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ESTIMATION OF SMALL MAMMAL DENSITY IN THREE FOREST BIOTOPES*

An intensive removal of small mammals in three forest biotopes in the Białowieża National Park has been carried out. The Standard-Minimum (SM) method (Grodziński, Pucek and Ryszkowski 1966) has been applied. Additionally coniform traps were set up at the points of trapping with the purpose of removing *Insectivora*. Total 1,522 individuals of small mammals were captured. The SM method not always enables to estimate the number of *Insectivora* according to the method of linear regression. It has been shown that *Rodentia* from the first day of removal come intensively to the area where the removal is carried out. Differences in the captures on the external strip and in the centre are significant for *Rodentia* and this may cause an overestimation of the number when catches from the whole area are considered. The density per one hectare should be calculated, according to this method, only for the central part. The period of removal can be shortened from seven to four-five days.

Contents

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Ecological investigations on small mammals are very often carried out with the help of various methods. In order to determine the number of animals two kinds of methods were mainly applied: the first – consisting of marking and releasing of captured animals and the second – removal of captured animals from the population.

The capturing of small mammals according to the Standard-Minimum method (Grodziński, Pucek and Ryszkowski 1966) belongs to the second kind. This method turned out to be useful when rodent numbers is wanted to determine. However, in investigations on the energy flow through populations of small mammals one cannot limit himself exclusively to *Rodentia*. *Insectivora* also play quite a significant part in the epigeic fauna of forests.

The aim of present investigations was to determine the number of small mammals, and consequently also *Insectivora*, using the Standard-Minimum method, and to compare the density of small mammals in different forest biotopes.

1. AREA AND METHODS OF INVESTIGATIONS

Investigations were carried out in the Białowieża National Park (BNP) in the period 7th July – 4th August 1966 in three biotopes: *Pinetum typicum* (*P*) – section 318 of the BNP, *Querco-Carpinetum* (*Q-C*) – section 369, and *Circaeo-Alnetum* (*C-A*) – section 398. The periods when the removal was carried out in individual biotopes differred more or less about a week and consequently the results obtained are temporally comparable.

The method of prebaiting and intensive removal (Grodziński, Pucek and Ryszkowski 1966) was applied with certain modifications. Modifications were necessary because the investigations were to give information on quantitative relations of *Insectivora*. At each point of removal, beside snap traps, a metal cone sized – diameter fifteen centimetres and height forty five centimetres, was added. These cones were dug into the ground on the first day of prebaiting. All three traps at the capturing point were placed close to each other not more than 1.5 m from the spot where the bait was put in. In order to prevent the capturing of mammals in the period of prebaiting a tree-branch was inserted into each cone so that the captured individuals could leave the trap. *Insectivora* were not prebaited. In the period of captures (the second week of investigations) in order to prevent small mammals (mainly *Apodemus flavicollis*)[1] from escaping from the cones a small amount of water was poured into them.

In the period of captures the total number of small mammals caught on all

[1] For the authors of species names see Table I.

the three areas was 1,522, including 696 *Insectivora* and 826 *Rodentia* (Tab. I). From this data in further analysis only four dominating species making up 93.8% of the total catch were taken into consideration: *Sorex araneus*, *S. minutus*, *Apodemus flavicollis* and *Clethrionomys glareolus*. The remaining species occurring only in small numbers were treated together and analyzed in the *Insectivora* and *Rodentia* groups.

Quantitative and qualitative composition of the small mammals captured in three forest biotopes

Tab. I

Species	Biotopes						Total	
	Pinetum typicum		*Querco-Carpinetum*		*Circaeo-Alnetum*			
	number	per cent	number	per cent	number	per cent	number	per cent
Insectivora:								
Sorex araneus Linnaeus 1758	72	38.3	66	12.6	319	39.4	457	30.0
Sorex minutus Linnaeus 1766	47	25.0	33	6.3	135	16.7	215	14.1
Neomys fodiens (Pennant 1771)	–	–	1	0.2	23	2.8	24	1.6
Total of *Insectivora*	119	63.3	100	19.1	477	58.9	696	45.7
Rodentia:								
Apodemus flavicollis (Melchior 1834)	37	19.7	158	30.1	28	3.4	223	14.7
Clethrionomys glareolus (Schreber 1780)	28	14.9	234	44.7	271	33.5	533	35.1
Pitymys subterraneus (dé Sélys-Longchamps 1835)	–	–	28	5.3	3	0.4	31	2.0
Sicista betulina (Pallas 1778)	2	1.1	1	0.2	15	1.8	18	1.2
Microtus arvalis (Pallas 1779)	–	–	–	–	8	1.0	8	0.5
Microtus oeconomus (Pallas 1776)	–	–	–	–	5	0.6	5	0.3
Micromys minutus (Pallas 1778)	1	0.5	1	0.2	3	0.4	5	0.3
Dryomys nitedula (Pallas 1779)	1	0.5	2	0.4	–	–	3	0.2
Total of *Rodentia*	69	36.7	424	80.9	333	41.1	826	54.3
Total of small mammals	188	100.0	524	100.0	810	100.0	1522	100.0

The density of small mammals in separate biotopes was calculated according to the method of linear regression (De Lury 1947, Hayne 1949, Grodziński, Pucek and Ryszkowski 1966).

2. ESTIMATION OF THE EFFECTIVENESS OF THE STANDARD-MINIMUM METHOD WHEN APPLIED TO *INSECTIVORA*

The aim of setting up additional coniform traps at the points of capturing was to enable a simultaneous estimation of the density of *Insectivora* and *Rodentia* according to the same method, that is the equation of linear regression.

The method of linear regression may be applied only when in the period of removal there is a decreasing tendency from day to day in the total number of captured animals. And so practically the day on which there occurs an increase in the number of captured animals, as compared with the previous one, should not be included in the calculations, in view of the fact that it affects a change in the directional coefficient of linear regression, and causes the results to be somewhat higher (De Lury 1947, Hayne 1949, Davis 1959).

The course and rate of the removal of *Insectivora* and *Rodentia* in three forest biotopes is given in Table II and Figure 1.

