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**Ants (*Formicidae*) in the Agroecosystems Affected by Intensive Pressure
of Industrial Emissions**

Mrówki (*Formicidae*) w agroceozach podlegających intensywnej presji emisji przemysłowych

Муравьи (*Formicidae*) в агроценозах, подвергнутых интенсивному воздействию промышленных эмиссий

INTRODUCTION

Deterioration of environment in the agroecosystems under the influence of intensive industrial pressures causes intensification of homeostatic reactions leading to reestablishing and preservation of ecological balance on these territories. At the same time, as a result of unsettled balance in the ecosystem, the phenomena of rivalry among fauna intensify (16).

The present investigations were to point to the intensifying rivalry between particular groups of invertebrate animals and to the possibilities of utilizing these changes as bioindicators of a degree of devastation and transformation as well as restoration of the agroecosystems damaged by industrial emissions. In the present investigation the interest concentrates mainly on predatory epigeic fauna, and in this context, on phenomena of the rivalry of ants with the remaining group of animals, and particularly with spiders and ground beetles.

THE AREA AND METHOD OF INVESTIGATIONS

The investigations were carried out in the years 1972—1977 in agrocenoses of the following regions, where a strong pressure of industrial emission was observed:

1. The region of the Nitrogen Fertilizer Plant in Puławy, which showed the intensive pressure of emissions resulting from the production of fertilizers.
2. The region of the Tarnobrzeg Sulphur Basin where sulphur is mined and processed.
3. The region of the Cement-Limestone Basin at Nowiny near Kielce connected with the production of lime and cement.

In these regions the investigations of fauna were carried out. They were based on the system of research stations in which complex investigations concerning the influence of various emissions on soil, water, plants, wild vegetation and micro-organisms (11, 12, 13) were executed.

In the investigations of fauna the method of Barber's wet traps (1, 5, 9, 10) was employed in order to grasp animal activity, and the biocenometric method of soil sample analysis (2, 9, 10) for evaluating the numbers and distribution of animals. Moreover, in the above regions Petal and her coworkers (4, 8) carried out the investigations on ant adaptation to unfavourable environmental conditions, simultaneously evaluating individual population parameters. In the region of the Nitrogen Fertilizer Plant in Puławy Górny (3, 7) and Sokółowski (14, 15) investigated the changes in ant distribution and the composition of their food in the woods which were subject to intensive industrial emissions.

RESULTS

A. THE REACTION OF FAUNA TO POLLUTION

The analysis of six-year investigations carried out in agrocenoses which were subject to strong pressure of intensive industrial emissions allowed to grasp a number of regularities, which provided the background for showing the phenomena of ant rivalry with other animal groups.

The changes in agrocenoses caused by intensive industrial emissions had clearly a zonal character. Around new factories newly damaged zones arose. The pace of their formation was conditioned by a particular kind and intensity of emission as well as by types of agrocenoses. Those zones were distinguished on the basis of complex investigations concerning changes in soil, water, plants, wild vegetation, recultivational and prophylactic measures indispensable to functioning of those agrocenoses.

In the zone I which showed the smallest damages and modifications, where periodical prophylactic measures were necessary to normal functioning of agrocenoses, there appeared changes in frequency of animals, and consequently in their distribution, which acquired clearly agglomerational character, grouping animals into particular ecological niches. Dominating species changed, and then sensitive species withdrew.

In the zone II which showed medium damages, where continuous prophylactic, as well as recultivational measures were necessary to functioning of agrocenoses, there appeared changes in domination of particular animal groups within one trophic level, and then the whole groups of sensitive animals withdrew, and were replaced by other groups, with no change of a trophic level.

In the zone III, which showed great damages, where complete recultivation of agrocenoses and changes in the profile of production were necessary to their functioning, there appeared a very strong decrease in the number of animals and annihilation of particular trophic levels, usually predatory epigeal fauna, feeding on immigrants flying over from the undamaged territories, remained.

