding to the prebaiting period for rodents in the standard method, all the results of captures obtained were treated as comparable to each other.

III. RESULTS

A total of 953 small rodents were caught in the Białowieża National Park (Białowieża) during the three series of captures made. The two species predominating numerically were *Clethrionomys glareolus* (Schreber, 1780) and *Apodemus flavicollis* (Melchior, 1834), which formed 98.2 per cent of all the rodents caught. The remaining 1.8 percent was formed by individuals of *Pitymys subterraneus* (de Sélys-Longschamps, 1835).

In the Ojców National Park (Ojców) a total of 343 small rodents were caught in spring and autumn. The dominating species were *C. glareolus* and *A. flavicollis*, which formed 98 per cent of all the rodents caught. The remaining 2 percent consisted of individuals of *Apodemus agrarius* (Pallas, 1771), *Mus musculus* (Linnaeus, 1758), *P. subterraneus* and *Muscardinus avellanarius* (Linnaeus, 1758).

In all 96 small rodents were caught in the Kampinos National Park (Dziekanów) during the two series of captures made in the forest. The dominating species were *C. glareolus*, *A. agrarius* and *A. flavicollis*, which formed almost 100 per cent of all rodents caught. Apart from these species only one individual of *Microtus oeconomus* (Pallas, 1776) was caught. In one series of captures made in the meadow 85 rodents were caught, representing only the two dominating species, *A. agrarius* and *Micromys minutus* (Pallas, 1778).

1. Bait Consumption

Calculation was made of the percentage of points with consumed bait from the total number of points during the seven consecutive days of prebaiting (Fig. 1, A, B, C). Comparison of the maximum percentages of points with consumed bait and the total number of rodents caught on each station revealed a lack of correlation between the two variables.

This conclusion is particularly strongly confirmed by the results of captures made at Ojców, where 203 rodents were caught in spring and the maximum percentage of points with consumed bait was 74 per cent, whereas 140 individuals were caught in autumn with maximum number of points with consumed bait of 100 per cent.

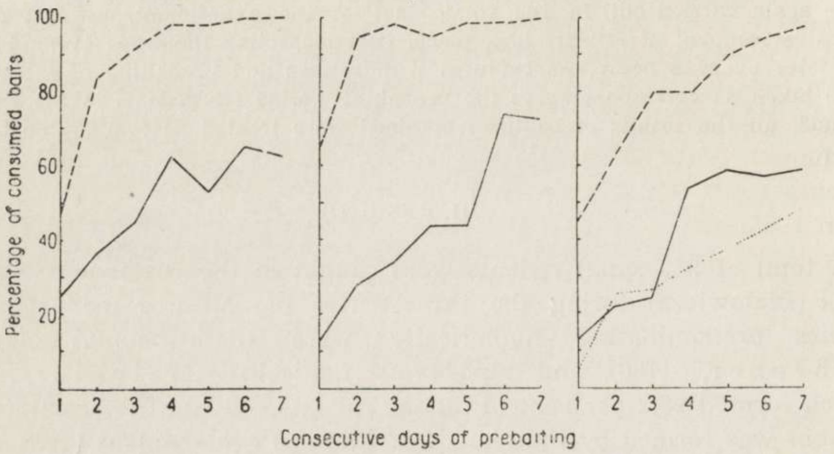

Fig. 1. Consumption of bait in 7-day prebaiting period.
——— spring 1965, – – – – autumn 1965, ... autumn 1965, meadow.

Table 1.

Correlation between number of points with consumed bait and number of rodents caught. (Białowieża, 1965)

(Figures in the table indicate the number of observations made).

No. of captures	SPRING								AUTUMN				
7												1	
6	1		r = 0.44						r = 0.06			1	2
5								3				10	3
4					3		4	6				23	8
3	1		2	1	4	9	6	8		2	4	34	12
2	8	4	8	5	9	12	10	6		2	6	49	30
1	33	30	23	9	17	14	10	10	3	1	3	36	16
No. of baits eaten out	1	2	3	4	5	6	7	8	1	2	3	4	5

Similarly, no correlation was found between the total number of rodents caught and the number of points with consumed bait on the first day of prebaiting the population.

Analysis was then made to ascertain whether is it possible to draw conclusion as to the number of rodents visiting the place from the frequency with which selected baits were consumed. For this purpose calculation was made, using material from Białowieża (spring and autumn 1965), of the correlation between the number of days on which bait was consumed from a defined point, and the number of rodents caught on this point. In spring the coefficient was $r = 0.44$, and in autumn $r = 0.06$ (Tab. 1). In the first case the maximum percentage of points with consumed bait was 65 per cent and in the second 100 per cent. The

Table 2.

