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# Synurbization Processes in Population of Apodemus agrarius
# I. Characteristics of Populations in an Urbanization Gradient [1]

R. ANDRZEJEWSKI, J. BABIŃSKA-WERKA, J. GLIWICZ &
J. GOSZCZYŃSKI

Andrzejewski R., Babińska-Werka J., Gliwicz J. & Goszczyński J., 1978: Synurbization processes in population of *Apodemus agrarius*. I. Characteristics of populations in an urbanization gradient. Acta theriol., 23, 20: 341—358 [With 6 Tables & 5 Figs.]

Examination was made of rodent communities and a population of *Apodemus agrarius* (P a l l a s, 1971), living in areas subject to different degrees of urbanization; a park in the centre of a city, a suburban tree stand and a wood outside the suburbs. Significant differences were found in the composition and variety of the rodent community and in the structure and population processes of the field mouse, such as: age structure, sex structure, weight of adult individuals, maturation rate of females, length of the reproduction season and survival of the population during winter. The different pressure of the rodent community (which becomes increasingly impoverished along the urbanization gradient) and environmental factors specific to urban areas are discussed as possible reasons for the above-mentioned changes occurring in a field mouse population.

[Res. Inst. Environ. Develop., Krzywickiego 9, 02-078 Warszawa, Poland].

## 1. INTRODUCTION

The spatial development of contemporary towns results in the inclusion within urban boundaries of areas, in which a wide variety of ecological processes persists. Within cities and towns such spaces are converted into recreational areas (parks, sport grounds, *etc.*) or also form green areas within housing estates. Despite the considerable changes taking place in them, favourable conditions continue there for the existence of a large number of plant, animal and microorganism species, and for the function of at least part of the tro-

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phic and paratrophic ecological processes. Important changes in the living conditions of many populations are, however, taking place in such changed ecosystems within towns, leading either to destruction or quantitative limitation of the populations or, conversely, to their outbreak. This last phenomenon is probably due to weakening of regulating mechanisms operating at the level of the ecosystem.

The release of populations from the regulating effect of the ecosystem, adaptation of populations to life under the specific conditions formed by a town, formation of new regulating mechanisms *etc.* may be termed synurbization, by analogy with synanthropization. The latter means proneness of species to live in close relation with man, regardless of whether such species live in or outside towns. The former term indicates a close connection between the species and a very specific urban environment. Populations of the same species living in urban ecosystems and in more natural ecosystems differ in respect of many parameters characterizing their structure, organization and intrapopulation processes, adapted to the place they occupy in these ecosystems. Among the species subject to synurbization it is the non-synanthropic mammals which merit particular attention. Little is known about the process of their adaptation to living in an urban environment, their possible tendency to mass occurrence under new conditions and their potential sanitary and hygienic role in towns. It is also possible that on account of the physiological similarities between man and other mammals, wild non-synanthropic mammals occurring within town areas may prove to be important bioindicators of changes taking place in the biotic and abiotic conditions of towns.

The present study was aimed at establishing what changes can be observed in the ecological processes taking place in a community of small mammals with an increasing degree of urbanization of the area and increasing pressure of urbanization on the ecosystem in which this community occurs. We were also interested in the changes in certain intrapopulation processes in a species belonging to this community, and exhibiting distinct tendencies to synurbization, that is, the field mouse *Apodemus agrarius* P a l l a s, 1771.

## 2. DESCRIPTION OF STUDY AREAS

The studies were carried out in 1975 and 1976 in Warsaw in three large wooded areas: in the Łazienki Park (together with the Botanical Gardens), Bielany Grove and Młociny Wood.

The Łazienki Park together with the adjacent Botanical Gardens occupies an area of about 50 ha, and is situated in the central part of Warsaw, surrounded by busy streets and compact built-up areas. The are in which trapping was carried

out was covered by the vegetation characteristic of old parks: groups of trees and shrubs, over 80 years old, and extensive grass areas. Although the vegetation was artificially planted, it is similar in respect of species composition and structure to the *Tilio-Carpinetum* association. The trees in groups reach densities of up to 90% and bushes up to 75%, which results in considerable shade and consequently a very poor herb layer. Stretches of lawns were partly covered by the community composed of cultivated garden species occuring on habitats of *Galinsogo-Setarietum*, with the dominating species *Galinsoga parviflora*; near roads and paths, the association with *Poa annua*, very resistant to treading, occurs, and also the association with *Agrostis canina*.

The second study area — the Bielany Grove — is situated in the northern part of Warsaw, and is a nature reserve 130 ha in extent. Although retaining its forest character (part of the ancient primeval forest) it is much frequented by humans, is intersected by a network of paths and functions as an urban park. It is bounded on two sides by compact built-up areas, on the third by less densely built houses and on the fourth by a motorway, or directly by the bank of the River Vistula.

The area in which studies were made consisted of an alder wood belonging to the *Carici elongatae-Alnetum* association, and of an association similar to *Tilio-Carpinetum*. In the first association the dominating species was *Alnus glutinosa* (50—60 years old), with *Impatiens noli-tangere* and *Rubus* sp., or *Urtica dioica* and *Lamium purpureum*, in the herb layer.