The recultivation of devastated agrocenoses, in spite of the fact that they were still subject to intensive emissions, caused instantaneous reconstruction of fauna, while the degree of reconstruction depended on the number and species of immigrants flying over to these areas from the affected agrocenoses.

B. THE REACTION OF ANTS TO POLLUTION

In spite of the fact that agrocenoses do not belong to the habitats the most actively penetrated by ants, the influence of industrial emissions could also be noticed here.

In the Tarnobrzeg Sulphur Basin, polluted intensely with gaseous compounds and sulphur powder, the quantity as well as the percentage of ants in the group of predatory epigeal fauna (Fig. 1) increased together with the increasing degree of pollution and modification of agrocenoses. This increase was the result of analogical decrease in the number of spiders. In the zones of the agrocenoses polluted to the highest degree with sulphur compounds, that is on the fields surrounding the mine, ants constituted the predominating group among the total of trapped animals. The group of atmobionts flying over to devastated fields from the territories which showed no negative influence of sulphur compounds was also numerous. The number as well as the percentage of ants were negligible (Fig. 2) in soil samples and showed no essential change. At the same time, together with the increasing degree of pollution, the number of the soil samples, in which animals had been found, decreased. The number of ant species found on the fields was small and did not vary much in particular zones of the influence of emission (Table 1). The species dominating in traps and in soil samples was *Lasius niger* L., and it determined the percentage of ants along with increasing environmental devastation. In the zones II and III *Myrmica ruginodis* Nyl. and *Myr-*

Table 1. The dominating ant species in the particular zones which are subject to industrial emissions — Pulawy 1972—1978
(in indiv./trap/month)

Species	Destruction					Restoration					Total
	FK	FD	ZD	ZF	ZW	FR	CT	FR	ZW	CT	
<i>Myrmica laevinodis</i> Ny l.	7.1	4.1	0.2	0.3	1.4	0.2	3.4	0.2	1.4	0.2	3.4
<i>M. ruginodis</i> Ny l. (<i>M. rubra</i> (L.))	11.1	4.3	0.8	—	2.1	—	0.2	1.4	2.1	0.2	3.4
<i>M. scabrinodis</i> Ny l.	0.9	3.7	0.6	0.6	1.3	0.6	—	0.1	0.4	—	0.2
<i>M. sabuleti</i> Mein.	0.1	3.7	0.9	0.7	0.4	0.7	—	4.2	0.4	—	0.2
<i>M. lobicornis</i> Ny l.	0.4	1.4	0.8	0.5	1.2	0.5	—	4.1	1.2	—	0.2
<i>M. schencki</i> Em.	0.2	0.1	—	—	—	—	—	—	—	—	—
<i>Leptothorax acervorum</i> (F.)	0.1	0.1	—	—	0.1	0.1	—	—	0.1	—	—
<i>L. muscorum</i> (Ny l.)	—	—	—	—	—	—	—	—	—	—	—
<i>Tetramorium caespitum</i> (L.)	0.1	0.1	0.1	0.5	0.2	0.1	—	0.1	0.2	0.1	0.1
<i>Lasius niger</i> (L.)	9.0	2.8	0.4	2.7	0.5	0.6	—	0.6	0.5	6.2	6.2
<i>L. fuliginosus</i> (L a t r.)	—	—	—	0.1	—	—	—	—	—	—	—
<i>Formica fusca</i> L.	1.7	—	—	0.1	0.6	0.2	—	0.1	0.6	—	—
<i>F. cinerea</i> Mayr.	0.1	—	0.1	0.1	0.1	0.1	—	6.5	0.1	—	—
<i>F. pratensis</i> Retz.	0.1	0.5	0.1	3.4	0.1	0.1	—	10.8	0.1	—	—
<i>F. polyctena</i> Foerst.	0.1	0.1	—	0.1	0.1	0.1	—	—	0.1	—	—
<i>F. sanguinea</i> Latr.	0.2	0.1	—	5.1	0.1	—	—	0.1	0.1	—	—
Number of individuals	1186	910	125	2294	1230	715	363	715	1230	363	7523

Explanation: FK — forest control, FD — forest devastated, ZD — zone devastated, ZF — zone destroyed, ZF — zone fertilized, ZW — zone watered, FR — field recultivated, CT — field control.