Cumulated percentage of all rodents caught on successive days.

Locality	Season	Days of removal									Number of rodents caught
		1	2	3	4	5	6	7	8	9	
Białowieża	Autumn, 1964	28	48	64	72	78	88	92	96	100	373
Białowieża	Spring, 1965	65	78	87	96	100	100	100	—	—	185
Białowieża	Autumn, 1965	61	85	92	94	96	100	100	—	—	395
Ojców	Spring, 1965	49	63	68	79	88	94	100	—	—	203
Ojców	Autumn, 1965	74	83	85	91	97	100	100	—	—	140
Dziekanów	Spring, 1965	35	70	98	98	96	100	100	—	—	17
Dziekanów	Autumn, 1965	39	55	71	88	93	95	100	—	—	98
Dziekanów-meadow	Autumn, 1965	30	55	76	81	90	98	100	—	—	85
Average		47.6	67.1	80.1	87.3	92.5	96.8	99.0	—	—	1495

density of the baited points was therefore too small in the autumn in relation to population numbers, as almost all the baited points were cleared during the seven consecutive days.

The material presented above shows that the relation between the numbers of rodents and number of points with consumed bait is very complicated. Therefore it is not possible to draw conclusions as to the numbers of rodents simply from the number of points on which bait was eaten.

2. Rate of Removal of Rodents

2. 1. R a t e o f r e m o v a l o f a l l r o d e n t s. Taking the total number of rodents caught over a period of seven days as 100 per cent (exceptionally 9 days of captures at Białowieża in the autumn 1964) calculation was made of the cumulated percentages of individuals caught in successive days (Table 2). From 78 per cent to 100 per cent of all the

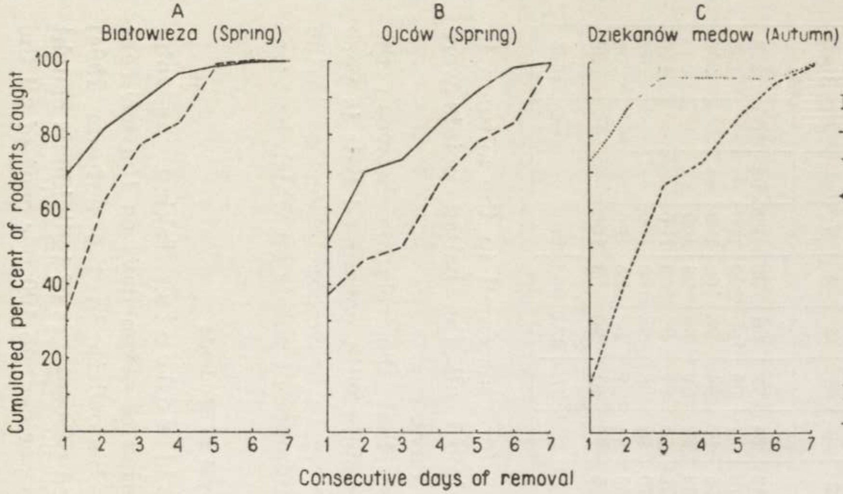

Fig. 2. Removal rate of different species of rodents.
——— *C. glareolus*, — — — *A. flavicollis*,
- - - - *M. minutus*, ... *A. agrarius*.