In the second association there were approximately equal numbers of *Carpinus betulus*, *Tilia cordata*, *Acer platanoides*, *Fagus silvatica* (over 70 years old), while *Stellaria holostea*, *Melampyrum nemorosum* and *Vinca minor* dominated in the herb layer.

The third study area was the Młociny Wood on the outskirts of Warsaw (about 50 ha in extent), situated 3 km further to the north than Bielany Grove. It is bounded on two sides by widely-spaced houses, on the third by a motorway, beyond which are wooded areas, and on the fourth directly by the riverbed of the Vistula. The studies were carried out in the alder wood — *Carici elongatae-Alnetum* and in the sub-association *Carici elongatae-Alnetum dryopteridetum cristatus*. In both cases *Alnus glutinosa* dominates, the trees being from 50—60 years old. In the alder wood the dominating species in the herb layer is *Impatiens noli-tangere* or *Aegopodium podagraria*, whereas in the second sub-association *Dryopteris cristata* was found in considerable numbers in the herb layer.

The three study areas thus formed a sequence leading from the centre of Warsaw towards its northern periphery, characterized by the decreasing influence of urbanization — from the park in the centre of Warsaw (Łazienki Park) to the Bielany Grove (situated 7 km from the centre of the city, but coming within the built-up area) to Młociny Wood, situated at a distance of 10 km from the centre of Warsaw, and close to suburban building only (separate houses).

Trapping of rodents in the Kampinos Forest (Kampinos National Park) was carried out once only. This forest constitutes an extensive wooded area in which the ecosystems are only very slightly affected by man. The study area was situated at a distance of 20 km from the middle of Warsaw.

## 3. MATERIAL AND METHODS

Studies were made in all three areas in 1975 and 1976 in the following series: spring (from 8th May to 20th June 1975 and from 5th to 25th May in 1976) and

autumn (from 4th September to 18th October 1975 and from 21st September to 16th October in 1976).

Trapping of rodents was carried out using live traps arranged in trapping lines, which operated in the same place for 5—7 days. After this period the trapping line was moved to a different place. The traps in the line were spaced every 15 m, except that in Łazienki Park this system could not be adhered to strictly on account of the mosaic character of vegetation in the Park. From 50 to 70 traps were set out in the various series in Młociny Wood and Bielany Grove, and from 30 to 80 traps in Łazienki Park.

The animals caught were anaesthetized, weighed and dissected to determine their sex and reproductive condition. Their age was estimated from analysis of dry mass of the eye lens (Adamczewska-Andrzejewska, 1973).

A total of 998 rodents belonging to 5 species were caught in 1975 and 970 in 1976 (Table 1): the striped field mouse *Apodemus agrarius*, the bank vole *Clethrionomys glareolus* (Schreber, 1970), the yellow-necked mouse *Apodemus flavicollis* (Melchior, 1834), European pine vole *Pitymys subterraneus* (de Selys-Longchamps, 1835) and the house mouse *Mus musculus* (Linnaeus, 1758).

Table 1
Numbers of rodents caught.

| | Młociny Wood | Bielany Grove | Łazienki Park | Total |
|---|---|---|---|---|
| Spring 1975 | | | | |
| Rodents | 55 | 131 | 126 | 312 |
| *A. agrarius* | 25 | 70 | 123 | 218 |
| Autumn 1975 | | | | |
| Rodents | 292 | 250 | 144 | 686 |
| *A. agrarius* | 164 | 171 | 130 | 465 |
| Spring 1976 | | | | |
| Rodents | 213 | 182 | 130 | 525 |
| *A. agrarius* | 81 | 124 | 124 | 329 |
| Autumn 1976 | | | | |
| Rodents | 235 | 179 | 31 | 445 |
| *A. agrarius* | 107 | 123 | 31 | 261 |
| Total | | | | |
| Rodents | 795 | 742 | 431 | 1968 |
| *A. agrarius* | 377 | 488 | 408 | 1273 |

Insectivores were sporadically caught — *Sorex minutus* (Linnaeus, 1766), *Sorex araneus* (Linnaeus, 1758), *Neomys fodiens* (Pennant, 1771). During the single trapping operation carried out in the Kampinos Forest in the spring of 1975 a total of 45 individuals of *C. glareolus*, 4 of *A. agrarius* and 3 of *A. flavicollis* were caught.

## 4. DESCRIPTION OF THE RODENT COMMUNITY

The three habitats examined differed from each other considerably in respect of the composition of the rodent community, both as to number

of species and the percentages which they form of the community. In Młociny Wood the following 4 species were caught: *C. glareolus*, *A. flavicollis*, *A. agrarius* and *P. subterraneus*. It is difficult to decide which is the dominating species in this habitat. The bank vole and striped field mouse occurred in approximately equal proportions and jointly formed 75—93% of the community, the yellow-necked mouse 6—24%, while *Pitymys subterraneus* was caught only sporadically (1%) (Fig. 1).