The trend of the removal of *Insectivora* (*I*) and *Rodentia* (*R*) in three forest biotopes

Tab. II

Group	Consecutive day of removal	*Pinetum typicum*: in a given day	*Pinetum typicum*: until a given day, number	*Pinetum typicum*: until a given day, per cent	*Querco-Carpinetum*: in a given day	*Querco-Carpinetum*: until a given day, number	*Querco-Carpinetum*: until a given day, per cent	*Circaeo-Alnetum*: in a given day	*Circaeo-Alnetum*: until a given day, number	*Circaeo-Alnetum*: until a given day, per cent
I	1	34	0	0.0	6	0	0.0	147	0	0.0
	2	24	34	28.6	21	6	6.0	140	147	30.8
	3	9	58	48.7	41	27	27.0	40	287	60.0
	4	7	67	56.3	14	68	68.0	41	327	68.4
	5	39	74	62.2	9	82	82.0	39	368	77.2
	6	4	113	95.0	5	91	91.0	43	407	85.5
	7	2	117	98.3	4	96	96.0	27	450	94.3
Total		119		100.0	100		100.0	477		100.0
R	1	22	0	0.0	226	0	0.0	208	0	0.0
	2	14	22	31.9	91	226	53.5	51	208	62.5
	3	12	36	52.2	49	317	74.8	18	259	77.7
	4	6	48	69.6	17	366	86.5	12	277	83.1
	5	15	54	78.4	14	383	90.5	8	289	86.8
	6	0	69	100.0	12	397	93.5	20	297	88.8
	7	0	69	100.0	15	409	96.5	16	317	94.5
Total		69		100.0	424		100.0	333		100.0

On the two areas (*P* and *C-A*) the course of the capturing of *Insectivora* showed from day to day a tendency to decrease which was more or less evident as the case may be. On the third area (*Q-C*), however, the number of *Insectivora* in successive days of removal was increasing until the third day. And so it is not always possible to estimate the number of *Insectivora* with the help of the linear regression method.

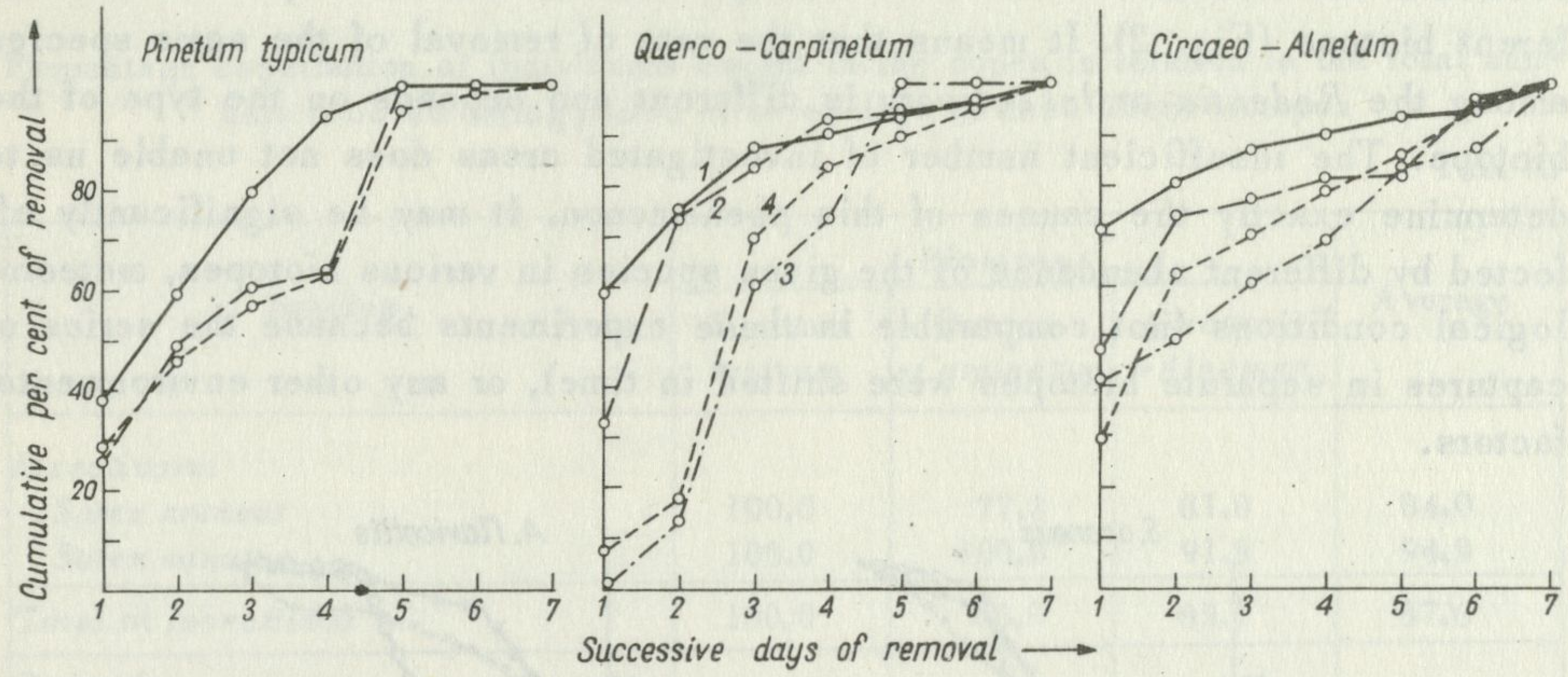

Fig. 1. Cumulative per cent of the removal of *Insectivora* and *Rodentia* in the three forest biotopes in the snap traps and in the cones

1, 2 – Rodentia: *1* – snap traps, *2* – cones; *3, 4 – Insectivora*: *3* – snap traps, *4* – cones

At the points of removal there was no bait attractive to *Insectivora*. Only very little agile beetles (mainly *Geotrupes stercorosus* Scr.) were caught in a natural way in the coniform traps and they rather did not constitute any attractive bait for *Insectivora*. This fact must be taken as a significant factor on which lower rate of removal intensity of *Insectivora* is depended.

In view of the fact that in certain cases the estimation of the number of *Insectivora*, according to the above-mentioned method, is quite impossible, we must take it for granted that the method is not always applicable in all cases, and that it should be improved.

3. RATE OF REMOVAL OF SMALL MAMMALS

The number of mammals removed in the period of seven days was taken as 100%, and numbers of animals taken to given day were calculated (Tab. II). For the first five days of the removal on the average 87.8% of *Insectivora* and 92.4% of *Rodentia* were captured out. Together with the sixth day 95.3% of *Insectivora* and 96.2% of *Rodentia* were captured. Because on the sixth and seventh days an increase in the number of captured animals was recorded for many species as compared with the results of the fifth day it might be assumed that there followed a change in the trappability or immigration. So practically for the first five days almost all the *Rodentia* and a majority of the *Insectivora* were captured out.

The shape of the curves presenting the cumulative per cent of mammals removed is approximately similar for various species inside the orders of *Insectivora* and *Rodentia* in the same biotope than for the same species in a different biotope (Fig. 2). It means that the rate of removal of the same species among the *Rodentia* or *Insectivora* is different and depends on the type of the biotope. The insufficient number of investigated areas does not enable us to determine exactly the causes of this phenomenon. It may be significantly effected by different abundance of the given species in various biotopes, meteorological conditions (not comparable in these experiments because the series of captures in separate biotopes were shifted in time), or any other environmental factors.