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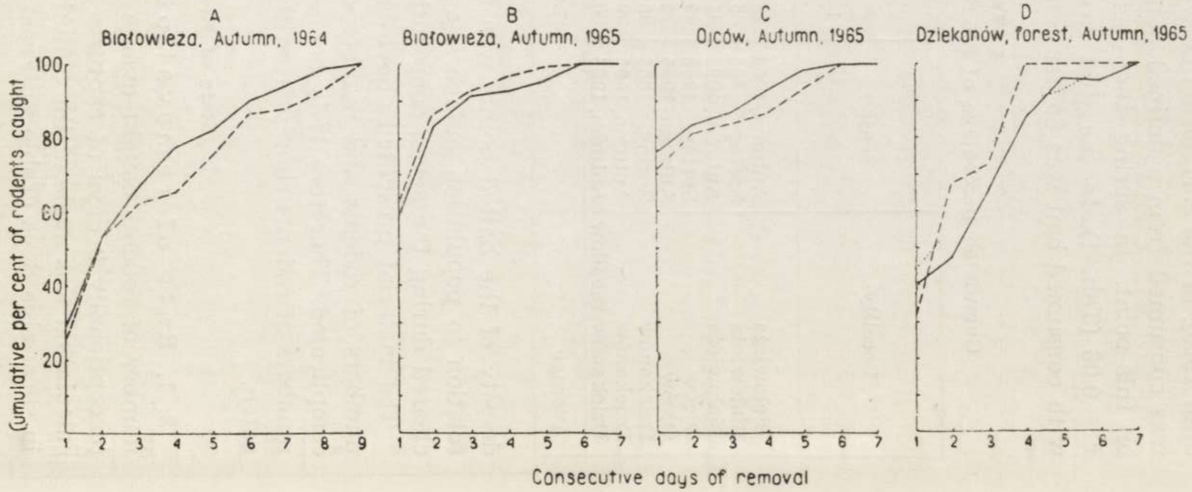

Fig. 3. Removal rate of different species of rodents.
——— *C. glareolus*, — — — *A. flavicollis*,
.... *A. agrarius*.

rodents had been caught by the fifth day in different places. On an average 92.5 per cent of the rodents had been caught by the fifth day. The results obtained from captures show that, practically speaking in the majority of places, almost all the rodents had been caught by the 5th day.

2. 2. Rate of removal of different species. Calculation was made in the same way of cumulated percentages of captured individuals on consecutive days for the dominating species (Fig. 2 A, B, C, Fig. 3 A, B, C, D). Results from captures made in spring at Dziekanów were omitted from the analysis, since the number of rodents was too small to enable calculations to be made. In autumn the rate of removal of the dominating species is similar on all the forest stations — regardless of whether two species (Ojców, Białowieża — Fig. 3 A, B, C) or three species (Dziekanów — Fig. 3 D) dominated.

Both at Białowieża and Ojców removal of *C. glareolus* was found to be quicker in spring than removal of *A. flavicollis* (Fig. 2 A, B). Similarly during captures in the meadow at Dziekanów *A. agrarius* was removed more quickly than *M. minutus* (Fig. 2 C). In all three cases differences between cumulated percentages of individuals caught up to the second day of captures for comparable species are statistically significant ($P=0.01$). Both at Ojców and Białowieża the more numerous dominating species was removed more quickly, while at Dziekanów the dominating species, with smaller numbers, was removed more quickly.

2. 2. Rate of removal of marked and unmarked individuals. The experiment made in the autumn of 1964 at Białowieża permitted of analysing separately the rate of removal of marked and unmarked individuals of different species of rodents. Those individuals were taken as marked which had been marked during the first phase of the experiment, before prebaiting, and individuals marked during the two final inspections before removal. Calculation was made of the cumulated percentages of marked and unmarked rodents caught on consecutive days of removal, taking the number of captured individuals of a given category over the whole period of captures as 100 per cent (Fig. 4 A, B).

Differences in the rate of removal of marked and unmarked individuals are statistically significant ($P = 0.01$) up to the fifth day of captures for *A. flavicollis* and up to the third day for *C. glareolus*.

3. Estimation of Small Rodent Numbers.

The method permitting of estimating the number of small rodents, proposed by De Lury (1947) and Hayne (1949), consists of comparing the number of individuals caught each day, plotted against cumulative numbers of individuals previously caught. Daily captures were set out on the axis of ordinates, and the cumulative number of animals previously caught on the axis of abscissae (Fig. 5). The points on the

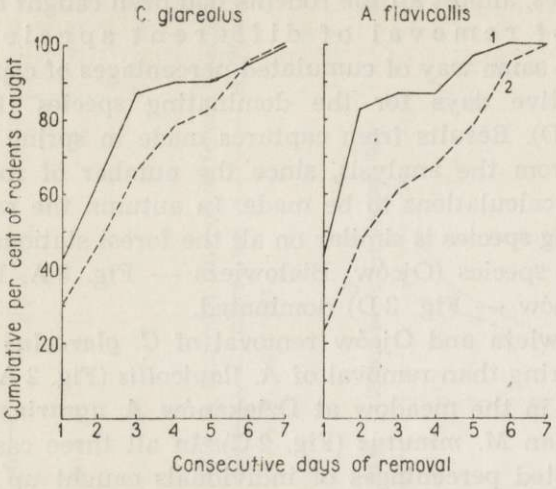

Fig. 4. Removal rate of marked (1 ———) and unmarked (2 — — —) individuals (Białowieża, autumn 1964).