In Bielany Grove the same 4 species occurred, but the percentages

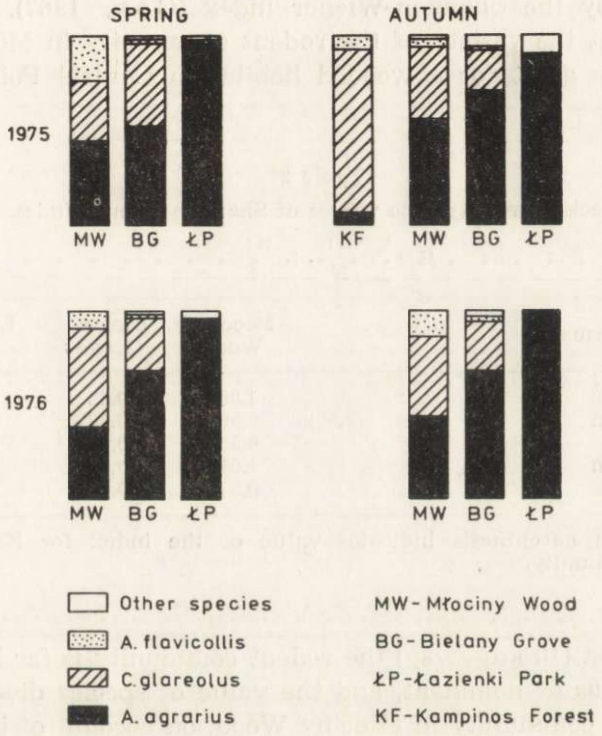


Fig. 1. Species composition of rodent communities (%).

they formed were different. In this case the species *A. agrarius* greatly predominated, forming 53—71% of the community, followed by *Clethrionomys glareolus* (21—44%), whereas *A. flavicollis* and *P. subterraneus* jointly constituted only 3—8%, the first of these two species slightly predominating. In Łazienki Park the rodent community was far from varied, consisting almost entirely of *A. agrarius* (90—100%), a small number of *M. musculus* and *P. subterraneus* being occasionally caught there.

No significant seasonal variations in species composition of the rodent community were found in any of the study areas, and it must therefore be assumed that populations of all the species recorded find favourable conditions throughout the year in these habitats. This is particularly remarkable in the case of *A. agrarius*, which is known to be a species changing its habitat with the season, probably in search of suitable food (Haitlinger & Korzeniowski, 1962; Holišova 1967; Zejda, 1967).

Species diversity in the rodent communities studied (Table 2) is best characterized by the Shannon-Wiener index (Cox, 1967). It must be emphasised that the variety of the rodent community in Młociny Wood is exceptionally great for a wooded habitat in Central Poland. In the

Table 2

Species diversity. The values of Shannon-Wiener Index

$$H = \sum \frac{n_i}{N} \cdot \ln \frac{n_i}{N}$$

| Time of census | | Młociny Wood | Bielany Grove | Łazienki Park |
|---|---|---|---|---|
| 1975 spring | | 1.06 | 0.82 | 0.11 |
| autumn | (0.50) | 0.90 | 0.79 | 0.35 |
| 1976 spring | | 0.95 | 0.87 | 0.21 |
| autumn | | 1.01 | 0.81 | 0.00 |
| Mean value | | 0.97 | 0.80 | 0.21 |

Figure in parenthesis indicates value of the index for Kampinos Forest community.

Kampinos Forest (10 km away) the rodent community is far less diverse, with *C. glareolus* as dominant, and the value of species diversity index 0.5. The rodent community in Młociny Wood, on account of its diversity, due probably to being situated between the city and the Kampinos Forest, will form the subject of further detailed studies.

The trapping method used permits only of making relative estimates of the rodents' density. For the purposes of this estimate we used the index of number of captures obtained in relation to the number of traps in operation jointly throughout the whole study period (traps × days). This permits only of drawing very general conclusions, but even so it is possible to establish on this basis that the density of rodents in Młociny Wood and Bielany Grove was similar or slightly higher during the study period than the density of rodents in Łazienki Park (Fig. 2a).

## 5. DESCRIPTION OF A POPULATION OF *A. AGRARIUS*

### 5.1. Density and Position in the Community

The domination of the field mouses increases in the gradient from suburban districts to city centre. This species, from being the co-dominant in Młociny Wood, becomes the dominant among the three other species