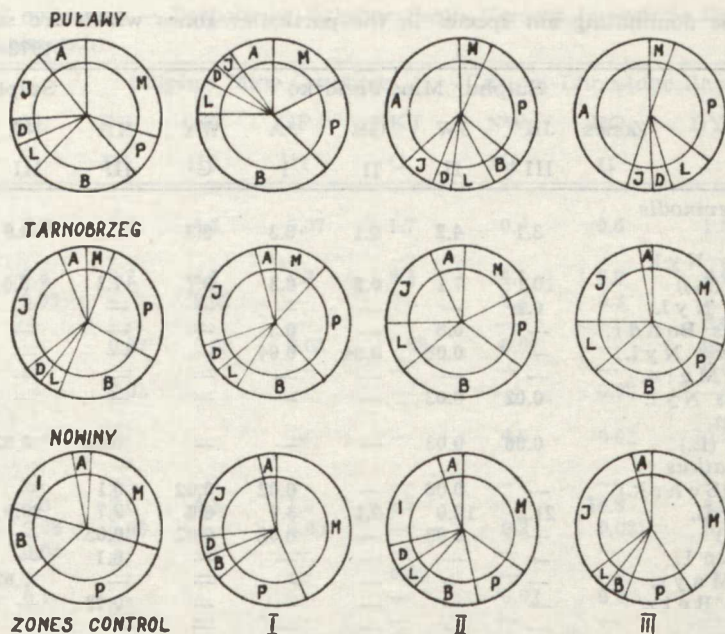


Fig. 1. Changes in the percentage of trapped predatory epigeal animals in Barber's traps in the particular zones which are subject to industrial emissions; D — earthworms, L — larvae, P — spiders, M — ants, B — carabids, A — atmobionts, I — other insects

mica laevinodis Ny l. joined the group of dominating species. The remaining species appeared sporadically, represented by small numbers of individuals.

A completely different situation was observed in the region subject to the emission from the Nitrogen Fertilizer Plant in Puławy (Fig. 1). In contrast to the area polluted with sulphur, the decrease of the percentage of ants in traps was observed there, accompanying the increase of the degree of pollution and environmental modification. At the same time the percentage of spiders increased gradually and was the highest in the neighbourhood of the factory. Consequently, the process of replacement of particular animal groups within predatory epigeal fauna took the opposite direction there than in the areas influenced by sulphur gases and powder. The percentage of atmobionts flying over to devastated fields from the territories still free from negative influence of the emission increased to a great extent. In this region the number of trapped animals exhibited much stronger tendency to decrease than in the region of Tarnobrzeg. Simultaneously, the temporary increase of the number of trapped animals, particularly ants, was observed on the fields situated in the zone II. In soil samples (Fig. 2) the decrease of the number of

Table 2. The dominating ant species in the particular zones which are subject to 1972—1978 (in