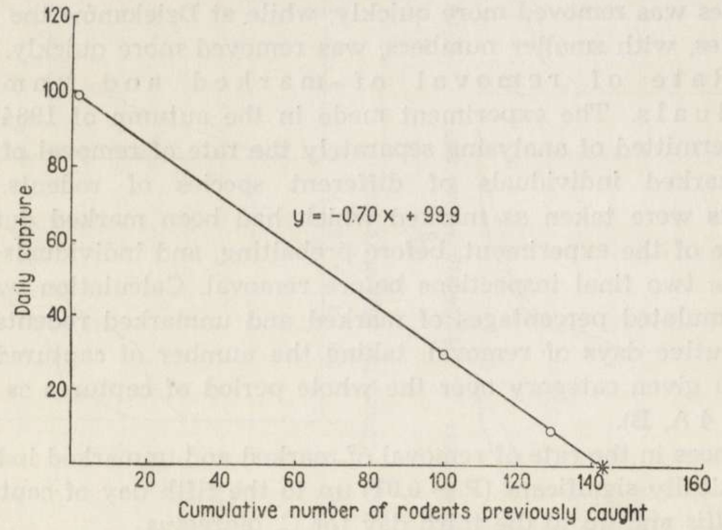

Fig. 5. Linear regression for first three days of removal at Ojców (spring 1965). ○ — empirical data. * — point of intersection of linear regression with axis of abscissae, giving an estimate of numbers of rodents.

diagram obtained in this way give the number of rodents caught after removal of a definite number of animals from the population. By calculating the equation of linear regression $y = -ax + b$ it is possible to calculate the intersection point of the straight line $y = -ax + b$ with the axis of abscissae, which point gives the estimated population size for the study area.

This method does not permit of assessing abundance in cases in which the number of individuals caught does not decrease in successive captures. In cases in which there was an increase in the number of rodents caught during the final days of capture the equation of regression was calculated only for the first days on which there was a tendency for the number of individuals captured to decrease. The choice of number of days for which regression was calculated is then to a certain extent subjective and arbitrary. This must be taken into consideration when comparing results obtained by different research workers. The tables giving the calculated numbers of rodents by means of regression also include the number of days for which regression was calculated (Table 3).

Table 3.
Estimation of the number of all rodents.

Locality	Season	Regression calculated for days:	Number estimated from regression		Total number caught		$A = \frac{\lvert N_2 - N_1 \rvert \times 100}{N_2}$
			Whole area (N_1)	Per 1 ha	Whole area (N_2)	Per 1 ha	
Białowieża	Autumn, 1964	5	355	58.4	373	61.4	4.8
Białowieża	Spring, 1965	6	180	31.2	185	32.1	2.7
Białowieża	Autumn, 1965	4	385	66.8	395	68.6	2.5
Ojców	Spring, 1965	3	141	24.5	203	35.2	30.5
Ojców	Autumn, 1965	3	119	20.6	140	24.3	15.0
Dziekanów	Spring, 1965	—	—	—	17	2.9	—
Dziekanów	Autumn, 1965	6	82	14.2	79	13.7	3.8
Dziekanów-meadow	Autumn, 1965	4	74	12.8	85	14.7	12.9
Average							10.3

3. 1. Estimation of the numbers of all rodents. The number estimated from equation of regression for the whole capture area was converted per hectare (Table 3). Population numbers estimated in this way (N_1) were compared with the number of rodents removed over the whole capture period (N_2), by means of index $A = \lvert N_2 - N_1 \rvert \times 100 : N_2$. The absolute value of the difference of these two estimates was expressed in percentages calculated in relation to the total number of rodents caught over the whole capture period (Table 3). The mean value of index A is 10.3 per cent. In seven cases out of eight estimated numbers obtained on the basis of regression were smaller than the total number of rodents removed. In cases in which the number of captured

rodents is small (Dziekanów, spring 1965, only 17 rodents), and no regular tendency to reduction is observed on successive days of removal, there is no possibility of estimating the numbers on the basis of regression. Since 98 per cent of the rodents were caught there by the third day it was assumed that the total number of individuals captured forms the entire number of rodents in the capture area.

Table 4.

Estimation of numbers of dominating species of rodents.

