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

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Estimation of Rodent Numbers in a Plot of *Querceto-Carpinetum* Forest [1])

[With 7 Tables and 6 Figs.]

Two times, in summer and in autumn, the area of about 0.75 hectare, was surrounded by a tight tin fence and all rodents from this plot were captured. Differences in the rate of trapping were found in two dominant species, *Apodemus flavicollis* and *Clethrionomys glareolus* and between the marked and non-marked individuals. The captures became fewer with the decreasing numbers of rodents. The method of the calendar of trapping results in an estimation lower than the numbers actually captured with the difference, 73% in the summer, and 54.7% in the autumn. However, there is a very close agreement between the number of specimens captured in the fenced area and the estimation from the regression of daily capture on the total number of rodents previously caught. From the trapping and the regression it was estimated that the density of rodents in *Querceto-Carpinetum* in Białowieża National Park in 1965 was 105 per ha. in the summer and 95 per ha. in the autumn.

I. INTRODUCTION

The productivity of rodents can be calculated only if their biomass can be determined precisely. This in turn requires an estimation of the number of animals living in the given area. The purpose of this study is to compare the results of estimations of population size based on (1) the calendar of catches (Petrusewicz & Andrzejewski, 1962), (2) a regression analysis based on trapping data (De Lury, 1947; Hayne, 1949), and (3) complete removal of rodents in a closed area.

II. METHOD

Experiments were carried out in the Białowieża National Park, in the forest association *Querceto-Carpinetum medioeuropaeum* Tx. 1936, from 12 June to 5 July 1965 in section no. 370 and from 8 September to 3 October 1965 in section no. 314. The study area was a square with sides 195 m. in length.

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

In this area, at each of 392 points, spaced 15 m. from each other two live-traps were placed. The traps were baited with husked oats. Over a period of 12 days the traps were inspected twice daily; captured rodents were marked and released and the bait replenished. The results were arranged according to the calendar of trapping (24 checks) (Petrusewicz & Andrzejewski, 1962). This method allows resident and transient individuals to be distinguished and their behaviour to be followed. In addition it is possible to determine how long each animal remains in the study area.

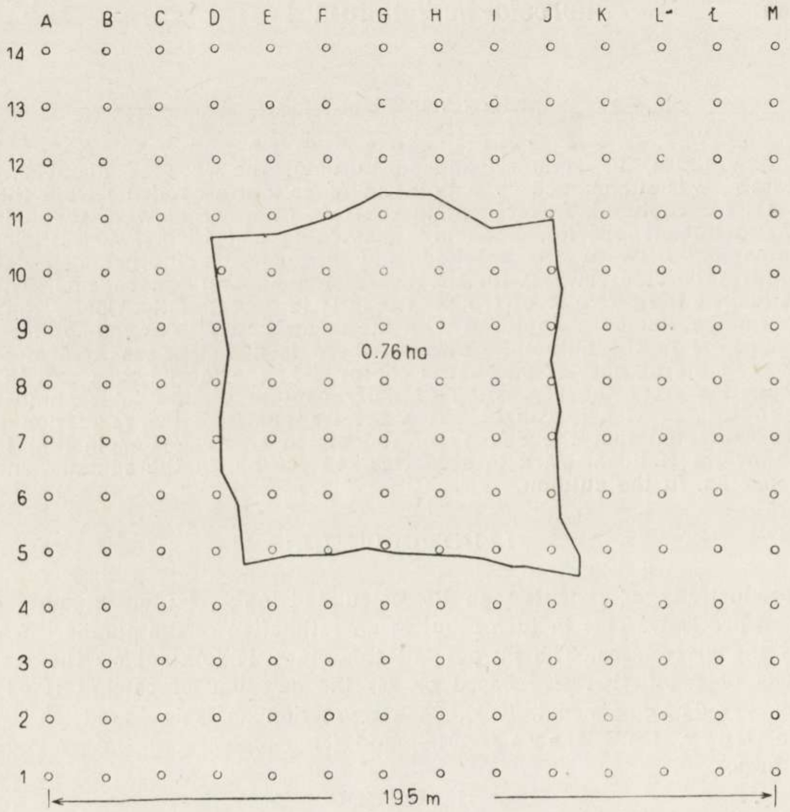

Fig. 1. The scheme of the experimental area; in the middle the fenced plot.