Species	Zones	Sulphur Mine Jeziorko					Sulphur Mine		
		JK	JW	GR	JA	WY	KA	NA	CY
		III	II	II	I	C	III	III	II
<i>Myrmica laevinodis</i> Nyl.		3.1	4.2	0.1	0.3	0.3	0.02	0.9	0.3
<i>M. ruginodis</i> Nyl. (<i>M. rubra</i> (L.))		10.1	7.1	0.2	0.3	0.7	17.1	3.0	0.1
<i>M. rugulosa</i> Nyl.		0.2	—	—	—	—	—	—	—
<i>M. specioides</i> Bondr.		—	0.8	—	0.3	—	—	—	—
<i>M. scabrinodis</i> Nyl.		—	0.08	0.04	0.04	—	—	—	0.9
<i>M. sabuleti</i> Mein.		—	—	—	—	—	—	—	—
<i>M. lobicornis</i> Nyl.		0.02	0.03	—	—	—	—	—	—
<i>Tetramorium caespitum</i> (L.)		0.06	0.03	—	—	—	0.02	0.02	—
<i>Strongylognathus testaceus</i> (Schrk.)		—	0.06	—	0.02	0.02	0.1	—	—
<i>Lasius niger</i> L.		21.2	12.0	9.1	3.7	6.6	9.7	29.9	39.0
<i>L. flavus</i> (F.)		—	0.03	—	0.02	0.02	0.05	—	0.3
<i>Formica fusca</i> L.		—	—	—	—	—	0.1	—	—
<i>F. cinerea</i> Mayr.		—	—	—	—	—	—	0.02	—
<i>F. pratensis</i> Retz.		—	—	—	—	—	0.08	—	—
<i>F. rufa</i> L.		—	—	—	—	—	—	—	—
<i>F. polyctena</i> Foerst.		—	—	—	0.02	—	—	—	—
Number of animals		1716	861	422	217	431	1088	1547	238

Explanation: Sulphur Mine Jeziorko: JK — Jeziorko mine, JW — Jeziorko Machów; KA — Kaimów, NA — Nagnajów, CY — Cygany, MO — Mokrzyszów, SL — Mine, GP — Grzybów field recultivated, GKT — Grzybów control, Cement-Zagórze control.

animals was stronger and still earlier than that in traps, along with the rapid decrease of the number of soil samples in which animals were found. Alike in traps, the strong decrease of ant percentage, simultaneous with the increase of the percentage of spiders, was observed.

In this region a slow decrease of the number of ant species accompanying increasing environmental pollution (Table 2) was noted. There also appeared greater changes in the domination of particular species than in the region previously mentioned. *Myrmica ruginodis* Nyl. dominated decidedly on control territories and only *M. sabuleti* Mein. and *L. niger* L. had also a small share, the latter dominating in the regions affected by sulphur. Together with increasing pollution of the environment, not only the number but also the percentage of *M. ruginodis* Nyl. decreased. *M. sabuleti* Mein. became the dominating species. In the zone II, however, the group of dominating species was joined by *L. niger* L., whereas in the zone III, where the destructions were the greatest, ants were not numerous. Moreover, all five species, because of small and irregular catch, belonged to the class of accessory species.

industrial emissions — Tarnobrzeg Sulphur Basin, Cement-Limestone Basin Nowiny indiv./trap/month)

Machów		Sulphur Mine Grzybów				Cement-Limestone Basin Nowiny			
MO	SL	DB	GK	GP	GKT	NW	PO	DY	ZG
II	I	III	III	III	C	III	II	I	C
1.2	0.2	0.4	4.2	0.07	1.7	0.4	0.6	1.3	1.1
3.8	0.8	0.2	3.7	1.3	2.4	4.1	5.0	6.9	2.8
—	0.03	—	0.02	—	—	0.8	0.3	0.4	0.02
—	—	—	—	—	—	—	—	0.02	—
0.06	—	0.07	0.02	0.02	0.09	0.07	—	0.02	0.02
—	—	—	—	—	—	—	—	0.02	0.5
—	—	0.03	—	—	—	—	0.02	—	0.5
—	—	—	—	—	—	4.9	0.02	30.2	0.02
—	—	—	—	—	—	—	—	—	—
2.3	3.3	2.6	4.3	1.3	4.5	30.3	14.8	4.2	21.3
0.06	0.08	0.03	—	0.03	—	0.2	0.02	0.12	—
—	0.05	—	—	—	—	—	—	—	—
—	—	—	—	—	0.02	—	—	—	—
0.02	0.1	—	—	—	—	0.02	0.2	—	—
—	—	0.1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	0.2	—
354	189	423	144	587	297	1722	965	1738	1046