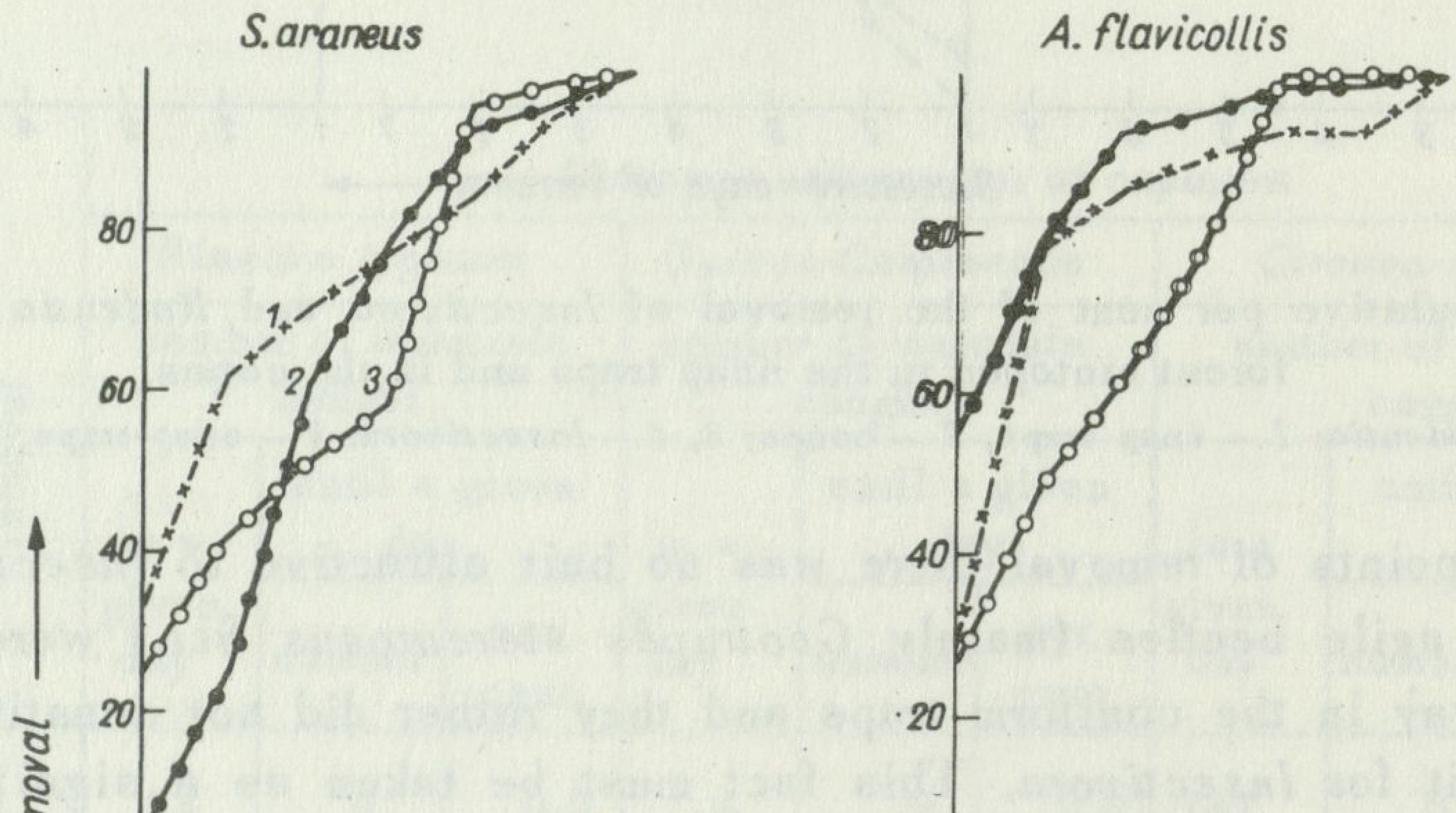

Fig. 2. Cumulative per cent of the removal of certain small mammals

1 – Circaeo-Alnetum, 2 – Querco-Carpinetum, 3 – Pinetum typicum, 4 – S. araneus, 5 – S. minutus, 6 – Insectivora, 7 – A. flavicollis, 8 – C. glareolus, 9 – Rodentia

Taking as 100% all the captured individuals of the given species on the are a, the contribution of the individuals captured in the coniform traps during seven days was calculated (Tab. III).

Percentage contribution of individuals caught in the cones in relation to the total numbers removed during period of seven days in three forest biotopes

Tab. III

Species	Biotopes			Average
	Pinetum typicum	*Querco-Carpinetum*	*Circaeo-Alnetum*	
Insectivora:				
Sorex araneus	100.0	77.3	81.8	84.0
Sorex minutus	100.0	100.0	91.8	94.9
Total of *Insectivora*	100.0	85.0	85.1	87.6
Rodentia:				
Apodemus flavicollis	35.2	12.0	60.7	22.0
Clethrionomys glareolus	64.3	23.5	26.2	27.0
Total of *Rodentia*	50.7	19.6	35.1	28.4
Total of small mammals	81.9	32.1	64.6	55.5

It follows from the analysis of Table III that the type of the trap has a selective effect on various groups of small mammals. The removal of *Insectivora* by snap traps was minimal. In certain cases even 100% of *Insectivora* were caught in the cones. On the other hand the majority of rodents was captured in the snap traps, However, the percentage indices for unabundantly occurring rodents from Table III give a false picture of the role of traps (e.g. *Clethrionomys glareolus* in *Pinetum typicum* and *Apodemus flavicollis* in *Circaeo-Alnetum*). On the average 87.6% of *Insectivora* and 28.4% of *Rodentia* were captured in the cones. These figures indicate that no one of the traps used can be taken to be universal for small mammals. And consequently the material of the removal must be treated as a whole and apply various types of traps in order to obtain a complete picture of the density of small mammals (Olszewski in press).

It seems that 12.4% of *Insectivora* were caught in the snap traps by accident because they make up only a very insignificant per cent of all the individuals. For *Rodentia* 28.4% of captures in the cones is, however, quite a significant number. It was investigated whether captures in the cones of the individuals passing by the points of removal were not only the result of the blocking of snap traps by the individuals previously captured. Table IV presents the distribution of the catches of rodents trapped in the cones according to degree of the occupation of snap traps. The two richest in *Rodentia* biotopes were analyzed in the first two days of the removal on the two external rows, and so at such points where the intensity of removal per one capturing point could be the highest one. From the data contained in Table IV it follows that the captures of rodents in the cones were also accidental and did not depend on the blocking of snap traps. Differences in the number of catches in the cones according to the degree of blocking of snap traps were examined with the help of the chi-square test proved to be insignificant.