Locality	Season	Species	Regression calculated for days:	Number estimated from regression		Total number caught		$A = \frac{\lvert N_2 - N_1 \rvert \times 100}{N_2}$
				Whole area (N_1)	Per 1 ha	Whole area (N_2)	Per 1 ha	
Białowieża	Autumn, 1964	*C. gl.*	7	250	41.2	241	39.7	3.7
Białowieża	Spring, 1965	*C. gl.*	6	145	25.2	151	26.2	3.9
Białowieża	Autumn, 1965	*C. gl.*	7	280	48.6	272	47.2	2.9
Ojców	Spring, 1965	*C. gl.*	3	113	19.7	148	25.6	23.6
Ojców	Autumn, 1965	*C. gl.*	3	73	12.6	85	14.7	14.1
Dziekanów	Spring, 1965	*C. gl.*	—	—	—	8	1.4	—
Dziekanów	Autumn, 1965	*C. gl.*	5	28	4.8	27	4.7	3.7
Białowieża	Autumn, 1964	*A. fl.*	7	117	19.2	120	19.7	2.5
Białowieża	Spring, 1965	*A. fl.*	5	35	5.2	30	5.2	16.6
Białowieża	Autumn, 1965	*A. fl.*	6	125	21.7	121	21.0	3.3
Ojców	Spring, 1965	*A. fl.*	3	26	4.5	52	9.0	50.0
Ojców	Autumn, 1965	*A. fl.*	3	43	7.5	51	8.8	15.6
Dziekanów	Spring, 1965	*A. fl.*	—	—	—	1	0.2	—
Dziekanów	Autumn, 1965	*A. fl.*	3	18	3.1	19	3.3	5.3
Dziekanów	Spring, 1965	*A. ag.*	—	—	—	7	1.2	—
Dziekanów	Autumn, 1965	*A. ag.*	6	32	5.5	33	5.7	3.0
Dziekanów-meadow	Autumn, 1965	*A. ag.*	3	22	3.8	23	4.0	4.3
Dziekanów-meadow	Autumn, 1965	*M. min.*	—	—	—	62	—	—
Average								10.9

3. 2. Numbers of individuals of different species. The abundance of dominating species estimated on the basis of regression were converted per hectare (Tab. 4). The mean difference between estimates of numbers obtained from regression and the total number of individuals caught over the whole capture period, also calculated by means of index A, was 10.9 per cent for all the species examined (Table 4). For *C. glareolus* the mean value of index A was 8.6 per cent, for *A. flavicollis* — 15.6 per cent and for *A. agrarius* — 3.6 per cent.

Captures of *Micromys minutus* in the meadow at Dziekanów differed completely from the type of removal of the species described above. The number of rodents captured did not decrease up to the third day, thus there was no point in calculating regression. Since individuals of *M. mi-*

nutus continued to be caught up to the last day of captures it is also impossible to assume that the total number of animals caught reflects population numbers (Fig. 6).

4. Trappability of Small Rodents

The realibility of calculations made by means of liner regression depends, *inter alia*, on the correctness of the assumption that probability of capture is the same for all individuals. If this assumption is correct, then the coefficient a of straight line regression $y = -ax + b$ is a measure of the rodent trappability. Coefficient a is the tangent of the positive angle ($180^\circ - \alpha$) formed by the straight line of regression with the axis of abscissae, where α is the angle contained between the straight line of regression and axis of abscissae. The tangent of the angle ($180 - \alpha$)

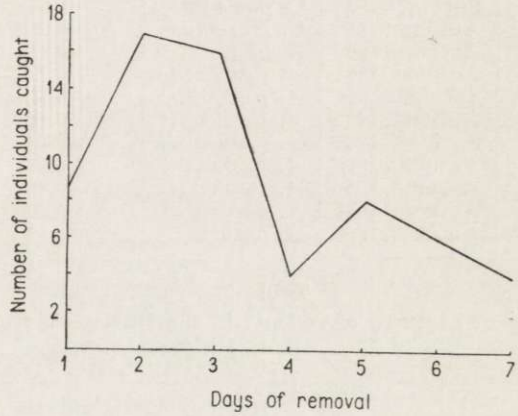

Fig. 6. Capture of *M. minutus* (Dziekanów, meadow).

equals the negative value of the tangent α. In other words it is the relation of the number of individuals caught on a given day to all those present in the area. Coefficient a thus defines the proportion of animals caught in one day to all the animals present at that time in the study area.

