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THE EFFECT OF SULPHUR INDUSTRY ON EPIGEIC AND SOIL FAUNA

ABSTRACT

The study was carried out in 1973—1977 in the Tarnobrzeg Sulphur Basin, in the region of the Sulphur Plants at Machów, and the hole sulphur mine Jeziórko, as well as in the reclaimed areas at the sulphur store and at the mine field at Grzybów. Pitfall traps and a soil sampler were used to catch the epigeic and soil fauna. It has been found that the effect of dust and gaseous sulphur compounds from emissions is more pronounced than the effect of changes in atmospheric conditions in successive years, the former being of zonal character. Sulphur emissions affect proportions among particular groups of the epigeic predatory fauna. In particular, the values of ecological indices are lowered for spiders and increased for ants. Some species and dominant groups are exchanged, and finally the whole animal world is destroyed. The reclamation and cultivation of the polluted areas was followed by re-establishment of the fauna, even if they were still subjected to pollution. But the species composition and proportions among particular groups of the restored fauna differed from the original.

INTRODUCTION

Changes in environmental conditions, including the impact of industrial factors, bring about specific defensive responses in biological systems, directed towards maintaining their functioning. According to Odum [5], the most important responses are such as changes in the distribution pattern, changes in numbers and dominance structure, decrease in the number of species, and a total decrease in production. These processes are analysed in the present study as bioindicators of the degree of destruction and transformation of agrocoenoses, on the one hand, and as a measure of the success of particular reclamation treatments, on the other.

STUDY AREA AND METHODS

The study was carried out in 1973—1977 in three areas of the Tarnobrzeg Sulphur Basin:

1. in the region of the hole sulphur mine at Jeziórko, where the effect of gaseous emissions from mine fields was studied at six points,
2. in the region of the sulphur plant "Siarkopol" at Machów, where the effect of gaseous emissions from processing plants was studied at five points,
3. in the region of the hole sulphur mine at Grzybów, near Staszów, where the effect of gaseous emissions from mine fields and the effect of dusts from sulphur stores were studied at five points each, as well as the processes occurring in animal communities in two adjoining 40 ha reclaimed fields, at one point on each.

Animals were sampled in the permanent plots — stations — where a team of research workers concurrently analysed the effect of sulphur compounds on ground waters, soil, crop plants, natural plant communities, and microorganisms [7].

Animal samples were taken by means of pitfall traps [1, 2, 6]. There were 20 traps at each station, functioning in monthly periods three times over the growing season. At the same time 25 soil samples were taken at each station three times over the growing season, by means of a sampler 10 cm high and 10 cm in diameter. The soil samples were extracted in a modified Tullgren funnel (with water jacket) and also selected by hand to isolate pupae and little mobile forms.

The collected materials were statistically processed, the following indices being calculated: numbers, catchability, frequency, dominance, and index of the total ecological importance [3, 4, 5, 8].

RESULTS

A total of 66 905 invertebrate animals were collected during the five-year study period. Among them, the epigeic predatory fauna classified into carabids, ants, and spiders was analysed in detail, and soil animals classified into insect larvae, myriapods, and earthworms, these groups being most representative of the agrocoenoses under study.

The effect of gaseous emissions from mine fields

The study was conducted in the region polluted with gaseous emissions of sulphur compounds from mine fields of the hole sulphur mine at Jeziórko, near Tarnobrzeg. The stations were arranged along a gradient of the increasing distance from the source of emissions, and the control station was located beyond the range of sulphur deposits and beyond the zone affected by the mine. In addition to the control

zone, three other zones were distinguished on the basis of soil analyses, plant cover, and treatments needed for the functioning of a biocoenosis in this region:

I — the zone of small changes in agrocoenoses, where only periodic preventive liming is needed for their functioning,

II — the zone of a moderate destruction, where permanent preventive treatments are needed, some periodic reclamation treatments, as well as the crop structure has to be changed,

III — the zone of a total destruction, where a complete reclamation is needed and a new type of agricultural management.

The effect of gaseous emissions from mine fields on the soil fauna (Fig. 1) was firstly revealed in a reduction of the number of samples containing animals, when a distance from the source of emissions decreased. The proportion of samples with soil animals dropped more rapidly than that with epigeic animals, and near the mine aerobionts were more abundant. Also the number of animals decreased along this gradient, mainly that of larval stages, for which this process started earlier than for earthworms, the number of which declined near the mine. In soil, the proportion of earthworms and insect larvae was the highest. The proportion of earthworms decreased only at the station located in the area of the mine, while the proportion of larvae did not show statistically significant differences. Instead, the proportion of aerobionts increased at the mine.