Village, GR — Grębów, JA — Jamnica, WY — Wydrza control; Sulphur Mine Słezaki; Sulphur Mine Grzybów: DB — Dobrów sulphur dump, GK — Grzybów -Limestone Basin Nowiny: NW — Nowiny, PO — Posłowice, DY — Dyminy, ZG —

In the agrocenoses subject to the influence of troublesome powders from the Cement-Limestone Basin at Nowiny near Kielce, no negative influence on ants was observed (Fig. 1) in contrast to spiders, which constituted a rival group in the above mentioned regions. There, their number as well as percentage decreased along with the increase of pollution with dust. Although the percentage of ants in soil samples was low (Fig. 2), it grew in the zone polluted to the highest extent. Changes in the composition of ant species, apart from the zone I, were negligible (Table 2), *L. niger* L. being decidedly the dominating one. *M. ruginodis* Ny l. had only a small share in the dominating group, and *M. laevinodis* Ny l. joined the group temporarily and only in the control territory.

The station situated in the zone I was in the region of intensive SO₂ fall, coming from high emitters of a cement plant, and within this distance from the plants the fall was not neutralized, by the cement and lime powders, which was the case in the zones II and III. That is why in the station situated in the zone I, the prevalence of such dominating species as were observed in the Sulphur Basin near Tarnobrzeg was noted.

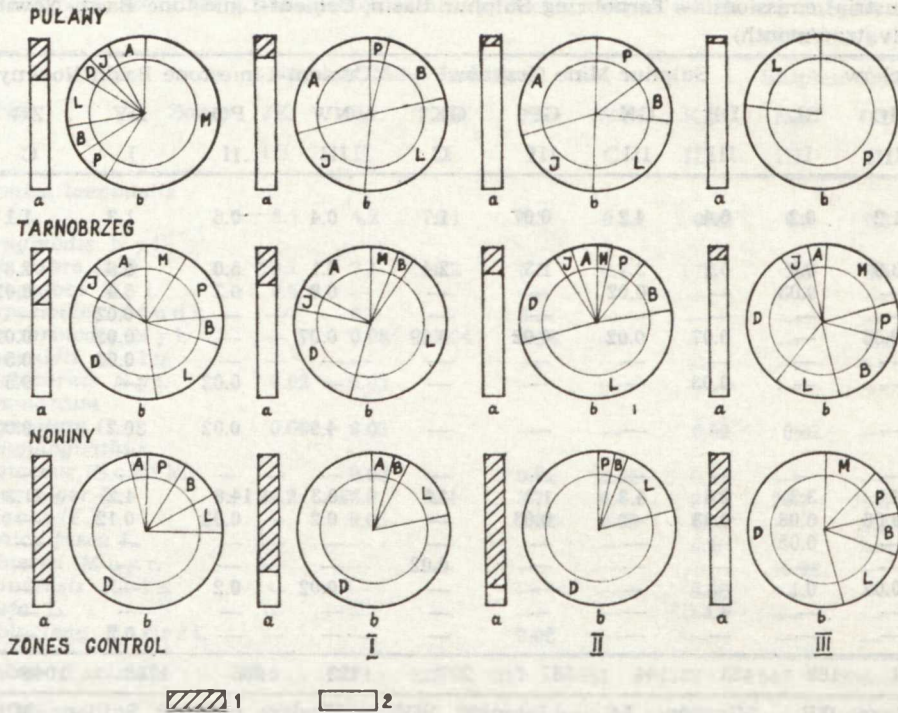


Fig. 2. Changes in the percentage of caught predatory epigeal animals in soil sample in the particular zones which are subject to industrial emissions; a — proportion of samples 1 — with soil animals, 2 — without animals, b — percentage of animals; for explanation of symbols see caption to Fig. 1