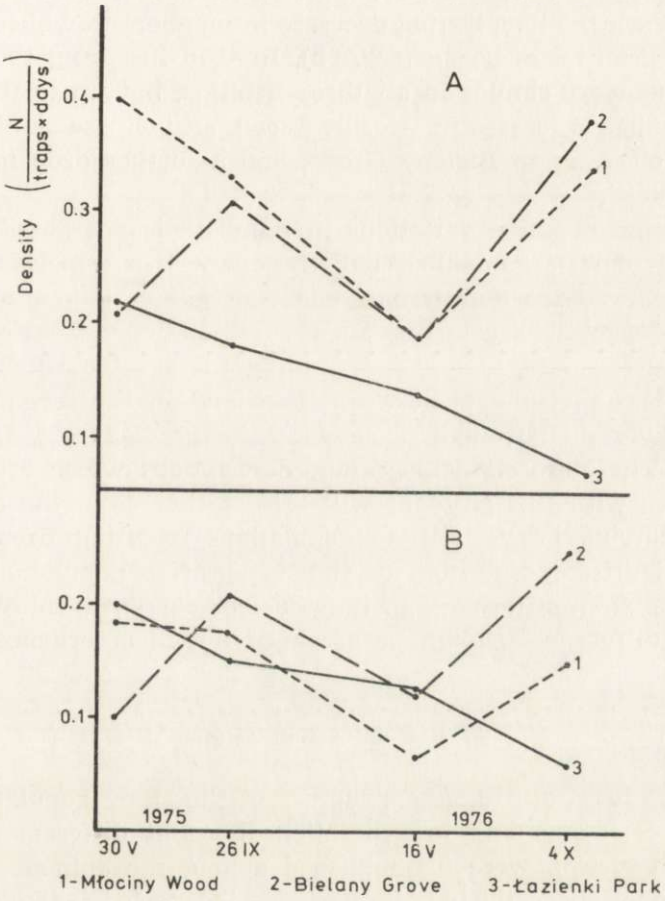


Fig. 2. Fluctuations in density, (A) of the whole rodent communities, (B) of *A. agrarius* populations.

of the community in Bielany Grove and the only rodent in the city park habitat.

Despite such significant changes in the role of the population its average density level does not vary significantly (Fig. 2b). In 1975 the relative density of *A. agrarius* in Młociny, Bielany and Łazienki is very si-

milar, whereas in 1976 distinct reduction in numbers can be observed in the park habitat, making it difficult, by the autumn of 1976, to obtain sufficient material for studies there.

Seasonal variations in numbers in the three study populations took different courses. In 1975 during the period from spring to autumn in Młociny Wood no variations in population numbers were observed, in Bielany Grove there was distinct increase in numbers in autumn and in Łazienki Park the long lasting decrease in numbers to which reference has already been made began (Fig. 2b). In 1976 in spring the numbers of *A. agrarius* were similar in all three habitats, but up to the autumn there was a slight increase in Młociny Wood, an increase similar to that of the previous year in Bielany Grove, and a further drop in numbers in Łazienki Park.

Interpretation of these variations in numbers is not possible on the basis of the material obtained, but there are two important matters here: in the first place the seasonal and two-year variations in numbers are of a different character in all the populations examined, which points to the different factors determining the level of their numbers and to the lack of contacts between them and in the second place — these variations do not take place with the gradient of »urban-ness« of habitats. Therefore all demographic descriptions which are arranged in accordance with this gradient will arise rather from the differences actually occurring between these populations resulting from different habitats and different position of the *A. agrarius* population in these habitats, than from differences in the phase or current level of numbers, since these differences should be arranged not in accordance with the gradient.

### 5.2. Sex and Age Structure

In order to illustrate the age structure of the study populations three age classes, corresponding to generations born at different periods of reproduction season, were distinguished among the animals caught. In June individuals born during the early spring period belong to class I (1—3 months old), the oldest individuals, termed old adults, to class III (over 7 months old), and individuals which were 4—6 months old in June belong to class II. If our estimate of age is correct these are individuals born in winter.

Since, however, there is no report of winter reproduction in *A. agrarius* in literature relating to Central European areas, and there are no direct proofs of winter reproductive activity in the study populations (no gestating or lactating females were caught in winter) this question

must be left open until such time as more comprehensive documentary material is obtained. If, however, our estimate of age were correct, it would indicate that winter reproduction in both urban and suburban populations is not a rare occurrence, since it took place in all three populations during the study period.

In October individuals from the autumn generation belong to class I (1—2 months old), individuals from the summer generation to class II (3—5 months old), and individuals present in the population in spring