Distribution of the captures of rodents in the cones due to the degree of occupation of snap-traps (captures from two days on the two external strips were treated together)

Tab. IV

Number of rodents in the cone	Biotopes											
	Querco-Carpinetum						*Circaeo-Alnetum*					
	number of occupied snap-traps at the point of removal											
	0		1		2		0		1		2	
	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
0	103	85.8	74	90.2	17	77.3	125	88.0	51	79.7	14	77.8
1–4	17	14.2	8	9.8	5	22.7	17	12.0	13	20.3	4	22.2
Σ	120	100.0	82	100.0	22	100.0	142	100.0	64	100.0	18	100.0

In order to investigate in which type of traps more small mammals were caught values of coefficients of linear regression were given without taking into account the realities of the estimated numbers (Tab. V). Figure 1 was also drawn up and it gives the cumulative per cent of the removal of *Insectivora* and *Rodentia* in relation to various types of traps. It follows that the snap traps most rapidly catch rodents (Tab. V). Only in the *Pinetum typicum* biotope, where the number of captured rodents was small the situation looked differently. But they may be accidental differences. With *Insectivora* in the *Circaeo-Alnetum* the situation was similar as with rodents. This was caused by a high per cent of the captured *Insectivora* on the first day of investigations. Figure 1 clearly shows that intensiveness of removal of *Insectivora* and *Rodentia* depends on the type of trap used.

4. SPACE DISTRIBUTION OF THE CAPTURES

The intensive removal of small mammals on a clearly defined area causes a "sink" which is filled after some time by immigration. Andrzejewski and Wrocławek (1962) came to a conclusion that the immigrants filled the "sink" after about four weeks. The inflow of individuals from outside occurs the more rapidly, the greater is the density of the neighbouring population and the quicker is the "sink" formed. In the Standard-Minimum method it was re-

Values of coefficients of linear regression for catches in the cones (c) and snap-traps ($s-t$)

Tab. V

Species	Biotopes and type of traps					
	Pinetum typicum		*Querco-Carpinetum*		*Circaeo-Alnetum*	
	c	$s-t$	c	$s-t$	c	$s-t$
Insectivora:						
Sorex araneus	0.358	–	×*	×	0.400	0.586
Sorex minutus	0.497	–	×	–	0.289	0.356
All *Insectivora*	0.422	–	×	×	0.358	0.569
Rodentia:						
Apodemus flavicollis	0.454	0.114	0.253	0.630	×	×
Clethrionimys glareolus	0.409	0.571	0.460	0.688	0.736	0.839
All *Rodentia*	0.357	0.286	×	0.635	0.577	0.803
All small mammals	0.405	0.286	×	0.612	0.407	0.764

* The calculation of the linear regression equation impossible.

corded the immigration of new individuals from outside only in a few last days of the removal (Grodziński, Pucek and Ryszkowski 1966, Ryszkowski, Andrzejewski and Petrusewicz 1966). In the Standard-Minimum method there is, besides of the natural process of the inflow of mammals to the area where the animals were captured, an additional inflow resulting from the seven-day prebaiting. It is assumed, as a rule, that baiting accustoms the individuals which are on the capturing area to permanent visits to the points of capturing and that increase chances of rodents to be quicker removed and enables the application of calculations according to the method of linear regression.

In order to record the effect of prebaiting on the inflow of mammals to the area of captures an analysis of the topography of captures from the first day of removal was carried out.

The whole area was divided into two parts: I – the centre (C) – square 10 by 10 capturing points, and II – external strip (Ext) going round the centre (156 capturing points). According to the initial assumption the external strip should undergo the inflow of small rodents from outside the area as a result, among others, of putting up the bait. *Insectivora* should not be subjected to the immigration under the influence of the stimulus because the corn cannot be treated as a bait for them.

The number of the small mammals on the external strip and in the centre, estimated according to the method of linear regression and recalculated per one hectare, is given in Table VI. There were much more rodents on the external strip than in the centre. The differences for *Insectivora* are not so striking.

Density of small mammals per one hectare estimated on the basis of the linear regression equation (for four days) on the external strip (*Ext*) and in the centre (*C*) in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q-C*) and *Circaeo-Alnetum* (*C-A*)

Tab. VI

Species	Biotope	*Ext*	*C*	*Ext:C*
Insectivora:				
Sorex araneus	*P*	13.16	5.62	2.34
	C–A	52.93	42.82	1.24
Sorex minutus	*P*	6.27	5.82	1.08
	C–A	24.98	24.26	1.03
All *Insectivora*	*P*	16.90	11.22	1.51
	C–A	81.39	67.98	1.20
Rodentia:				
Apodemus flavicollis	*P*	14.10	2.65	5.32
	Q–C	32.45	19.27	1.68
	C–A	6.54	2.28	2.87
Clethrionomys glareolus	*P*	5.08	2.72	1.87
	Q–C	46.66	24.12	1.93
	C–A	45.08	34.32	1.31
All *Rodentia*	*P*	15.48	8.13	1.90
	Q–C	85.22	44.65	1.91
	C–A	56.04	39.42	1.42
All small mammals	*P*	32.45	17.80	1.82
	Q–C	109.78	58.19	1.89
	C–A	128.17	102.37	1.25

Statistically significant differences occur only sporadically in *Insectivora* and nearly every differences in the trappability of *Rodentia* on the external strip and in the centre were significant (Tab. VII). This indicate that prebaiting not only made the removal more intensive but also caused the immigration of rodents onto the experimental area from the very first day. They are as well typical migrants, as individuals intensively penetrating the area during an artificial increase in the food base on the capturing area.

Table VIII presents the intensity of the removal of *Insectivora* and *Rodentia* per one capturing point in different biotopes. These data support the assumption concerned with the inflow of individuals onto the capturing area from the first day of removal (the process was initiated in the period of prebaiting). In the last days of removal the trappability was quite obviously considerably smaller than in the first four days but, as far as rodents were concerned, it was always

Significance of differences (chi-square at $P = 0.05$) between the density of small mammals on the external strip and in the centrum in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*)

Tab. VII

Species	Biotope	Number calculated according to: linear regression	total number of captures	
		period of four days	period of four days	period of seven days
Insectivora:				
Sorex araneus	*P*	+*	—**	—
	Q–C	—	—	+
	C–A	—	—	—
Sorex minutus	*P*	—	—	—
	Q–C	—	—	—
	C–A	—	—	—
All *Insectivora*	*P*	—	—	—
	Q–C	—	—	+
	C–A	—	—	—
Rodentia:				
Apodemus flavicollis	*P*	+	+	+
	Q–C	+	+	+
	C–A	+	+	—
Clethrionomys glareolus	*P*	—	—	—
	Q–C	+	+	+
	C–A	+	+	+
All *Rodentia*	*P*	+	+	+
	Q–C	+	+	+
	C–A	+	+	+
All small mammals	*P*	+	+	+
	Q–C	+	+	+
	C–A	+	+	+

*, **Significant (+) and non-significant (—) differences.