The reciprocal of the coefficient a [$C = \frac{1}{a}$] is an estimate of the average time which would separate two consecutive captures of the same individual, if the individuals had been caught in live-traps. Coefficients a in the calculations made always have a negative value (decreasing number of animals captured on successive days), and therefore their absolute (positive) values must be taken for calculations. The average time between consecutive captures for *C. glareolus* would vary from 1.2 days to 4.0 days and for *A. flavicollis* from 1.2 days to 3.5 days in different capture places (Table 5).

5. Topography of Captures of Rodents in the Final Period of Captures

In order to check the correctness of the assumption that rodents caught in the final period of removal are animals entering the study area from the surrounding terrain, the capture area was divided into an external belt containing three rows or lines of traps and into an internal square

Table 5.
Estimated trappability of dominating species of rodents.

Locality	Season	Species	Coefficient a of a regression line $y = -ax + b$	Index of trappability $C = \frac{1}{(a)}$
Białowieża	Autumn, 1964	*C. glareolus*	—0.25	4.0
Białowieża	Spring, 1965	*C. glareolus*	—0.70	1.4
Białowieża	Autumn, 1965	*C. glareolus*	—0.57	1.7
Ojców	Spring, 1965	*C. glareolus*	—0.68	1.4
Ojców	Autumn, 1965	*C. glareolus*	—0.86	1.2
Dziekanów	Autumn, 1965	*C. glareolus*	—0.33	3.0
Białowieża	Autumn, 1964	*A. flavicollis*	—0.28	3.5
Białowieża	Spring, 1965	*A. flavicollis*	—0.29	3.4
Białowieża	Autumn, 1965	*A. flavicollis*	—0.61	1.6
Ojców	Spring, 1965	*A. flavicollis*	—0.76	1.3
Ojców	Autumn, 1965	*A. flavicollis*	—0.86	1.2
Dziekanów	Autumn, 1965	*A. flavicollis*	—0.40	2.5
Dziekanów	Autumn, 1965	*A. agrarius*	—0.39	2.5
Dziekanów-meadow	Autumn, 1965	*A. agrarius*	—0.77	1.3

Table 6.
Topography of captures of rodents in the final period of removal (from 4th to 7th day).

Species	Season	Number of individuals per point:	
		External belt (156 points)	Inner square (100 points)
C. glareolus	Spring	0.23	0.13
C. glareolus	Autumn	0.22	0.11
A. flavicollis	Spring	0.12	0.12
A. flavicollis	Autumn	0.09	0.09
M. minutus	Autumn	0.07	0.09

containing 10 internal rows and lines of traps. The outer belt contained 156, and the internal square 100 points with traps. On account of the small amount of material the spring and autumn data from different places of capture were pooled for each species. Calculation was next made of how many rodents were caught on an average on one point with traps in the outer belt and inner square during the last four days of removal i.e. from 4th to 7th day (Table 6).

A larger number of captures per point in the outer belt, both in spring and autumn, was found in the case of *C. glareolus* only. It may therefore be assumed that some of these rodents caught in the final period of captures immigrated into the capture area from outside. *A. flavicollis* and *M. minutus*, however, were caught uniformly intensively both in the centre and on the edges of the experimental area.

IV. DISCUSSION

Prebaiting of small rodents before their removal was intended to render uniform and accelerate removal. It was desired to ascertain whether there was a relation between the degree to which bait was consumed and the number of rodents. The different degree of attraction of bait to rodents in connection with the food resources of the habitat, climatic conditions and differences in the biology of the species examined has been emphasised by many authors, e.g. Novikov, 1953; Fitch, 1954; Kučeruk *et al.* 1963; Kikkawa, 1964; Southern, 1964; Tanton, 1965, but direct research on estimation of numbers based on the amount of bait consumed is very scanty. Only one paper was found in the literature available to the authors of this study. Panteleev (1959) demonstrated the lack of correlation between the amount of bait eaten and population numbers of *Arvicola terrestris* L. This result is fully confirmed in our material. The amount of bait eaten not only did not reflect the numbers of animals, but does not even represent the direction taken by variations in numbers. For instance at Ojców in the spring of 1965 beech seeds formed on an average 68 per cent and 87 per cent of the stomach contents of *Clethrionomys glareolus* and *A. flavicollis* (Drożdż, 1966). This was connected with the rich yield of beech seeds in the autumn 1964 (about 44 kg of dry mass of seeds per 1 hectare). It may be taken that as the result of the greater attractiveness of beech seeds, despite the larger rodent population in spring than in autumn — the percentage of bait eaten was far smaller in spring than in autumn. Chitty & Kempson (1949) consider that prebaiting rodents before removal renders the trappability of individuals in the population uniform. The difference observed in rate of removal of marked and unmarked individuals (Białowieża, autumn 1964) does not confirm this result. Prebaiting before removal also failed to even up differences in rate of removal of *C. glareolus* and *A. flavicollis* (Białowieża and Ojców — spring captures) or of *A. agrarius* and *M. minutus* (Dziekanów — meadow).