On the 13th day of trapping the central part of the study area (about 0.8 ha) was enclosed by a tight fence of galvanised tin, 70 cm above ground level and 30 cm below. A 10 cm ring of smooth oilcloth was placed on all trees and bushes which had twigs above the fence in order to prevent rodents moving out or in by this routs (Figs. 1, 2, 3).

Within the fenced area 86 spring traps were set: two in each corner, two by the fence on each of the rows and one between every two points of the row. In addition, 40 metal cones (40 cm deep) were placed one by

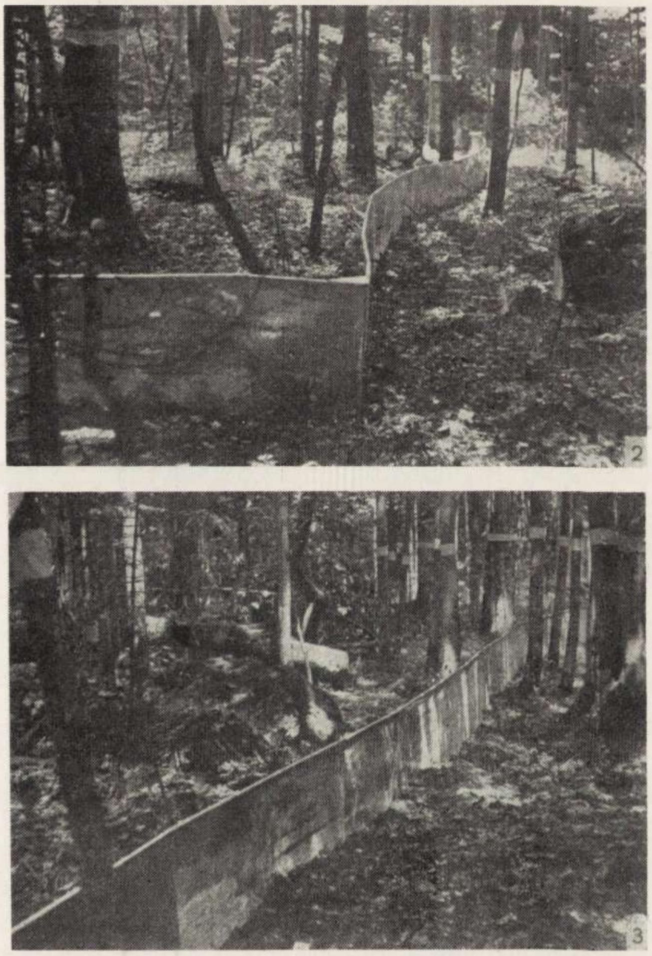

Fig. 2 & 3. The experimental area.

each pair of traps and one in each corner. The cones were placed so as to prevent the capture of Insectivores and thereby facilitate the trapping of rodents [2]).

[2]) The method of this experiment was based on the instructions of the theriological section of the Polish National Committee of IBP, outlined by Dr. L. Ryszkowski, whose suggestions are gratefully acknowledged.

The traps were inspected every 4 hours, and all animals removed. Simultaneously trapping with the CMR method was used on the remaining part of the experimental plot.

III. RESULTS

In the study area *Clethrionomys glareolus* (Schreber, 1780) and *Apodemus flavicollis* (Melchior, 1834) formed the bulk of the captures both in summer and in autumn; and in the fenced area they comprised 96.2% of all captured mammals. In addition, *Sorex araneus* Linnaeus, 1758, *S. minutus* Linnaeus, 1767 and *Pitymys subterraneus* (de Sélys-Longchamps, 1835) were caught occasionally. Both shrew species and the pine vole were disregarded in the calculations because the results obtained do not reflect the actual abundance of these species in the area, since the method of trapping was designed mainly for rodents.

In spite of all the precautions taken to prevent movement between the inner fenced area and the rest of the experimental plot 5 marked specimens of *C. glareolus* entered the fenced area from outside in summer and 4 *C. glareolus* and 13 *A. flavicollis* in autumn. It seems likely that all these individuals travelled across on twigs, since several of the oilcloth rings were later found to have been bitten through. (The small number of animals which entered the fenced plot from outside were disregarded in the calculations).