higher on the external strip than in the centre. For *Insectivora* differences in the intensity of captures on the external strip and in the centre were smaller and sometimes just opposite than as the case was with *Rodentia* (Tab. VIII). For the most numerously occurring species of rodents curves presenting the intensity of removal were drawn up (Fig. 3). Decreases in the intensity of removal marked themselves in two directions: 1) from outside towards the centre, and 2) from the first to the last days of removal. For certain species in the last day of removal no captures were recorded in the centre of the area, and that indicated that those individuals which lived there permanently were removed, and the immigrated individuals did not penetrate to the very centre of the area. For certain species there could be recorded a minimal renewed removal on the area where captures were already carried out after some break. It is quite characteristic that in the first day of removal differences in its intensity on the *Ext* and in the *C* were less significantly marked than in the following days (Tab. IX). And consequently it follows that the intensity of removal in the centre decreased more rapidly (the removal of individuals living there permanently, no further inflow) than on the external strip (immigrants). Besides on the first day of removal, when the trappability was quite significant, certain part of inflowing individuals penetrating to the centre of the area came upon some of the traps already occupied and that considerably decreased their chances of being trapped. In the following days, when the intensity of removal was lower, penetrating to the centre was less probable.

Intensity of captures of small mammals per one capturing point in one day on the external strip (*Ext*) and in the centre (*C*) in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*)

Tab. VIII

Species	Biotope	Period of removal (days)					
		1–4		5–7		1–7	
		Ext	*C*	*Ext*	*C*	*Ext*	*C*
Insectivora:							
Sorex araneus	*P*	0.05	0.03	0.05	0.03	0.05	0.03
	Q–C	0.06	0.04	0.03	0.01	0.04	0.03
	C–A	0.40	0.22	0.14	0.10	0.21	0.17
Sorex minutus	*P*	0.03	0.03	0.02	0.02	0.03	0.02
	Q–C	0.03	0.02	0.01	–	0.02	0.02
	C–A	0.09	0.12	0.04	0.04	0.07	0.08
All *Insectivora*	*P*	0.08	0.06	0.07	0.05	0.07	0.05
	Q–C	0.09	0.06	0.03	0.01	0.06	0.04
	C–A	0.37	0.34	0.14	0.15	0.27	0.26
Rodentia:							
Apodemus flavicollis	*P*	0.04	0.01	0.01	0.01	0.03	0.01
	Q–C	0.17	0.11	0.01	–	0.10	0.06
	C–A	0.03	0.01	–	–	0.02	0.01
Clethrionomys glareolus	*P*	0.03	0.01	0.01	0.01	0.02	0.01
	Q–C	0.26	0.14	0.04	0.01	0.16	0.08
	C–A	0.26	0.20	0.05	0.03	0.17	0.12
All *Rodentia*	*P*	0.07	0.02	0.02	0.02	0.05	0.02
	Q–C	0.45	0.25	0.07	0.02	0.29	0.15
	C–A	0.32	0.23	0.07	0.04	0.21	0.15

Tab. VIII (*cont.*)

Species	Biotope	Period of removal (days)					
		1–4		5–7		1–7	
		Ext	*C*	*Ext*	*C*	*Ext*	*C*
All small mammals	*P*	0.15	0.08	0.09	0.07	0.12	0.08
	Q–C	0.69	0.32	0.10	0.03	0.36	0.20
	C–A	0.68	0.57	0.32	0.19	0.48	0.41

The ratio of the removal intensity of *Rodentia* per one capturing point on the external strip (*Ext*) to the ones in the centre (*C*) in the first three days of removal in *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*)

Tab. IX

Biotope	Successive day of removal	*Ext*	*C*	*Ext*:*C*
Q–C	1	1.00	0.71	1.41
	2	0.46	0.19	2.42
	3	0.27	0.07	3.86
C–A	1	0.85	0.76	1.12
	2	0.26	0.11	2.36
	3	0.10	0.03	3.33

The above-showed significant differences in captures on the central and external parts indicate that the estimate of the population density is too high when the calculations from the whole capturing area are taken into consideration. In view of this we may assume that density should be calculated only for the central part treating the external strip only as a sort of isolating zone. And consequently the size of the central part should be determined as well as the number of files and preferential rows, which should not be taken into account when carrying out this sort of calculations.

The area of 2.25 hectares including ten by ten capturing points was taken to be the central part (100 capturing points). No smaller area would do because, e.g. the density of small mammals in various parts of our capturing area differed in some biotopes in a significant way (Tab. X). And then a comparison was carried out with the help of the significance test (chi-square) between the empirical and estimated number of mammals in the centre and the successive strips: 6, 7 and 8 counted from the centre of the area (Tab. XI). It follows from this Table that at least two external rows and files should be treated as a sheltering belt for the proper capturing area. Row 6 only in the two cases differed significantly from the centre, however, having only three areas for investigation it is difficult to decide whether it should be included in the internal part ot the sheltering belt. In the present paper for the purpose of calculating the density of small mammals it was included in the proper capturing area.