Frequency of the occurrence of particular animal groups was generally low. The index of ecological importance gradually decreased for earthworms and increased for larvae, particularly at the station near the mine, where it was also increased for aerobionts.

Differences in the total catchability of the epigeic predatory fauna (Fig. 2) captured with pitfall traps were not statistically significant, however, the catchability of spiders tended to change in an opposite direction than that of ants. The catchability, dominance, and ecological importance dropped for spiders, while increased for ants along the gradient of a decreasing distance to the source of emissions.

The frequency of the occurrence of particular animal groups in traps was high and little differentiated, except for ants.

The effect of gaseous emissions from processing plants

This effect was studied in the region of the sulphur plant "Siarkopol" at Machów. The stations were located at distances of 0.3, 4.0, 6.0, and 8.0 km from the plant. The control station was located beyond

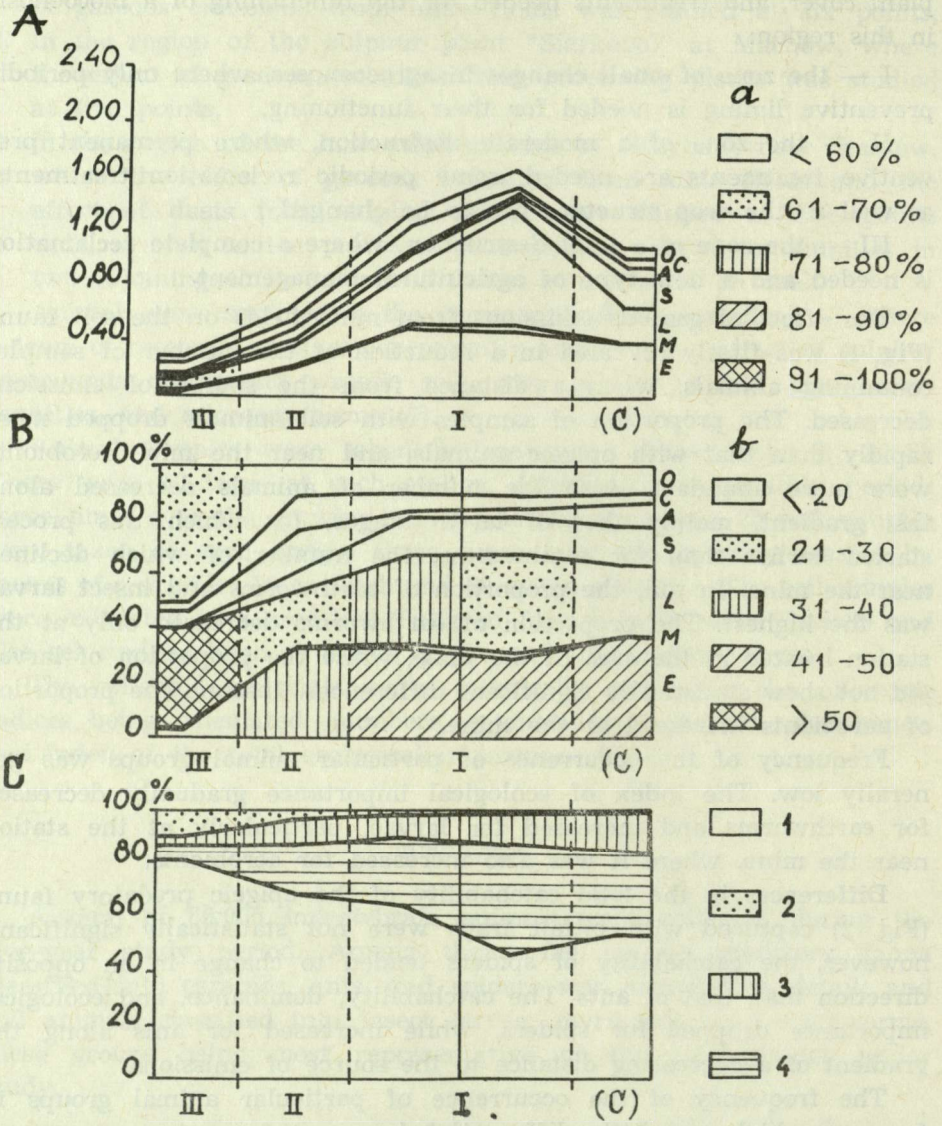

Fig. 1. Changes in some ecological indices for animals found in soil samples taken at Jeziórko in 1974—1977.