1. The Estimation of Rodent Number by the Method of a Trapping Calendar

The number of "resident", "transient" and "new" animals in the study area was calculated from the trapping calendar down in Table 1.

All individuals which were captured more than once were considered as resident and those, captured only once transient. Unmarked individuals (found during almost every check of the traps) were considered new, they were either immigrants or young that had recently left the nest.

The total number of rodents per hectare was only slightly higher in autumn than in summer. During summer there were almost twice as many voles as mice per hectare of the study area (Table 1) but in autumn this ratio was reversed.

Values from the summer experiment (Table 1) are probably changed by wild boars which moved through the area and destroyed some of the traps. Therefore, only some of the data collected during the summer outside the fenced area can be considered.

The number of new animals appering in the fenced and in the outer area respectively was estimated roughly both in summer and in autumn and results were expressed in the number of animals/ha (Table 2). In autumn of 1965 the number of new individuals was nearly three times higher outside than inside the fence. This undoubtedly reflects the high mobility of unmarked (= new) individuals during this period. The mean body weight of unmarked specimens within the fence was 11.2 g for *C. glareolus* and 21.5 g for *A. flavicollis* whereas in the rest of the plot

Table 1.

The numbers of rodents estimated from the calendar of trapping

		C. glareolus		*A. flavicollis*		All rodents	
		$\bar{x}$/day	$\bar{x}$/day/ha	$\bar{x}$/day	$\bar{x}$/day/ha	$\bar{x}$/day	$\bar{x}$/day/ha
Summer	Resident	131.0	29.7	68.7	15.1	199.7	52.5
	Transient	1.3	0.3	2.0	0.5	3.3	0.9
	New	19.0	4.3	9.3	2.1	28.3	7.4
	Total	151.3	34.3	80.0	17.7	231.5	60.8
Autumn	Resident	61.6	13.9	139.0	31.5	200.6	52.7
	Transient	1.2	0.3	1.6	0.4	2.8	0.7
	New	9.6	2.2	20.6	4.7	30.2	7.9
	Total	72.4	26.4	161.2	36.6	233.6	61.3

Table 2.

The mean number of new rodents per hectare in the fenced and non-fenced area during the period of 11 days.

Season	Number of rodents	
	fenced area	non-fenced area
Summer	26.3	18.7 ?
Autumn	11.1	29.1

it was 14.7 and 26.4 g, respectively. This indicates that in the fenced plot most of the new animals were young that had recently left the nest but in the outer part of the area there were many adult immigrants as well.

The data from summer indicate reverse relations between new animals caught in the fenced area and outside. However, these data are incomparable with autumn since 30—40% of traps were destroyed in summer by wild boars.

2. Estimation of Number by the Removal Method

2.1. Complete removal

During the 11-day trapping period almost the same number of rodents was captured in the fenced area in summer as in autumn (80 and 77 specimens, respectively). The number caught on subsequent days were

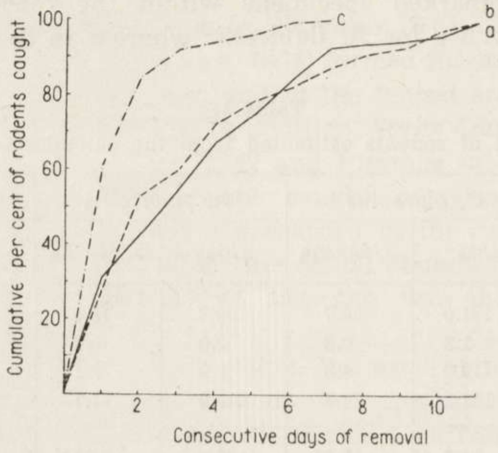

Fig. 4. The rate of trapping rodents from the fenced plot in summer (*a*) and in autumn (*b*) as compared with the non-fenced plot (*c*). The value of (*c*) from Grodziński *et al.*, 1966; same habitat (*Querceto-Carpinetum*) and comparable season (autumn 1965)