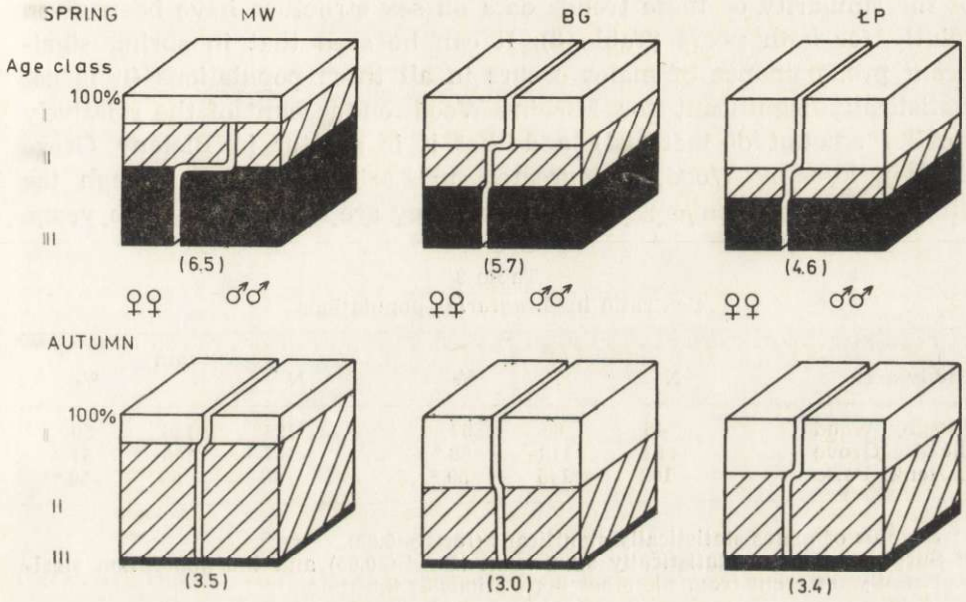


Fig. 3. Age structure of *A. agrarius* populations (%). (Figures in parenthesis indicate an average age of individuals).

(overwintered animals and those born in winter and spring) to class III (over 6 months old). The picture of age structure in spring (for the two years jointly) differs in accordance with habitat gradient (Fig. 3). The population in Łazienki Park is the youngest, and in Młociny Wood the oldest. The average age of individuals was 6.6 months for Młociny Wood, 5.7 for Bielany Grove and 4.6 for Łazienki Park. The percentage of the youngest individuals (born in spring) increases in the gradient from suburban areas to city centre, while the percentage of overwintered individuals decreases. Although the differences referred to are not statistically significant, they are clearly related to the given direction.

Variation with given direction does not occur in the picture of age structure in autumn. The population in Bielany Grove is the youngest, the average age of its individuals being 3.0 months. In the population from Młociny Wood and Łazienki Park the average age of individuals is very similar (respectively 3.5 and 3.4 months), although age structure is slightly different. In all three populations the oldest individuals (class III) *i.e.* those present in the study areas in spring, are very scantly represented in autumn.

Analysis of sex ratio revealed considerable predominance of males in the whole material, occuring in both years and in all populations. In view of the similarity of these trends data on sex structure have been given jointly for both years (Table 3). It can be seen that in spring significant predominance of males occurs in all three populations (it is not statistically significant for Młociny Wood on account of the relatively smaller amount of material), and that it is greater in Bielany Grove than in Młociny Wood, and greatest in Łazienki Park. Although the differences in percentages are minimal, they are observed in both years.

Table 3
Sex ratio in *A. agrarius* populations.

| Study area | Spring N | Spring N | Spring % | Autumn N | Autumn N | Autumn % |
|---|---|---|---|---|---|---|
| Młociny Wood | 46 | 60 | 57 | 135 | 136 | 50 |
| Bielany Grove | 81 | 113 | 58 * | 147 | 155 | 51 |
| Łazienki Park | 102 | 145 | 59 * | 66 | 95 | 59 ** |

* Surplus of males statistically significant (for $P=0.05$).
** Surplus of males statistically significant (for $P=0.05$) and the population significantly different from the other populations at the time.

They may thus be genuine differences, especially as the fact of there being significantly greater numbers of males in the population from Łazienki Park is confirmed in autumn. Sex ratio was balanced in autumn in the other two populations.

The numerical predominance of males in *A. agrarius* populations during the reproductive season has been described several times (H a i t l i n g e r, 1962; P e l i k a n 1965). It may be due to their greater activity, and the consequently greater trappability of sexually active males, or to sex disproportion in fact occurring in the population, *i.e.* due to difference in mortality rate of males and females. The authors of the studies referred to above consider that there is a real preponderance of males during this period in the case of the field mouse, due to greater mortality among young females born in the current year.

The balancing of sex ratio in autumn would therefore be due to higher mortality among males directly after the end of the reproductive season. Pelikan (1965) considers that the cause of this increased mortality is »exhaustion« by intrapopulation competition, intensified among males during the reproductive season.

The picture of age structure of females and males in our own study populations is not in complete accord with the opinions put forward by these authors, since it was found that the greatest sex disproportion occurs in the group of old adults in spring. It is similar at Młociny, Bielany and Łazienki, where 66, 62 and 64% of males were found respectively (Fig. 3).

In other age groups sex ratio is closer to 1:1, and therefore the spring predominance of males would be due to their better survival during winter. In autumn in the populations at Młociny and Bielany, as the overwintered individuals die, disproportion disappears, since in the youngest age groups a ratio of 1:1 is maintained. In the city population, however, although other age groups become predominant, the preponderance of males persists. This points to the differences in social relations or to the effect of other factors eliminating individuals from the city population in comparison with the outlying and suburban populations.

### 5.3. Intensity of Reproduction Processes

Intensification of reproductive processes in the population is revealed by such parameters as the percentage of gestating and lactating females, litter size, rate of attainment of sexual maturity and the percentage of sexually active individuals at the end of the reproductive season. The following groups of individuals have been distinguished in the present study: sexually mature or immature, and among mature animals active females (gestating, lactating, with fresh placental scars) and inactive females (*i.e.* not characterized by any of the above features, but having an enlarged uterus showing that they have already taken part in reproduction). In spring all sexually mature males were active, but in autumn no differentiation was made between mature individuals with seasonally retarded testes and young, as yet immature individuals, and therefore only the sexually active groups was distinguished among all males in autumn. Groups of individuals distinguished in this way occur in different percentages in the study populations, pointing to different degrees of intensification of reproductive processes (Fig. 4).