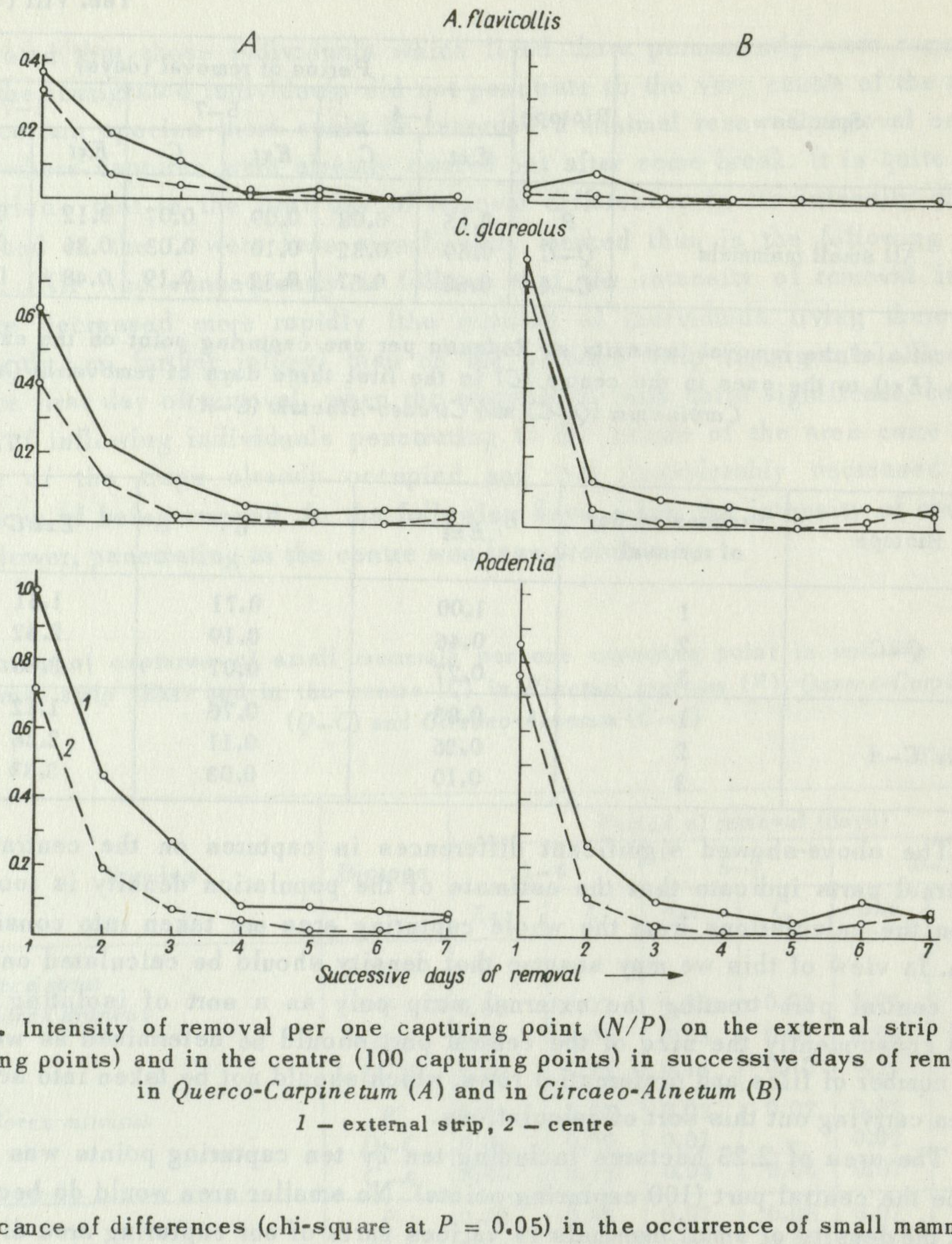

Fig. 3. Intensity of removal per one capturing point (N/P) on the external strip (156 capturing points) and in the centre (100 capturing points) in successive days of removal in *Querco-Carpinetum* (*A*) and in *Circaeo-Alnetum* (*B*)

1 – external strip, *2* – centre

Significance of differences (chi-square at $P = 0.05$) in the occurrence of small mammals in four equal sections of the capturing area in the three forest biotopes: *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*)

Tab. X

Species	Biotopes		
	P	*Q–C*	*C–A*
Insectivora:			
Sorex araneus	–*	–	+**
Sorex minutus	–	–	–
All *Insectivora*	–	–	+

Tab. X (*cont.*)

Species	Biotopes		
	P	*Q–C*	*C–A*
Rodentia:			
Clethrionomys glareolus	–	+	+
Apodemus flavicollis	–	–	+
All *Rodentia*	–	–	+
All small mammals	–	–	+

*,**Non-significant (–) and significant (+) differences.

Significance of differences (chi-square at $P = 0.05$) between the empirical and expected number of small mammals in the centre of the area (C) and on the peripheral rows (6, 7, 8) in *Pinetum typicum* (P), *Querco-Carpinetum* ($Q–C$) and *Circaeo-Alnetum* ($C–A$)

Tab. XI

Species	Biotope	Comparison of the centre with successive peripheral rows		
		$C-6$	$C-7$	$C-8$
Insectivora:				
Sorex araneus	*P*	–*	+**	–
	Q–C	–	–	+
	C–A	–	–	+
Sorex minutus	*P*	–	–	–
	Q–C	–	–	–
	C–A	–	–	+
All *Insectivora*	*P*	–	–	–
	Q–C	–	+	–
	C–A	–	–	–
Rodentia:				
Apodemus flavicollis	*P*	–	–	+
	Q–C	–	–	+
	C–A	–	–	+
Clethrionomys glareolus	*P*	–	–	–
	Q–C	–	–	+
	C–A	–	–	+
All *Rodentia*	*P*	–	–	+
	Q–C	+	+	+
	C–A	–	+	+
All small mammals	*P*	–	+	+
	Q–C	+	+	+
	C–A	–	–	+

*,**Non-significant (–) and significant (+) differences.

5. ESTIMATION OF SMALL MAMMAL NUMBERS IN THREE FOREST BIOTOPES IN THE BIAŁOWIEŻA NATIONAL PARK

Small rodents on all the three areas showed a tendency to a decrease in the captures so that it was possible to apply to them the method of linear regression. Only *Apodemus flavicollis* in the *C–A* biotope, when the total number of animals was small, showed a somewhat greater trappability on the second day of captures as compared with the first day. On the third day the number of captures of this species dropped to its minimum so that after compensating the linear regression this small increase on the second day of captures did not cause any significant differences between the number estimated according to the equation of linear regression and the real number of captured animals.

It was impossible to estimate *Insectivora* in the *Querco-Carpinetum* biotope with the help of the method of linear regression (see chapter 2).

The number of mammals was estimated according to captures carried out on the third and fourth days of removal (Tab. XII). It follows from this Table that differences between the number estimated on the basis of captures carried out on the third and fourth days were not particularly striking. It is not always possible to estimate on the basis of a greater number of days because for many species an increase in captures showed itself already on the fifth day.

Estimate of the number of small mammals per one hectare in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*), calculated on the basis of captures from the whole area (*Ext + C*) and in the centre (*C*) from three and four days, respectively

Tab. XII

Species	Biotope	*Ext + C*		*C*	
		3 days	4 days	3 days	4 days
Insectivora:					
Sorex araneus	*P*	8.66	8.78	5.36	5.62
	C–A	49.64	49.02	43.06	42.82
Sorex minutus	*P*	6.12	6.01	6.14	5.82
	C–A	23.23	23.85	23.12	24.26
All *Insectivora*	*P*	14.51	14.51	10.94	11.22
	C–A	76.26	76.08	67.28	67.98
Rodentia:					
Apodemus flavicollis	*P*	6.51	8.37	3.85	2.65
	Q–C	27.86	27.19	18.74	19.27
	C–A	5.83	5.06	3.85	2.28

Tab. XII (*cont.*)

Species	Biotope	Ext + C		C	
		3 days	4 days	3 days	4 days
Clethrionomys glareolus	*P*	4.57	3.96	–	2.72
	Q–C	37.23	37.62	24.09	24.12
	C–A	39.70	40.69	34.11	34.32
All *Rodentia*	*P*	13.10	12.02	–	8.13
	Q–C	68.84	68.72	43.89	44.65
	C–A	48.69	49.66	39.93	39.42
All small mammals	*P*	27.37	26.40	18.22	17.80
	Q–C	92.02	89.09	56.72	58.19
	C–A	117.60	120.16	100.10	102.37

The number estimated according to the method of linear regression (N_{regr}) on the basis of captures carried out on the third and fourth days was compared with the number of removed individuals (N_{rem}) respectively during three and four days and the number of individuals during seven days with the help of the index:

$$A = \frac{N_{regr} - N_{rem}}{N_{rem}} \times 100 \text{ (Tab. XIII).}$$

Absolute values of coefficient $A = \frac{N_{regr} - N_{rem}}{N_{rem}} \times 100$