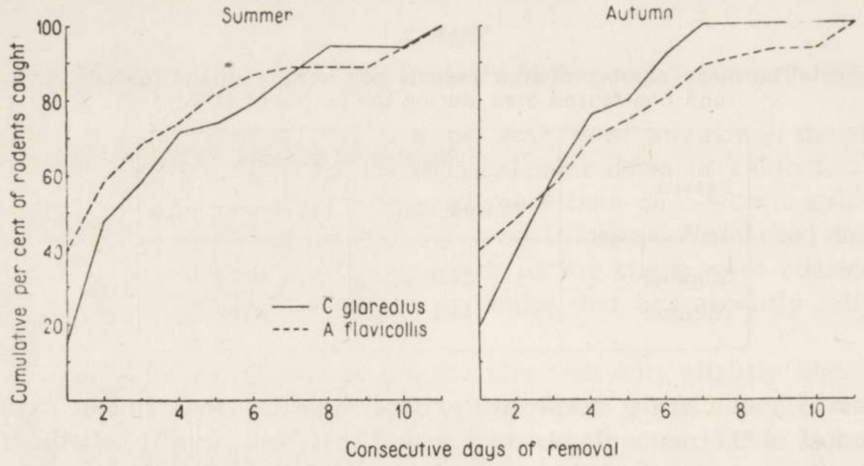

Fig. 5. The rate of trapping individual species.

also very similar in both seasons. Considering these first numbers of rodents as 100% the cumulative per cent of individuals captured on subsequent days of trapping was calculated. Corresponding curves (Figs. 4, 5, 6) show the rate of removal of rodents in the fenced plot.

There was no difference between the curves obtained from summer and autumn experiments (Fig. 4) in the fenced area but there was a difference in the non-fenced area. This indicates a greater delay in capturing the rodents in the fenced than in the rest of the area.

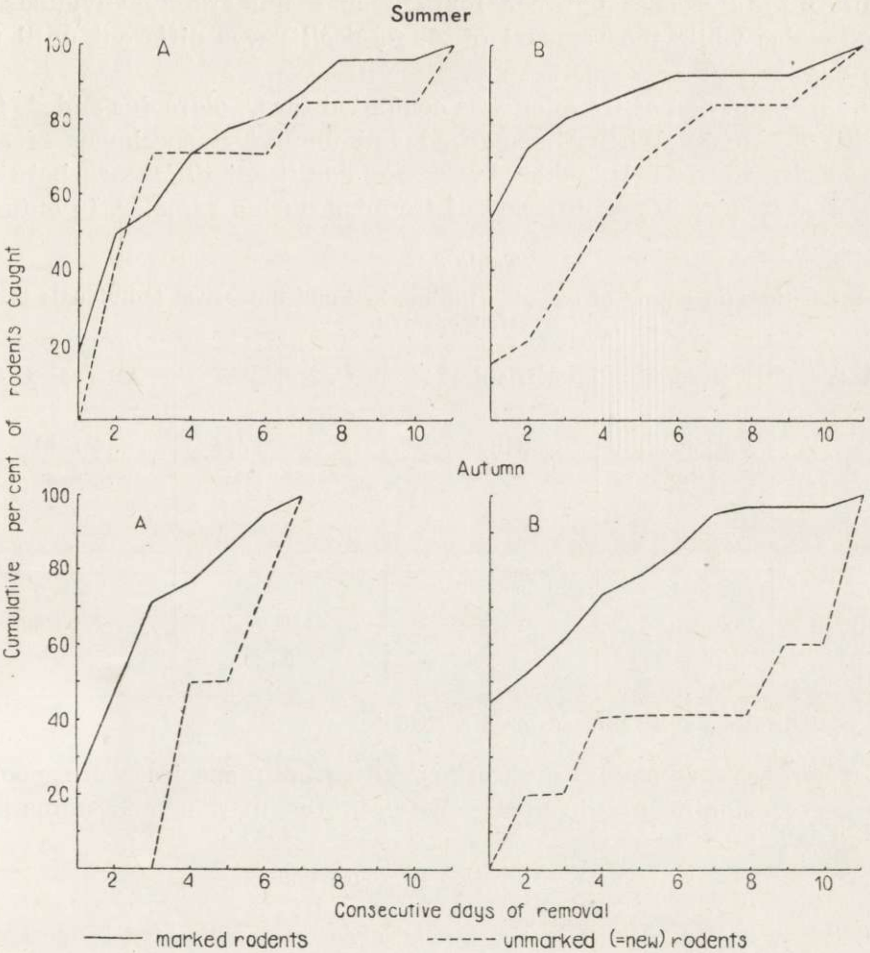

Fig. 6. The rate of capturing the marked and non-marked individuals.
A — *C. glareolus*, B — *A. flavicollis*.