This is particularly well marked in the group of females in spring. In both 1975 and 1976 in Młociny Wood there were no immature females at all, and very few in Bielany Grove (9.0 and 10.4%), and far more in

the park population (26.8 and 30.4%). It might seem that this is the result of the increasing percentage of young individuals in the same gradient in the study populations, but it is not a question of a simple relation of this kind, since in the spring of 1975 the percentage of young individuals in all three populations was higher than in 1976, when there were 6—10 times fewer of them, particularly at Młociny and Bielany. The degree of sexual activity of females, however, remained unchanged in the two years. In this case it must be other, probably intrapopulation, factors which play a decisive part, causing the process of sexual matu-

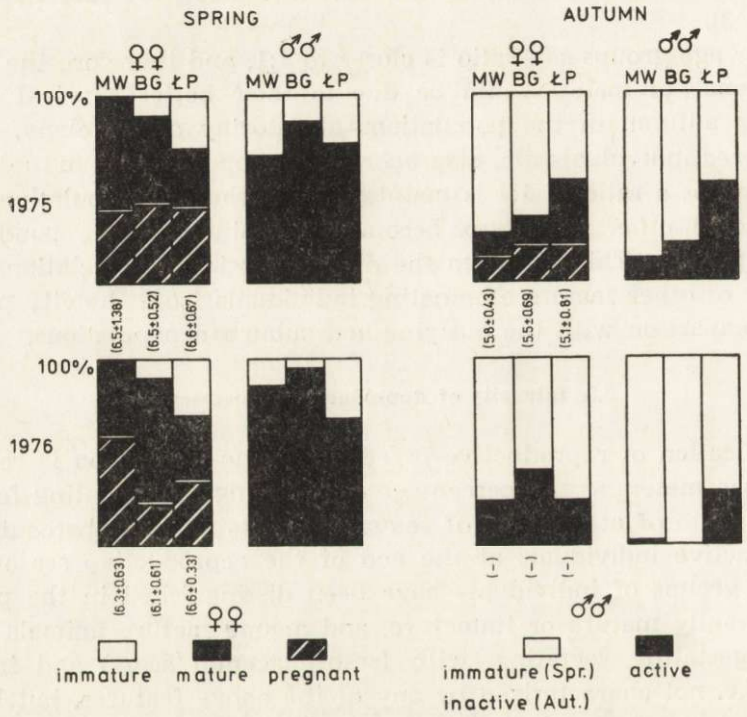


Fig. 4. Intensity of reproductive processes (figures in parenthesis indicate average litter size).

ration of females to be rapid in spring in Młociny Wood, slower in Bielany Grove and slowest in Łazienki Park. At the same time other parameters which could form indicators of reproduction are very similar in all populations. These include average litter size, which according to data for the two years was 6.3 in spring at Młociny, 6.3 also at Bielany and 6.6 in Łazienki Park (differences are not statistically significant), and the percentage of gestating females, which at least in 1975 was almost identical (40, 45, 43%).

In autumn differentiation in reproductive activity of the study population is more easily observed in the case of males. The largest number of active males was recorded in 1975 in Łazienki Park (52%), less in Bielany Grove (21%) and least at Młociny Wood (12%). In 1976 studies were carried out a week later (the middle day of the trapping period was October 4th) than in 1975 (September 26th). It is not known whether as the result of this shift in time, or as the result of the earlier ending of the reproductive season in 1976, that there were no gestating females and no active males recorded in the Młociny and Bielany populations, although 26% of the males were active in the park population. The percentage of active females was about that of males, although differences between populations were smaller. This means that reproductive processes last longer in the urban population.

The average litter in autumn was smaller than in spring, but was also similar in all three populations (Młociny $5.8 \pm 0.43$, Bielany $5.5 \pm 0.69$, Łazienki $5.1 \pm 0.81$, differences not statistically significant, $t$ Student test $P > 0.05$).

### 5.4. Survival

As intensity of reproductive processes is similar in both years, the different course taken by dynamics in numbers of the three populations in each of the study years (Fig. 2b) points to differences in intensification of mortality. The variations in numbers observed during the study period, rendering the city population in particular different from the other two populations, may also be due to its different natality or mortality.

The material available, however, permitted only of rough analysis of mortality processes in these populations. It was possible to grasp on its basis only the survival of the populations during the winter period, *i.e.* to find what percentage of the individuals forming the population in the autumn of 1975 survived to the spring of 1976; and survival during the reproductive season, finding what percentage of the spring population survived up to the end of the reproduction season in both years.