A — numbers indiv./sample; a — frequency; B — domination; b — ecological importance; C — proportion of samples: 1 — without animals, 2 — with earobionts, 3 — with epigeic predators, 4 — with soil animals.

I, II, III, (C) (control) — zones.

Animals: C — carabids, A — ants, S — spiders, M — myriapods, E — earthworms, L — larvae, O — other species.

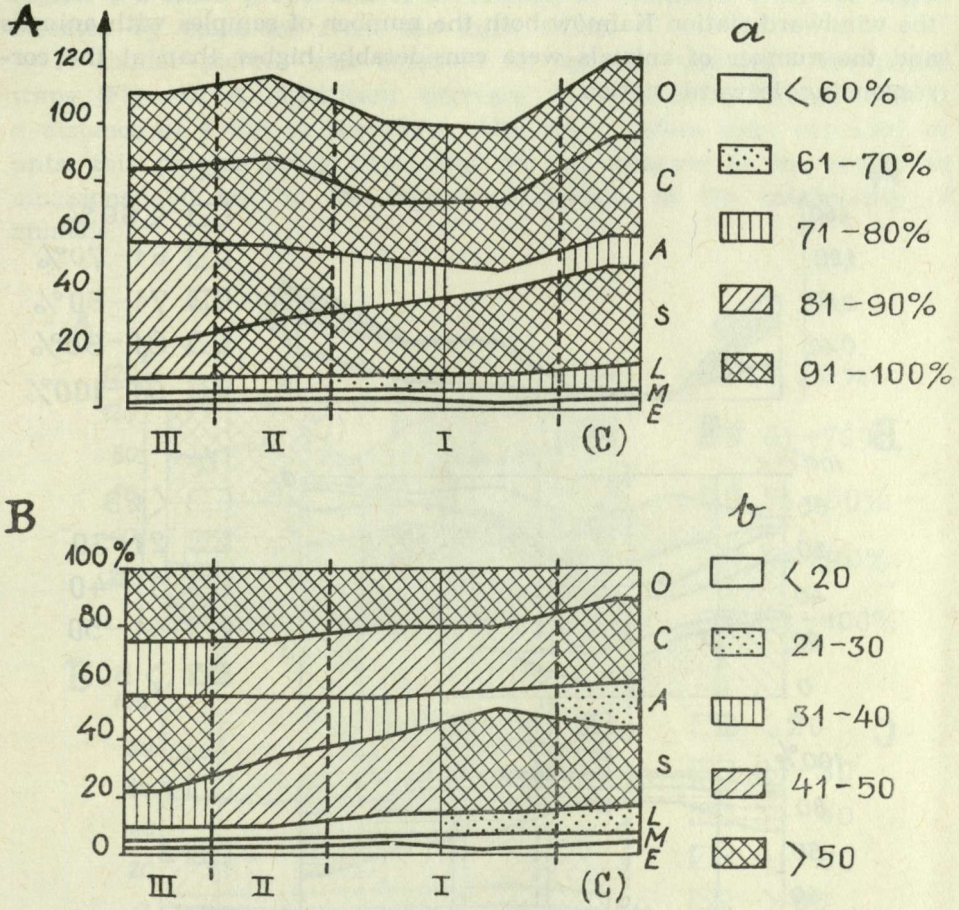

Fig. 2. Changes in some ecological indices for animals caught in pitfall traps at Jeziórko in 1974—1977.
A — catchability indiv./trap; a — frequency; B — domination; b — ecological importance.
Animals and zones — explanations as in Fig. 1.

the region polluted with emissions. In addition, one station was located at Kaimów, at a distance of 0.3 km from the plant on the windward to test the effect of wind direction.

The number of soil samples containing animals dropped with the decreasing distance to the source of emissions (Fig. 3), like it was the case in the areas polluted with emissions from the mine fields. The number of animals was reduced at a considerably higher distance to the source of emissions than in the case of emissions from the mine fields. Firstly earthworms and then insect larvae declined. The lowest numbers of animals were recorded at distances of 300 m and 4 km

from the plant along the main wind direction, i.e., on the leeward. At the windward station Kaimów both the number of samples with animals and the number of animals were considerably higher than at the corresponding leeward station.