Similary, the rate of removal was computed for individual rodent species and for marked and unmarked animals. In summer experiment the course of removal of *C. glareolus* and *A. flavicollis* is very similar. Both species were captured until the 11-th day i.e. throughout the whole period of trapping. However, in autumn the vole was being trapped faster than in summer (100% by the 7-th day) (Fig. 5).

The rate of trapping marked specimens, which were captured several times before building the fence, was usually higher than that of unmarked animals. This appears to be true of both most abundant species and at both times of year (Fig. 6). Only in summer there were no significant differences between marked and unmarked individuals of *C. glareolus* while the removal of *A. flavicollis* was different until the 7-th day.

The mean period of trapping was computed for *C. glareolus* and *A. flavicollis* (Table 3). When the marked and unmarked specimens of any one species were pooled, there was no significant difference between these two species in mean period of trapping during summer. In autumn

Table 3.

The mean time (in hours) of trapping the marked and unmarked individuals in the fenced area.

Season	Group	*A. flavicollis*	*C. glareolus*	All rodents
Summer	Marked	44h 18′	77h 36′	63h 00′
	Unmarked	86h 6′	82h 12′	84h 48′
	Differences	—	—	—
Autumn	Marked	67h 42′	62h 48′	66h 6′
	Unmarked	184h 48′	120h 00′	156h 00′
	Differences	+	+	+

+ Statistically significant, — Non significant.

the difference was significant (test *t*). When both species were pooled there were significant differences between the marked and unmarked animals.

2.2. Estimation by regression

The numbers of rodents in the fenced area were estimated by comparing the number caught daily with the total number previously caught and from the linear regression $y = ax + b$ (De Lury, 1947; Hayne, 1949; Grodziński *et al.*, 1966). This method allows the estimation population density only when the number of individuals captured in subsequent days is decreasing. Consequently, the choice of days used for computing the regression is somewhat subjective. In this study the rodent population was estimated after 4, 6, 9 and 11 days of trapping respectively (Table 4).

Both the absolute number of individuals caught and the number as estimated from the regression gradually increase over the period of

Table 4.

Population size estimated from complete removal and from the regression.

Season	Species		Marked	Non-marked	The catch after 4 days	The number from the regression (4 days)	The catch after 6 days	The number from the regression (6 days)	The catch after 9 days	The number from the regression (9 days)	The catch after 11 days	The number from the regression (11 days)
Summer	*C. gl.*	n	32	7	28	48.8	31	37.5	37	40.9	39	41.0
		n/ha	42.1	9.2	36.8	64.2	40.7	49.6	48.6	53.8	51.2	54.0
	A. fl.	n	26	13	29	29.6	34	33.6	35	34.7	39	36.5
		n/ha	34.2	17.1	38.2	44.7	44.7	44.2	46.0	45.6	51.2	48.0
	All species	n	58	22	58	74.2	66	73.1	75	78.5	80	80.1
		n/ha	76.4	28.9	76.4	97.4	86.8	96.1	101.3	103.3	105.2	105.4
	All species Marked	n	—	—	45	51.0	50	52.2	55	54.8	58	61.2
		n/ha	—	—	59.2	67.1	65.7	68.6	72.3	72.1	76.4	80.4
Autumn	*C. gl.*	n	21	4	18	45.0	23	37.5	25	29.5	25	27.7
		n/ha	25.9	4.9	22.2	55.0	28.3	46.3	30.8	36.4	30.8	34.0
	A. fl.	n	42	5	33	32.0	38	35.5	44	42.5	47	43.7
		n/ha	51.8	6.1	40.7	39.5	46.8	43.8	54.3	52.4	58.0	54.0
	All species	n	63	14	52	52.1	65	73.5	73	77.6	77	79.1
		n/ha	77.7	17.2	63.9	64.3	80.2	90.8	90.1	95.8	95.0	97.6
	All species Marked	n	—	—	47	50.6	56	57.6	62	62.5	63	62.9
		n/ha	—	—	58.0	61.7	69.1	71.1	76.5	77.1	77.7	77.6