Table 4

Survival rate (%) of *Apodemus agrarius* populations.

| Study area | Summer 75 | Winter 75/76 | | Summer 76 |
|---|---|---|---|---|
| | | all ind. | autumn gener. | |
| Młociny Wood | 16 | 23 | 26 | 9 |
| Bielany Grove | 21 | 29 | 32 | 8 |
| Łazienki Park | 17 | 31 | 39 | 4 |

For this purpose, on the basis of the index of relative population density and the percentage formed in the population by chosen groups of individuals, calculation was made of the index of relative numbers of these groups during time $t$ and $t+1$. On this basis an estimate was made of survival rate during the periods given above (in accordance with the equation $(N_{t\ 1} \times 100\%): N_t$ (Table 4). In general it may be said that winter survival was greater than that of the summer in all the populations and fluctuated within limits of 20—30%, and that during the reproductive season of 1975 survival was greater than in 1976. The youngest autumn individuals exhibit particularly distinct trends in survival during the winter period: they overwintered more successfully in the urban population, and least successfully in Młociny Wood.

### 5.5. Body Weight of Adult Individuals

One of the characteristics which may form evidence of the population's living conditions is the body weight of its individuals. Comparison was made of the average body weight of adult males ($\geqslant$5 months old) in three populations. The body weight of adult males is not subject to significant further increase and it may therefore be assumed that small

Table 5
Mean body weight of adult males (g).

| Time | | Młociny Wood | Bielany Grove | Łazienki Park |
|---|---|---|---|---|
| Spring | 1975 | 27.3±3.16 | 27.1±1.47 | 29.7±1.68 |
| | 1976 | 27.0±0.87 | 27.2±0.72 | 29.1±0.86 |
| Autumn | 1975 | 23.1±2.35 | 27.5±1.9 | 29.5±1.99 |
| | 1976 | 20.7±2.77 | 20.1±5.76 | 24.7±7.32 |

differences in the age structure of the males used for the comparison could not significantly contribute to obtaining differences in average weights (Table 5), especially in view of the fact that the regularity found is repeated in all four trapping series. It is always the males in the urban population which have the greatest weight, and those in the population of Młociny Wood which have the least.

## 6. DISCUSSION

It is clear from the analysis made in this study that a large number of ecological processes, and also the dynamics of numbers of the study populations, change with the urbanization gradient of habitats occupied by the field mouse. The material available did not permit of completely

determining the differences in biotic and abiotic factors of the habitat in different places in the study gradient. It can be stated, however, that these habitats vary in their attractiveness to rodent species, as is most clearly shown by the index of species diversity (Table 2), which is highest in Młociny Wood, lower in Bielany Grove and lowest in Łazienki Park.

The population processes observed may by affected by: (1) intrapopulation relations, (2) relations prevailing in the rodent community and (3) factors of the environment, understood in a wide sense, which act directly or indirectly through the structure of both community and population. The hypothesis may be put forward that the reciprocal relations between these three kinds of factors are formed differently in the study habitats (Fig. 5).

In Młociny Wood the field mouse population is probably subject to intensive pressure of interrelations with other species and the chief

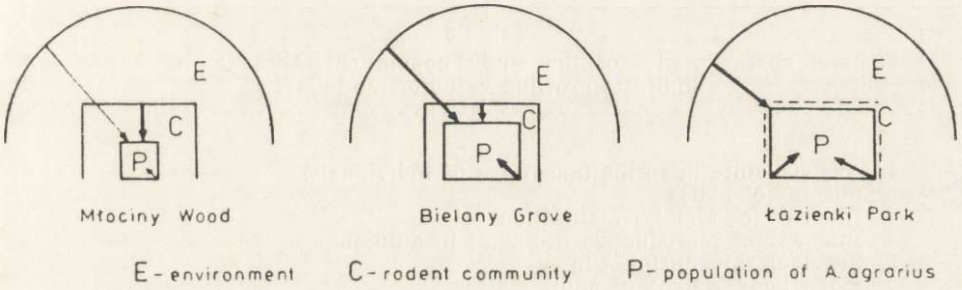


**Fig. 5. Hypothetic relationships between environmental factors, community and population in urbanization gradient.**

forces limiting the study population are social relations with other species, competition and limitation (in both time and space). In the city population, however, the pressure from the community disappears and intrapopulation interactions become more important. These interactions might be especially strong as a result of the specific distribution of mice in the park habitat. Not all the habitats created by man in parks are equally favourable to rodents, and consequently distribution of these mice in parks is characterized by large aggregations in the most favourable spots (clumps of trees and bushes, hedges), separated by spaces devoid of rodents (extensive lawns, network of roads and paths). In such aggregations, when the density of the rodents is considerable, a strong social hierarchy may be formed determining the course taken by many popu-

lation processes. In Bielany Grove there is an intermediate situation although more similar, due to the more uniform (for mice) habitat, to the situation in Młociny Wood.