DISCUSSION

Agrocenoses, whose characteristic features are quick changes of the environment and particularly great changes caused by mechanical cultivation destroying ants, nests, do allow ants to occupy these areas permanently but only to penetrate them temporarily. This penetration, occasionally very intensive, makes it possible to count ants among constant components of fields, playing an important role, especially in the group of predatory epigeal fauna. This statement is supported by the investigations of predatory animals carried out on the meadows (6), since in the basic mass the species dominating on the fields and on the meadows are similar, and the differences result primarily from the smaller number of species living on the fields. Similarly, the analysis of food composition of these dominants on the meadows (6) makes it possible to include ants in the group of predatory epigeal fauna.

In the unaffected control agrocenoses, ground beetles dominated de-

cidedly, and spiders to a lesser extent, the percentage of ants being low. In the agrocenoses which were subject to the pressure of intensive industrial emission, where the deterioration of the environmental conditions took place, the withdrawal of ground beetles was observed, along with the growing importance of spiders and ants. The basic factor of those changes was the reduction of the phytophagous fauna living on plants, which was observed at that level of destruction. Consequently, temporary shortages in accessibility of food appeared, which was not tolerated by ground beetles.

The further aggravation of food shortages resulting from almost complete reduction of phytophagous fauna along with, connected with it, specialized predatory animals, brought about the necessity of utilizing another source of food, less easily accessible in unaffected agrocenoses, i.e. brisk atmobionts. In the regions of intensive industrial pressure, they were flying over from unaffected agrocenoses and tried to colonize devastated fields. In the zones of intensive industrial pressure, they were caught by ants in great quantities, their activities being additionally inhibited as a result of staying in the regions with high concentration of toxic substances (3, 7). In this zone the importance of spiders and of ants was similar, with simultaneous elimination of predatory ground beetles.

Only this group of animals could stay in the zones of the highest pollution and was able to adapt to often extremal and specific conditions of life. In the region of Tarnobrzeg Sulphur Basin, that group consisted of ants, which could regulate in the active way the level of pH in the soil in the neighbourhood of ants nests (4, 8). In the region of the Nitrogen Fertilizer Plant in Puławy in the neighbourhood of ants nests, a remarkable increase of denitrificational processes (4, 8) was observed, but spiders constituted decidedly the dominating group there. This phenomenon is explained thanks to a detailed analysis of microclimatic conditions (9, 10, 16) which points to an enormous increase of insolation, drying up of the soil and a great difference between the maximum and minimum temperatures within twenty-four hours. This seems to contribute to the elimination of ants.

Great adaptational capabilities of ants are also proved by the fact that they took possession of the agrocenoses situated in the highly polluted with dusts regions, in which spiders were eliminated.

To support the regularities enumerated above, one could add that the changes in the relations among particular groups of predatory epigeal fauna were observed. This observation was made in the regions with the highest emission on the recultivated fields. There, the ground beetles and spiders became the dominating group immediately after the recult-

ivation had taken place. Ants were the withdrawing group, in spite of the fact that they dominated decidedly on a neighbouring field, which was also cultivated, but without any application of recultivation measures, whereas the percentage of spiders was low.

CONCLUSION

1. In spite of the limited possibilities of building nests, ants constitute an important group of predatory epigeal fauna in these surroundings, thanks to their active penetration of fields.

2. The percentage and importance of ants in agrocenoses increased along with the growing destruction of agrocenoses caused by industrial emissions. They replace ground beetles and, later, spiders in these agrocenoses.

3. Due to their social organization of life and capabilities of active adaptation to the environment, they replace predatory insects in the zones of the greatest environmental modification.

4. Changes in the relations among individual groups of predatory epigeal fauna, and particularly ants, prove to be a very important indicator both of a degree of devastation and restoration of agrocenoses.