trapping. Towards the end of the trapping period the difference between these two sets of values decrease and after 11 days of trapping they are in fairly good agreement. However, the population size as estimated by regression was always higher than the total number of animals captured. For *C. glareolus* these differences were considerable; in autumn the estimates obtained by regression were almost twice as high as the number actually captured. This might have been due to the fact that during the first three days of trapping there was no decrease in the number of animals caught. However, for *A. flavicollis* the estimates were usually, but not always, lower than the number of animals actually captured.

3. Estimation of Trapability on the Fenced and Non-fenced Area

The reciprocal of the regression coefficient ($C = \frac{1}{a}$) corresponds to the mean time between subsequent captures of the same individual. The value C is the trapability index (Grodziński et al., 1966). The

Table 5.

The estimation of trapability of the two most abundant rodent species in the fenced area.

Season	Species	Sex	Coefficient *a* of the regression				Trapability index			
			4	6	9	11	4	6	9	11
Summer	*A. flavicollis*	♀♀	—0.25	—0.31	—0.29	—0.25	4.0	3.2	3.4	4.0
,,		♂♂	—0.14	—0.29	—0.22	—0.31	7.1	3.4	4.5	3.2
,,		♀♀+♂♂	—0.19	—0.26	—0.23	—0.23	5.2	3.8	4.3	4.3
Autumn		♀♀	—0.31	—0.16	—0.22	—0.24	3.2	6.2	4.5	4.1
,,		♂♂	—0.11	—0.16	—0.20	—0.21	9.0	6.2	4.8	4.7
,,		♀♀+♂♂	—0.12	—0.14	—0.20	—0.21	8.3	7.1	5.0	4.7
Summer	*C. glareolus*	♀♀	—0.49	—0.41	—0.42	—0.38	2.0	2.4	2.3	2.6
,,		♂♂	—0.65	—0.49	—0.43	—0.39	1.5	2.0	2.3	2.5
,,		♀♀+♂♂	—0.53	—0.44	—0.42	—0.38	1.8	2.2	2.3	2.6
Autumn		♀♀	—0.45	—0.31	—0.15	—0.19	2.2	3.2	6.6	5.3
,,		♂♂	—0.61	—0.51	—0.46	—0.44	1.6	1.9	2.1	2.2
,,		♀♀+♂♂	—0.55	—0.49	—0.35	—0.36	1.8	2.0	2.8	2.8

values of the coefficient *a* and the trapability index for selected days in the fenced area are given in Table 5. It is evident that the trapability of *A. flavicollis* is considerably higher than that of *C. glareolus*, except in autumn when the rate of trapping *C. glareolus* was higher. The probability of capture (trapability) of females *C. glareolus* was higher than that of males during first four days of trapping. In *A. flavicollis* on the other hand the trapability of females was lowest. These differences decreased during the trapping period and by the 11th day were reversed. These results differ somewhat from those of Andrzejewski *et al.*, 1959, who reported that in three populations of mice the males were more easily caught at the beginning of the experiment and females at the end of the trapping period. The changes in trapability index during the trapping period indicate rates of capture in the fenced area at the beginning and at the end of my experiment. The trapability of *A. flavicollis* decreased towards the end of the experiment both in summer and autumn. However, in *C. glareolus* the mean time between successive captures decreased during the final stage of summer experiment but almost doubled during the corresponding stage of autumn series.

The mean times between successive captures of all individuals of both abundant species during the first four days after setting the plot was calculated from the trapping calendar. The trapability of both species was compared in the fenced and non-fenced area (Table 6).

Table 6.

The estimation of trapability of the two most abundant species in the fenced and in the non-fenced plots respectively during the first 4 days of the experiment. (Trapability index expressed in days).