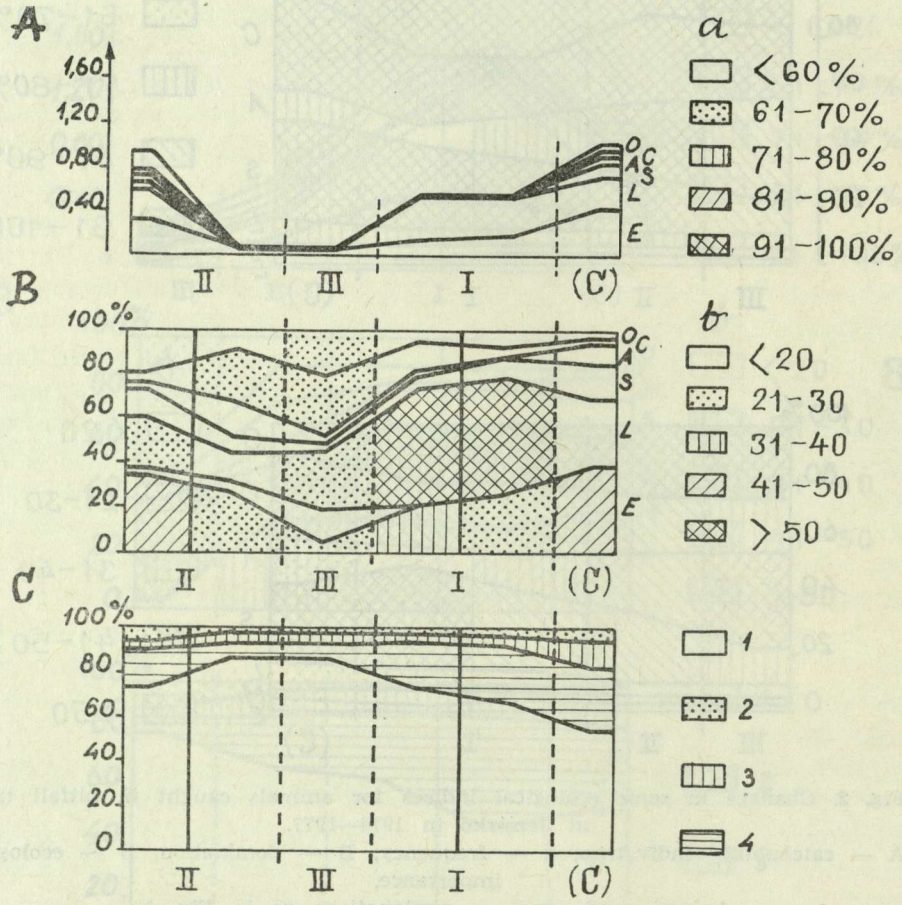

Fig. 3. Changes in some ecological indices for animals isolated from soil samples taken at Machów in 1974—1977.
A — numbers indiv./sample; a — frequency; B — domination; b — ecological importance; C — proportion of samples. Remaining explanations as in Fig. 1.

At the control station the proportion of earthworms was the highest, and then that of insect larvae. The soil fauna at the stations with lowest numbers of animals was dominated by carabids, while at the station nearest to the plant, earthworms were most abundant again, independent of wind direction. Thus largest changes in the soil fauna were recorded at a distance of 4 km, where the gaseous fall was the heaviest, and not at the plant. A characteristic feature of this whole

region is a small proportion of aerobionts, as compared with the region affected by emissions from the mine fields.

A similar picture was obtained for animals sampled with pitfall traps (Fig. 4). A significant decrease in catchability was noted at a distance of 4 km to the plant. Also here spiders were replaced by ants, this process being dependent on the distance to the source of emissions and not on the course of changes in the catchability of animals.