Tab. XIII

Species	Biotope	N_{regr} on the basis of three days		N_{regr} on the basis of four days	
		N_{rem} on the basis of days:			
		3	7	4	7
Insectivora:					
Sorex araneus	*P**	34.8	30.7	20.4	5.9
	*C–A***	27.6	10.4	14.3	4.9
Sorex minutus	*P*	17.5	25.0	8.1	26.4
	C–A	52.0	0.9	33.4	1.8
All *Insectivora*	*P*	24.8	29.8	13.0	29.8
	C–A	34.3	7.9	19.1	8.1
Rodentia:					
Apodemus flavicollis	*P*	63.1	1.4	66.2	30.3
	*Q–C****	9.9	1.6	4.4	0.9
	C–A	40.0	19.2	16.7	4.2

Tab. XIII (*cont.*)

Species	Biotope	N_{regr} on the basis of three days		N_{regr} on the basis of four days	
		N_{rem} on the basis of days:			
		3	7	4	7
Clethrionomys glareolus	*P*	25.3	6.0	8.6	18.5
	Q–C	4.6	8.4	1.3	7.4
	C–A	1.0	1.6	2.8	13.5
All *Rodentia*	*P*	57.2	9.4	28.2	0.3
	Q–C	8.4	6.5	3.4	6.6
	C–A	1.2	15.8	0.9	14.1
All small mammals	*P*	37.1	16.1	18.8	19.1
	Q–C	22.1	1.2	10.4	2.1
	C–A	12.2	16.4	5.3	14.6

**Pinetum typicum*, ***Circaeo-Alnetum*, ****Querco-Carpinetum*.

The average values of A are higher when compared with N_{regr} from three days with N_{rem} also from three days then the calculations based on four days catch. It is quite a regular phenomenon because the numbers of N_{regr} from three and four days are not significantly different. And hence similar compared values with an underestimated number of catches from three days give higher values of A than for captures from four days.

When we compare N_{regr} with N_{rem} from seven days then the values of A show considerable changeability depending on the fact whether the species during the days between fifth and seventh| showed a higher or lower tendency to an increase in the captures.

Index A is, of course, relative because the number of captures (N_{rem}) from seven days does not make up 100% of individuals occurring on the area. The values contain an error in the direction of an overestimate (immigration, births) or in the direction of an underestimate (emigration, deaths, individuals not captured till the given day). From an analysis of the whole material it follows that the fixing of a certain, clearly defined number of days taken as a basis to calculate the number according to the method of linear regression is quite impossible. The period of five days is often too long because on that days there appears a tendency to an increase in the captures. The period of three days is in many cases too short particularly when the empirical points lie at too long distances from the linear regression line. Moreover the straightening of the points to from a straight line according to only three points is wrong. The period of four days seems to be the "proper middle road", nonetheless in those cases where in five days of captures there occurs a tendency to a decrease the number should be estimated according to the period of five days. The data presented here support the conclusion that the period of removal may be shortened to five days (Grodziński, Pucek and Ryszkowski 1966).

For the three biotopes which were compared proportions between *Insectivora* and *Rodentia* were set up (Tab. XIV) according to the number of captures and according to calculations carried out with the help of the method of linear regression. Both these methods recorded a per cent preponderance of *Insectivora* in the biotopes: *Pinetum typicum* and *Circaeo-Alnetum*, on the other hand in *Querco-Carpinetum* there was a marked preponderance of *Rodentia*.

Percentage contribution of *Insectivora* and *Rodentia* in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*), calculated according to the total number of captures and linear regression from the whole area (*Ext + C*) and from the centre (*C*)

Tab. XIV

Biotope	Group	According to the total number of captures		According to linear regression	
		Ext + C		*Ext + C*	*C*
		7 days	4 days	4 days	
P	*Insectivora*	63.3	57.8	54.7	58.0
	Rodentia	36.7	42.2	45.3	42.0
Q–C	*Insectivora*	19.1	17.6	×*	×
	Rodentia	80.9	82.4	×	×
C–A	*Insectivora*	58.9	56.0	60.5	63.3
	Rodentia	41.1	44.0	39.5	36.7

*It was impossible to calculate the number of *Insectivora* according to the method of linear regression.

In the calculations of the total number of captures from the whole area the participation of *Rodentia* was somewhat higher according to four days than according to seven days. It is understandable when we take into account the fact that the intensity of removal of rodents is higher and in the initial period of removal (four days) their participation is greater than in the whole period of removal.

Percentage relations on the basis of an estimate according to the method of linear regression for four days for the whole area of the centre showed a lower participation of rodents in the centre and that may be treated as a result of the lack of an intensive inflow of *Rodentia* from outside.

Table XV presents the density of small mammals per one hectare calculated with the help of various methods. The results obtained from the total number of captures are in the majority of cases higher than the ones obtained from the estimate of density on the basis of regression. This is a result of an inflow of individuals from the neighbouring area particularly during the last days of removal.

Density of small mammals per one hectare in *Pinetum typicum* (*P*), *Querco-Carpinetum* (*Q–C*) and *Circaeo-Alnetum* (*C–A*) on the whole area (*Ext + C*) and on the centre (*C*)

Tab. XV

Species		Biotope	Density calculated according to:			$\frac{N_1 - N_2}{N_2} \times 100$
			total number of captures	linear regression		
			7-day period	4-day period		
			Ext + C = 5.76 ha	*Ext + C* = 5.76 ha (N_1)	*C* = 3.24 ha (N_2)	
Insectivora	*Sorex araneus*	*P*	12.5	8.8	6.1	44.3
		Q–C	11.4	×*	×	–
		C–A	55.4	49.0	45.6	7.5
	Sorex minutus	*P*	8.2	6.0	6.8	−11.8
		Q–C	5.7	×	×	–
		C–A	23.4	23.8	25.9	−8.1
All *Insectivora*		*P*	20.6	14.5	13.2	9.8
		Q–C	17.4	×	×	–
		C–A	82.8	76.1	73.5	3.5
Rodentia	*Apodemus flavicollis*	*P*	6.4	8.4	×	–
		Q–C	27.4	27.2	22.7	19.8
		C–A	4.9	5.1	2.7	88.9
	Clethrionomys glareolus	*P*	4.9	4.0	×	–
		Q–C	40.6	37.6	26.0	44.6
		C–A	47.0	40.7	34.2	19.0
All *Rodentia*		*P*	12.0	12.0	×	–
		Q–C	73.6	68.7	50.9	35.0
		C–A	57.8	49.7	39.6	25.5
All small mammals		*P*	32.6	26.4	25.5	3.5
		Q–C	91.0	89.1	66.8	33.4
		C–A	140.6	120.2	107.8	11.5

*It was impossible to calculate density according to the method of linear regression.