Area	Sex	*A. flavicollis*		*C. glareolus*	
		summer	autumn	summer	autumn
Non-fenced plot	♀♀	2.5	3.0	2.5	2.2
	♂♂	2.7	3.6	2.7	2.3
	♀♀ + ♂♂	2.7	3.3	2.7	2.3
Fenced plot	♀♀	4.0	3.2	2.0	2.2
	♂♂	7.1	9.0	1.5	1.6
	♀♀ + ♂♂	5.2	8.3	1.8	1.8

Both in summer and in autumn the trapability of *C. glareolus* was considerably lower in the fenced plot than in the rest of the study area (Tab. 6). The trapability index of male voles was nearly three times higher in the fenced area during both seasons. In autumn this index was the same both within the fence and outside it. However, in *A. flavicollis* the trapability index was slightly higher in the non-fenced area both in summer and in autumn. In the non-fenced area in summer the trapability index of both dominating species was the same. In autumn, however, the mean time between subsequent captures was slightly higher in *C. glareolus*.

IV. DISCUSSION

The results of this work allow a comparison of estimates of population size obtained by different methods (Table 7). The difference between the estimates obtained from the calendar of trapping and from the removal method was 73.0% in summer and 54.7% in autumn. These values indicate that the estimates from the trapping calendar are too low. Estimations obtained by regression on the other hand were in very good agreement with the data collected by complete removal. Besides, the CMR method indicated that the density was slightly smaller in summer than in autumn while the method of complete removal yielded reciprocal results.

The data of trapping in the fenced area were also compared with the data collected in the "Standard-minimum" experiment in the non-fenced area (G r o d z i ń s k i *et al.*, 1966). In autumn both experiments were done in Białowieża, one immediately after another. The density of

Table 7.
The number of rodents per hectare estimated by three different methods.

Method	Calendar of catches	Complete trapping after 11 days/ha.	Estimation from the regression after 11 days/ha.
Summer	60.6	105.2	105.4
Autumn	61.4	95.0	97.6

rodents per hectare calculated from the regression after 4 days of trapping was almost the same in both experiments: 64.3 and 66.8 animals per hectare respectively.

The amount of labour involved is the chief disadvantage with the method of complete removal in a fenced area. Thus N i k i f o r o v (1963) reported that fencing an 4 ha area and setting up the traps took 64 menhours, and in my own study digging the ditches, building the tight fence and placing the oilcloth rings on trees took 70 menhours. Besides, about 2 tons of fencing had to be transported into the forest.

It appears therefore that the described method is unusually laborious and cannot be recomended for routine use, even though it gives good results. Reported experiments probably allow the methods of estimating the density of rodents from the rate of removal in non-fenced areas to be evaluated. This is further indicated by the very close agreement between the estimates from linear regression in both fenced and non-fenced area (Standard-minimum) and the absolute number of rodents captured within the fence.

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OCENA LICZEBNOŚCI GRYZONI W *QUERCETO-CARPINETUM*

Streszczenie

Doświadczenie przeprowadzono w Białowieskim Parku Narodowym, w grądzie niskim dwukrotnie, latem i jesienią. Na badanej powierzchni o boku 195 m ustawiono pułapki żywołowne, po dwie w każdym z 392 punktów, rozmieszczonych w więźbie 15 × 15 m. Przez dwanaście dób prowadzono kontrolę tych pułapek, znakując i wypuszczając złowione gryzonie. Prowadzono w tym czasie kalendarz złowień.

Trzynastego dnia środkową część powierzchni (ca 0.8 ha) ogrodzono szczelnym płotem z blachy (Fig. 1, 2, 3). Dostawiono 86 pułapek zabijających oraz wbito 40 metalowych stożków, po czym rozpoczęto intensywny wyłów gryzoni, prowadząc kontrolę pułapek co 4 godz. Równolegle z wyłowem wewnątrz ogrodzenia, prowadzono odłowy metodą CMR na pozostałej powierzchni doświadczalnej.

Zarówno w lecie, jak i jesienią łowiły się głównie *C. glareolus* i *A. flavicollis* (96.2% wszystkich ssaków złapanych). Na podstawie kalendarza złowień wyliczono średnią liczbę zwierząt osiadłych, efemerycznych i nowych na całej powierzchni

doświadczalnej (Tab. 1). Stwierdzono, że latem zarejestrowana ilość nornic na 1 ha powierzchni lasu była dwa razy wyższa, niż myszy leśnej, jesienią natomiast stosunek liczebności tych gatunków był odwrotny.