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STRESZCZENIE

W latach 1972—1978 w agrocenozach objętych intensywnym oddziaływaniem wysokich emisji przemysłowych przeprowadzono badania nad reakcjami mrówek jako części składowej drapieżnej fauny naglebowej na zmiany środowiska spowodowane tymi emisjami. Badaniami objęto agrocenozy w rejonie oddziaływania Zakładów Azotowych w Puławach, w Tarnobrzeskim Zagłębiu Siarkowym oraz w Zagłębiu Cementowo-Wapienniczym Nowiny k. Kielc. Zastosowano metodę analizy gleby pobieranej przy pomocy cylindra oraz odłów zwierząt w mokrą pułapki Barbera. Próby pobierano raz w miesiącu w punktach, w których prowadzono kompleksowe badania rolnicze.

Badania wykazały istotne zmiany stosunków ilościowych w obrębie drapieżnej fauny naglebowej w zależności od rodzaju emisji, stopnia zniszczenia środowiska oraz efektów jego odbudowy. Na penetrację agrocenoz przez mrówki nie miały wpływu emisje pyłowe w Zagłębiu Cementowo-Wapienniczym Nowiny, natomiast w rejonie Puław wykazano eliminowanie mrówek, przede wszystkim ze względu na radykalną zmianę czynników mikroklimatycznych. W Tarnobrzeskim Zagłębiu Siarkowym dzięki możliwościom adaptacyjnym, a szczególnie obniżaniu *pH* gleby w rejonie mrowisk stanowiły one grupę zdecydowanie dominującą w obrębie drapieżnej fauny naglebowej. W zależności od rodzaju emisji i stopnia przekształcenia środowiska zmieniało się nie tylko natężenie penetracji mrówek w agrocenozach, ale i skład gatunkowy, a przede wszystkim zmianom ulegały gatunki dominujące. Zmiany zachodzące zarówno w obrębie drapieżnej fauny naglebowej, jak i zmiany składu gatunkowego oraz dominantów u mrówek były tak znaczne i charakterystyczne, że mogą znaleźć zastosowanie jako wskaźnik stopnia przekształcenia i odbudowy agrocenoz.

РЕЗЮМЕ

1972—1978 гг. в агроценозах, находящихся под интенсивным воздействием промышленной эмиссии, были проведены исследования над реакцией муравьев, являющихся составной частью хищной напочвенной фауны, на изменение среды, вызванной эмиссией. Исследованиями были охвачены агроценозы в районе воздействия азотного комбината в Пулавах, в тарнобжегском серном бассейне и в цементно-известковом комбинате Новины недалеко от Кельце. Применен метод анализа почвы, которая бралась для исследований при помощи цилиндра, а также отлов животных в мокрые ловушки Барьера. Пробы брались один раз в месяц в тех пунктах, в которых проводились комплексные сельскохозяйственные исследования.

Исследования показали существенные изменения количественных соотношений в хищной напочвенной фауне в зависимости от вида эмиссии, степени загрязнения естественной среды и эффектов его восстановления. На пенетрацию агроценозов муравьями не имели влияния пылевые эмиссии цементно-известкового комбината Новины, в то же время в районе Пулав обнаружено отсутствие муравьев, связанное прежде всего с радикальным изменением микроклиматических факторов. Муравейники решительно доминировали в хищной напочвенной фауне Тарнобжегского серного бассейна благодаря их адапционным способностям, прежде всего благодаря снижению рН почвы в районе муравейников. В зависимости от вида эмиссии и степени деградации среды изменялась не только концентрация пенетрации муравьев в агроценозах, но и видовой состав, а прежде всего подвергались изменению доминирующие виды. Изменения, происходящие в хищной напочвенной фауне, в видовом составе и в составе доминантов, настолько значительны и характерны, что могут служить показателем деформации и восстановления агроценозов.