The results, summarised and set out in Table 6, lead to the conclusion that where the population of *A. agrarius* is released from the pressure of the community and begins to be more subject to intrapopulation control, the limiting factors are transferred from mortality to natality. This may be gathered, *e.g.* from the lowest maturation rate of young females in spring in the park population (line 3 in Table 6). This limitation is most certainly caused by social relations unfavourable to maturation and to participation in reproduction of too great a number of females. On the other hand the youngest individuals occur in this very population (line 1), which indicates that survival rate during the nest period and the initial period of independent life was much higher than in other populations. There is distinct prolongation of the reproduction season in the city population as compared with the other two populations (line

Table 6

General characteristics of the study populations. Direction of arrow indicates growing value of the index.

| | MW BG ŁP |
|---|---|
| 1. Age structure in spring (mean age of individuals) | ← |
| 2. Surplus of males | → |
| 3. Intensity of females maturation | ← |
| 4. Intensity of reproductive processes in autumn | → |
| 5. Survival rate during winter | → |
| 6. Mean body weight of adult males | → |

4). This may be due to the fact that in both the study years the density of the park population was lowest in autumn (Fig. 2b), which would create a situation favourable to prolonged reproduction if habitat conditions were also favourable. It seems that in autumn in the park, the population find such favourable conditions owing to the abundance of seeds and the slightly milder microclimate. It is probably these same population factors (lower density, favourable social relations) and the absence of interspecific competition that provide the explanation for the better survival rate of individuals from the city population (line 5).

The higher body weight of adult individuals in the town population in comparison with the other two populations (line 6) can be explained most simply by the more favourable food conditions in the park habitat. It is not however easy at present to state whether these conditions are more favourable owing to the greater abundance of food produced, or to

the lack of competition from other rodents (In order to solve this problem studies are being carried out at the present time on the composition of the food of the field mouse in urban and more natural habitats).

It is, however, impossible on the basis of the material available to explain the increase in numerical predominance of males in the urbanization gradient. Undoubtedly some intrapopulation factors, which act with different strength in the gradient studied, are responsible for this.

There are no studies in literature based on rodent material derived from urbanized areas, the relatively largest number on this subject being ornithological studies. The data given in such studies show that changes similar to those given above for rodents occur in an urbanization gradient in bird populations and communities. The bird populations of towns differ from those of other areas in respect of mortality (Batten, 1974), fecundity (Božko, 1971) and effective reproduction (Batten, 1974). Nuorteva (1971) additionally found the smallest number of bird species, and their greatest biomass, in central urban areas as compared with suburban and more natural areas.

It would therefore appear that we have succeeded in the study presented here in grasping ecological phenomena which are not only connected with the particular species but may be generally characteristic of synurbic vertebrate populations. The phenomena reported here, their significance and mechanisms should be the subject of further studies.

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Roman ANDRZEJEWSKI, Joanna BABIŃSKA-WERKA, Joanna GLIWICZ i Jacek GOSZCZYŃSKI

## PROCESY SYNURBIZACJI W POPULACJI *APODEMUS AGRARIUS*. I. CHARAKTERYSTYKA POPULACJI W GRADIENCIE URBANIZACJI

Streszczenie

Prezentowane w niniejszej pracy materiały pochodzą z przeprowadzonych w latach 1975—1976 badań nad zespołem gryzoni i populacją *Apodemus agrarius* (Pallas, 1771) na trzech terenach leżących w gradiencie urbanizacji, od centrum Warszawy ku jej północnym peryferiom. Rejon śródmiejski reprezentował Park Łazienki, przedmiejski — Lasek Bielański a podmiejski — Las Młociński. Gryzonie odławiano dwukrotnie w ciągu roku (wiosną i jesienią) w linię pułapek, a następnie poddawano je sekcji określając płeć, ciężar i kondycję rozrodczą osobników, a także oznaczano ich wiek. Ogółem złowiono 1980 gryzoni należących do 5 gatunków (Tabela 1, Ryc. 1). Badane tereny różniły się składem i różnorodnością gatunkową zespołu gryzoni, który najbogatszy był w Lesie Młocińskim, a najuboższy w Parku Łazienki (Ryc. 1, Tabela 2). Ubożeniu zespołu towarzyszy wzrost dominacji myszy polnej, która jest gatunkiem wybitnie synurbijnym t.zn. wnikającym i rozprzestrzeniającym się w miastach. Zagęszczenie myszy polnej na badanych terenach było podobne, choć przebieg jego zmian miał charakter odmienny (Ryc. 2). Ponadto badane populacje charakteryzowały się odmienną strukturą wiekową (Ryc. 3), wzrostem przewagi liczebnej samców zgodnym z gradientem urbanizacji (Tabela 3), innym przebiegiem procesów rozrodczych (Ryc. 4), lepszą przeżywalnością w okresie zimy populacji śródmiejskiej (Tabela 4), oraz wzrastającym, wraz ze stopniem urbanizacji terenu, ciężarem ciała dorosłych osobników (Tabela 5).

Odmienność tylu parametrów populacyjnych (podsumowanych w Tabeli 6) świadczy o poważnych zmianach zachodzących w ekologii (a być może także fizjologii i genetyce) myszy polnej, na skutek wnikania jej do środowiska zurbanizowanego. Postawiono hipotezę (Ryc. 5), że obok specyfiki samego środowiska miejskiego, poważną rolę w tych przemianach odgrywa wydostanie się synurbijnych populacji tego gatunku spod kontroli zespołu gryzoni, w skład którego wchodzi on w środowiskach pozamiejskich.