Differences in rate of removal of different species on the same station were found by Calhoun (1959) and Pelikan, Zejda & Holišova (1964). Calhoun explains the phenomenon observed by competition, and Pelikan *et al.* by differences in intensity of migration.

Our material shows that the differences in rate of removal probably do not depend on the numbers of rodents. Both at Białowieża and Ojców this phenomenon occurred in spring only, despite the fact that numbers were smaller at Ojców in the autumn, and larger at Białowieża than in the spring. At Dziekanów in the meadow, the species with smaller numbers was removed more quickly. Estimated trappability of the species cannot assist in explaining this phenomenon. Linear regression was calculated with the omission of the final days of removal in which there was an increase in the number of rodents caught, rejecting in this way the assumption that these individuals had been in the capture area since the start of removal.

Similarly it is unknown whether the differences observed in the rate of removal of marked and unmarked individuals are connected with the greater migratory tendency of the latter, or whether they point to real differences in the trappability of individuals in a population.

If we assume that entering individuals should be caught in greater numbers in the external belt than in the centre square of the capture area, then in the case of *M. minutus* there was no entry into the trapping area from outside (Dziekanów, meadow). At the same time no regular decrease was observed in the number of animals caught in consecutive days of removal. These results indicate that the probability of catching different individuals in the *M. minutus* population is not uniform. Results of captures of *A. flavicollis* should be interpreted far more carefully, since a distinct drop in the number of individuals caught was found everywhere during the initial consecutive capture days, and a slight increase took place only towards the end of removal. At the same time no differences were found between the outer belt and inner square in the number of individuals caught. In the case of *C. glareolus* increase in the number of individuals caught in the final days of removal could be explained by the increased immigration of individuals into the capture area.

The reliability of the estimates of numbers obtained on the basis of regression depends on the correctness of the following premises: (1) All the individuals in the population have a uniform chance of being caught, (2) There is either no, or very little, immigration and emigration of individuals during the capture period (in cases in which intensive emigration or immigration takes place, regression will have to be calculated in a different way e.g. De Lury, 1951; Fredin, 1954), (3) Variations in numbers due to mortality or reproduction are slight during the capture period, (4) capture conditions are similar throughout the whole of the capture period. For example no sudden changes take place in climatic conditions which may affect trappability (Burt, 1940; Borowski & Dehnel, 1953; Sidorowicz, 1960; Gentry & Odum, 1957).

Although many authors have drawn attention to the necessity for checking the correctness of these premises (e.g. Hayne, 1949; De Lury, 1947; Moran, 1951; Chapman, 1955; Calhoun & Casby, 1958) yet in studies estimating numbers by means of regression no conclusive check was made of them. It would seem that variations in climatic conditions did not affect greatly the estimates of numbers in the captures made. For instance at Białowieża in the autumn of 1964 rain fell at times during the capture period. When elaborating regression a less regular decrease in the number of individuals caught on successive days was obtained as a result. Under these circumstances the three first premises may be checked for correctness by analysing the difference between the total number of animals caught and the number estimated on the basis of regression. If all the premises are fulfilled, then the total number of animals caught should coincide with the estimate of numbers made on the basis of regression. If we accept that these two estimates are similar, if they differ less than 10 per cent (accidental differences) then in 9 cases out of 14 — when regression is calculated for the dominating species (Table 4) the above premises are fulfilled.

If numbers estimated from regression are smaller than the total number caught then either the premise as to the uniform probability of capture of individuals in a population is incorrect, or we have to do with the appearance of new individuals during removal (immigration or reproduction). In four cases out of the remaining five we have a situation of this kind.

If the criterion of immigration used above is correct, then we should have to do with non-uniform probability of removal of different individuals in a population (two cases of spring and autumn captures of *A. flavicollis* at Ojców). In the case of *C. glareolus* (Ojców: spring, autumn) we should have had to do with immigration, although it is not possible to exclude the possibility of differences in probability of capture among individuals forming the population.