Prowadzono również w obu sezonach przybliżoną ocenę ilości nowych zwierząt, ujawniających się na terenie nieogrodzonym i ogrodzonym (Tab. 2). Jesienią na terenie nieogrodzonym liczba ich była trzykrotnie wyższa, niż wewnątrz ogrodzenia.

W obu badanych sezonach, na ogrodzonej działce w ciągu 11 dni, złowiono prawie taką samą ilość gryzoni (odpowiednio 80 i 77 osobników). Liczby te przyjęto za 100% i obliczono skumulowane procenty osobników wyłowionych na kolejny dzień połowów (Fig. 4, 5, 6). Krzywe wyłowu gryzoni w badanych sezonach nie różnią się między sobą, natomiast odbiegają istotnie od krzywej wyłowu z powierzchni nieogrodzonej, co wskazuje na opóźnienie wyłowu na terenie zamkniętym.

Przebieg wyłowu *C. glareolus* i *A. flavicollis* latem był bardzo zbliżony i trwał do 11 dnia, natomiast jesienią szybciej wyłowiła się nornica (Fig. 5).

Tempo wyłowu osobników znakowanych jest większe niż nieznakowanych, tak w lecie jak i w jesieni (Fig. 6). W przypadku *C. glareolus*, latem różnice te są statystycznie nieistotne, a wyłów *A. flavicollis* w tym doświadczeniu różni się istotnie do 7 dnia.

Średni czas wyłowu wszystkich osobników znakowanych i nieznakowanych, traktowanych łącznie, różnił się istotnie (Tab. 3).

W czasie trwania wyłowu wzrasta stopniowo absolutna liczba odłowionych osobników, jak również ocena zagęszczenia otrzymana z równania regresji prostoliniowej. Różnice między obu wartościami maleją w miarę zbliżania się do końca wyłowu gryzoni i największą zgodność osiągają po 11 dniach doświadczenia. Ocena z regresji była jednak zawsze wyższa od całkowitej liczby wyłowionych gryzoni (Tab. 4).

Zmiany współczynnika łowności w czasie trwania doświadczenia wskazują na niejednakowe tempo ubywania gryzoni na początku i pod koniec ich wyłowu z terenu ogrodzonego (Tab. 5).

Z kalendarza złowień wyliczono średni czas między kolejnymi złowieniami osobników obu dominujących gatunków dla pierwszych czterech dni od momentu uruchomienia powierzchni odłownej. Następnie porównano ich łowność (= średni czas między złowieniami) dla terenu nieogrodzonego, z danymi dla działki ogrodzonej (Tab. 6). Zarówno w lecie jak i w jesieni, łowność *C. glareolus* na terenie ogrodzonym jest znacznie niższa, niż na pozostałej powierzchni. *A. flavicollis* wykazuje stosunki odwrotne. Na terenie nieogrodzonym latem, oba dominujące gatunki mają jednakowe współczynniki łowności. Jesienią natomiast średni czas między kolejnymi złowieniami jest nieco wyższy dla *C. glareolus*.

Na podstawie porównania liczebności oznaczonej różnymi metodami stwierdzono, że latem różnica między liczebnością oznaczoną przy pomocy kalendarza złowień, a całkowitym wyłowem sięga 73.0%, a jesienią 54.7% (Tab. 7). Przytoczone cyfry wskazują na to, że wyniki uzyskane metodą kalendarza złowień są zaniżone. Istnieje natomiast duża zgodność między liczbą osobników złapanych na ogrodzonej powierzchni, a oceną uzyskaną z regresji między liczbą osobników złowionych w danym dniu i całkowitą ilością gryzoni złowionych do danego dnia.

Na podstawie wyłowu i regresji stwierdzono, że zagęszczenie gryzoni w *Querceto-Carpinetum* Białowieskiego Parku Narodowego wynosiło latem 1965 roku — 105 osobników/ha, a jesienią — 95 osobników/ha.