In the last column of Table XV differences are given (in per cent) between the number of small mammals estimated: 1) from the whole area, and 2) only from its central part. The estimated density of rodents with the help of the first method is higher on the average by more than 25% (between 19.0 and 88.9%), on the other hand these differences for *Insectivora* on the average did not exceed 10% (from –8.1 to 44.3%). It is quite understandable because the capture of rodents in the centre differs significantly from the captures on the external strip.

6. DISCUSSION

An analysis of only three investigation areas is undoubtedly insufficient to provide definitive generalizations, nonetheless quite a copious material enables us to elaborate on certain methodic observations.

The setting up of additional coniform traps at the points of removal has as its aim to enable to get information on quantitative relations of *Insectivora*. Out of the three investigated biotopes for one of them there was no possibility to estimate the number of *Insectivora* according to the method of linear regression in view of the fact that there was a tendency to an increase in the removal. It is quite possible that this should be attributed to the changeable weather which dominated in the period of removal. For conditions of weather may significantly affect the result of removal (Sidorowicz 1960, Mystkowska and Sidorowicz 1961, Gentry, Golley and Mc Ginnis 1966). Quite probably we are in a position to attribute a considerable effect of the lack of active baiting of these mammals to the points of removal. This may be supported by the fact that a lower intensity of removal of *Insectivora* and *Rodentia* was recorded. When investigating quantitative relations of epigeic small mammals various types of traps should be applied (at least cones and snap traps) in view of the fact that at present there is no universal trap. The coniform trap may be taken to be a better one because besides capturing almost all the *Insectivora* it also caught a considerable per cent of *Rodentia*.

The application of prebaiting (an artificial way of enlarging the food base for rodents) in the first week of our investigations caused the inflow of individuals from outside onto the area of removal. It forced us to separate some sheltering belt out of the total area and this reduced the proper capturing area to 3.24 ha. This inflow was not so significant when *Insectivora* were concerned. Any reduction of the area of removal may turn out to be insufficient to carry out calculations and this may cause in its turn the necessity of enlarging the total manipulatory area of removal particularly in those biotopes in which there occurs a considerable differentiation of micro-habitats (e.g. *Circaeo-Alnetum*). And consequently at least two sheltering belts and strips should be added to the area used at present and containing sixteen by sixteen rows and strips of traps (and so all in all twenty by twenty capturing points). Because the

Standard-Minimum method is very laborious it might be possible to compensate this increase in laboriousness when the area of removal was enlarged by shortening the period of removal to four-five days.

The enlargement of the area of removal is not always possible because it is sometimes very difficult to find on the investigated area a homogeneous section of the biotope as large as 9.00 ha. As far as economically exploited forests are concerned this is practically an impossible thing to achieve.

In view of the above-said it seems that a good outcome of the situation might be some lessening of the estimated number of mammals by a certain per cent, by which the area used at present (5.76 ha) raises the results in relation to the proper equipment of the biotope. It follows from an analysis of the data contained in Table XV that this per cent is not permanent and changes according to the species of mammals and according to the biotope (it may also depend on the density of small mammals).

A third way to render the results obtained with the help of the Standard-Minimum method more real might be to stop prebaiting at the points of capture in the first week when the investigations were carried out.

It is evident from the above said that any improvement in the method of estimating the density of small mammals according to the Standard-Minimum method requires further investigations.

I wish to express my deep appreciation and gratitude to Doc. Dr. Z. Pucek for enabling me to carry out the present investigations with the help of means and facilities of the Mammals Research Institute, Polish Academy of Sciences, Białowieża.

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OCENA ZAGĘSZCZENIA DROBNYCH SSAKÓW W TRZECH BIOTOPACH LEŚNYCH

Streszczenie

Dokonano (w lipcu 1966 r.) intensywnego wyłowu drobnych ssaków w trzech biotopach leśnych Białowieskiego Parku Narodowego: *Pinetum typicum*, *Querco-Carpinetum* i *Circaeo-Alnetum*. Zastosowano metodę Standard-Minimum (Grodziński, Pucek, Ryszkowski 1966), którą zmodyfikowano przez dostawienie w każdym z 256 punktów, obok dwu pułapek zatrzaskowych, jednego metalowego stożka, wkopanego w grunt. Z wyłowu uzyskano łącznie 696 owadożernych (głównie *Sorex araneus* i *S. minutus*) oraz 826 gryzoni (głównie *Clethrionomys glareolus* i *Apodemus flavicollis*) (tab. I). Liczebność ssaków szacowano według metody prostej regresji. Do analiz szczegółowych wzięto pod uwagę cztery gatunki dominujące.

W ciągu pięciu pierwszych dni wyłowu wyłowiono średnio 87,8% *Insectivora* i 92,4% *Rodentia*. U większości gatunków zauważono po pięciu dniach tendencję do wzrostu odłowów, co było spowodowane imigracją zwierząt na terenie odłowów. Krzywe skumulowanego procentu odłowu poszczególnych gatunków w obrębie rzędów *Insectivora* i *Rodentia* są do siebie podobne w tym samym biotopie, natomiast różne w różnych biotopach (fig. 2). Stwierdzono, że w warunkach doświadczenia (jednoczesne stosowanie pułapek zatrzaskowych i stożków) zachodziła większa intensywność wyłowu *Insectivora* w stożki, *Rodentia* natomiast – w pułapki zatrzaskowe (fig. 1).

Ilość odławianych owadożernych wykazywała – w dwu przypadkach na trzy – tendencję spadkową i pozwalała na oszacowanie ich liczebności według równania prostej regresji (tab. II).

Ilość ssaków złowionych na jeden punkt w części centralnej powierzchni doświadczalnej jest u *Rodentia* od pierwszego dnia wyłowu istotnie niższa niż w części peryferyjnej. U *Insectivora* różnice te są nieistotne (tab. VI i VII). Oszacowanie liczebności *Rodentia* według prostej regresji z odłowów na całej powierzchni jest więc zawyżone przez napływ i wyłapywanie gryzoni z terenów sąsiednich.

Z analizy materiału wynika, że co najmniej dwa peryferyjne rzędy pułapek należy uznać za pas osłonowy a liczebność gryzoni szacować tylko w obrębie części centralnej (tab. XI).

Najmniejsze różnice między ocenami liczebności gryzoni z równania regresji i liczby gryzoni faktycznie złowionych do danego dnia uzyskano dla wyłowu w ciągu 4 dni. Z tego wynika, że wyłów może być skrócony do czterech-pięciu dni (tab. XIII).

Zagęszczenie na 1 ha, szacowane dla części centralnej z równania regresji, wynosiło w badanych biotopach leśnych:

biotop	owadożerne	gryzonie
Pinetum typicum	13,2	?
Querco-Carpinetum	?	50,9
Circaeo-Alnetum	73,5	39,6

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