In one case only out of all those analysed was the number estimated on the basis of regression greater than the number of individuals caught during the whole removal period (*A. flavicollis* — Białowieża, spring 1965, Table 3). Since all individuals were caught up to the fifth day (Fig. 2—4) it cannot be presumed that not all the mice were caught within 7 days. The cause of this phenomenon is, however, unknown.

To recapitulate, out of the 18 cases examined, in as many as 17 it proved possible to estimate numbers either (1) — by means of regression (in 9 cases estimates were accurate, and in 5 certain corrections had to be introduced into estimates of regression, taking into consideration immigration or delayed trappability of a certain group of individuals) or (2) it could be taken that all the individuals caught represented the population numbers (three cases at Dziekanów, spring 1965). Only in one case out of 18 (Dziekanów, meadow, *M. minutus*) was it impossible to estimate population numbers.

It would therefore appear that the "Standard-Minimum" method presented in this study may be recommended for rapid and easy estimation of the numbers of small rodents, both in forest and grassland.

Since practically speaking almost all the rodents were removed by the fifth day, shortening of the removal period to 5 days is suggested. It would also seem possible to curtail the prebaiting period similarly to 5 days. The method proposed here for estimating population numbers for investigation of the productivity of small rodents would then cover a five-day prebaiting period and five-day period of intensive removal.

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OCENA LICZEBNOŚCI GRYZONI METODĄ ZANĘCANIA I INTENSYWNEGO WYŁOWU

Streszczenie

Badania miały na celu opracowanie dokładnej a zarazem ekonomicznej metody oceny liczebności drobnych gryzoni. Są one rezultatem wspólnych prac Zakładu Badania Ssaków PAN, Zakładu Ekologii PAN oraz Zakładu Ewolucjonizmu UJ, prowadzonych w związku z Międzynarodowym Programem Biologicznym w Polsce. Badania prowadzono na terenie Białowieskiego Parku Narodowego, Ojcowskiego Parku Narodowego i Kampinowskiego Parku Narodowego.

Wykonano osiem dwutygodniowych serii połowów. Każda seria składała się z: (1) — siedmiodniowego okresu przynęcania gryzoni owsem; oraz (2) — siedmiodniowego okresu wyłowu gryzoni pułapkami zabijającymi. Na kwadratowej powierzchni połowów o boku 240 m (= 5,76 ha) rozmieszczono sieć 256 punktów

z przynętami. W okresie wyłowu, w każdym z punktów przynęcania ustawiano po dwie pułapki zabijające (łącznie 512 pułapek).

We wszystkich seriach połowów złowiono ogółem 1495 drobnych gryzoni (Tabela 2). Najliczniejszymi gatunkami były: nornica ruda, *Clethrionomys glareolus* (Schreber, 1780), mysz leśna, *Apodemus flavicollis* (Melchior, 1834), mysz polna, *Apodemus agrarius* (Pallas, 1771), i badylarka, *Micromys minutus* (Pallas, 1778). Nie stwierdzono zależności między liczbą wyjedzonych przynęt a ilością złowionych gryzoni (Tabela 1).

Do piątego dnia połowów odławiano od 78 do 100% wszystkich gryzoni, złowionych w całym okresie wyłowu. Stwierdzono różnice w tempie wyłowu *C. glareolus* i *A. flavicollis* — wiosną oraz *A. agrarius* i *M. minutus* — jesienią (Fig. 2, 3, Tabela 2).

Ocenę liczebności gryzoni przeprowadzono metodą regresji, zaproponowaną przez De Lury (1947) i Hayne (1949) (Tabele 3, 4). Zanalizowano słuszność założeń tej metody, wykazując, że uzyskane oceny liczebności mogą odchylać się od rzeczywistej liczebności populacji w wyniku niejednakowego prawdopodobieństwa złowienia poszczególnych osobników w populacji, imigracji i emigracji podczas trwania wyłowu oraz zmian łowności gryzoni zależnie od warunków klimatycznych. Na skutek niezgodności warunków połowów z tymi założeniami, uzyskanie oceny liczebności nie było możliwe tylko w jednym przypadku na osiemnaście.

Autorzy polecają przedstawioną metodę do szybkiej i niepracochłonnej oceny liczebności drobnych gryzoni w lesie i na łące, proponując jednocześnie skrócenie zarówno okresu przynęcania jak i okresu intensywnego wyłowu do 5 dni.