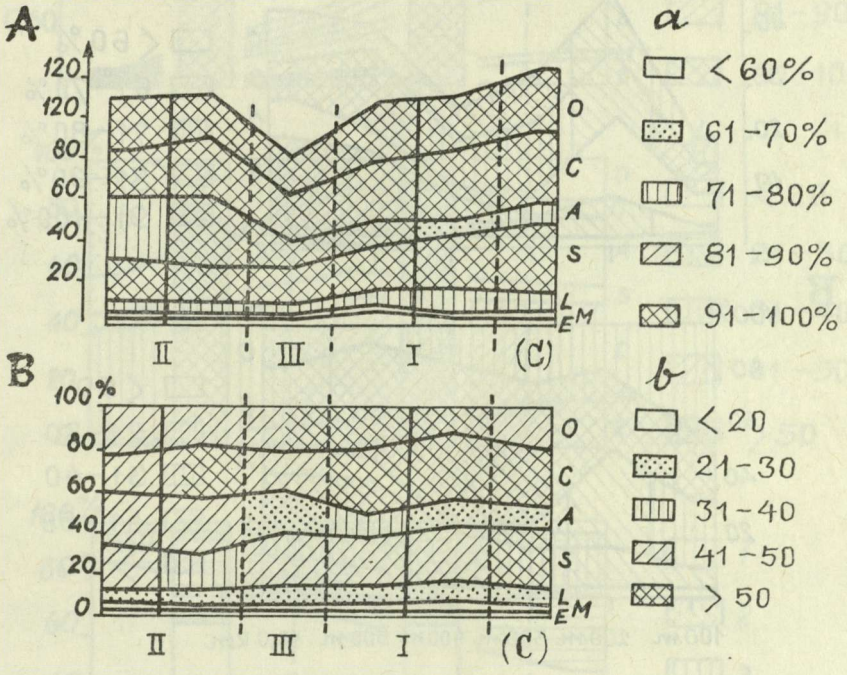

Fig. 4. Changes in some ecological indices for animals caught in pitfall traps at Machów in 1974—1977.
A — catchability indiv./trap; a — frequency; B — domination; b — ecological importance.
Remaining explanations as in Fig. 1.

The effect of dust emissions from a sulphur store

The tests were conducted in the region of Grzybów near Staszów The stations were located every 100 m along a gradient of the increasing distance from the sulphur store. A similar trend of changes in the fauna was observed as in the areas polluted with gaseous emissions. The catchability of animals dropped with decreasing distance

to the store (Fig. 5). An increase in the catchability at a distance of 200 m to the store resulted from a considerable increase in the catchability of ants. Predatory animals in the control and most distant polluted areas were dominated by spiders, and at the next station by carabids; ants dominated near the store, and aerobionts at the store.

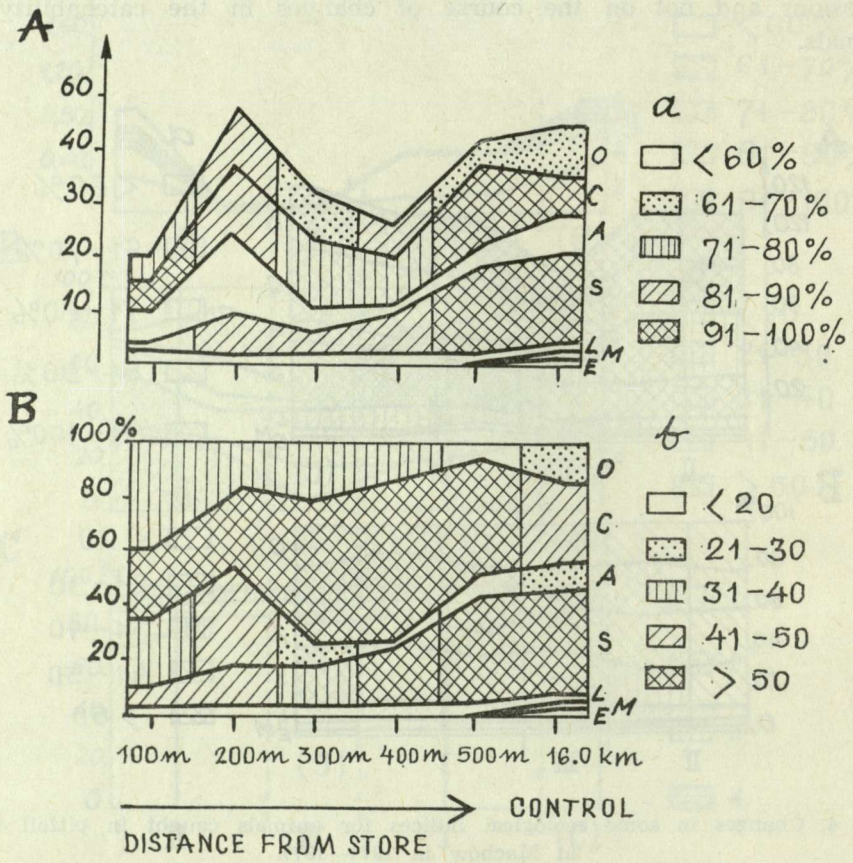

Fig. 5. Changes in some ecological indices for animals caught in pitfall traps at Dobrów-Grzybów in 1973—1977.
Explanations as in Fig. 4.

Changes in the fauna of reclaimed fields

The study was carried out in the region of Grzybów. The reclaimed and nonreclaimed plots were located in pairs near the mine field and the sulphur store. The control plot was beyond the range of emissions.

The proportion of soil samples with animals (Fig. 6) was particularly decreased in the nonreclaimed plot in the region of the sulphur store.

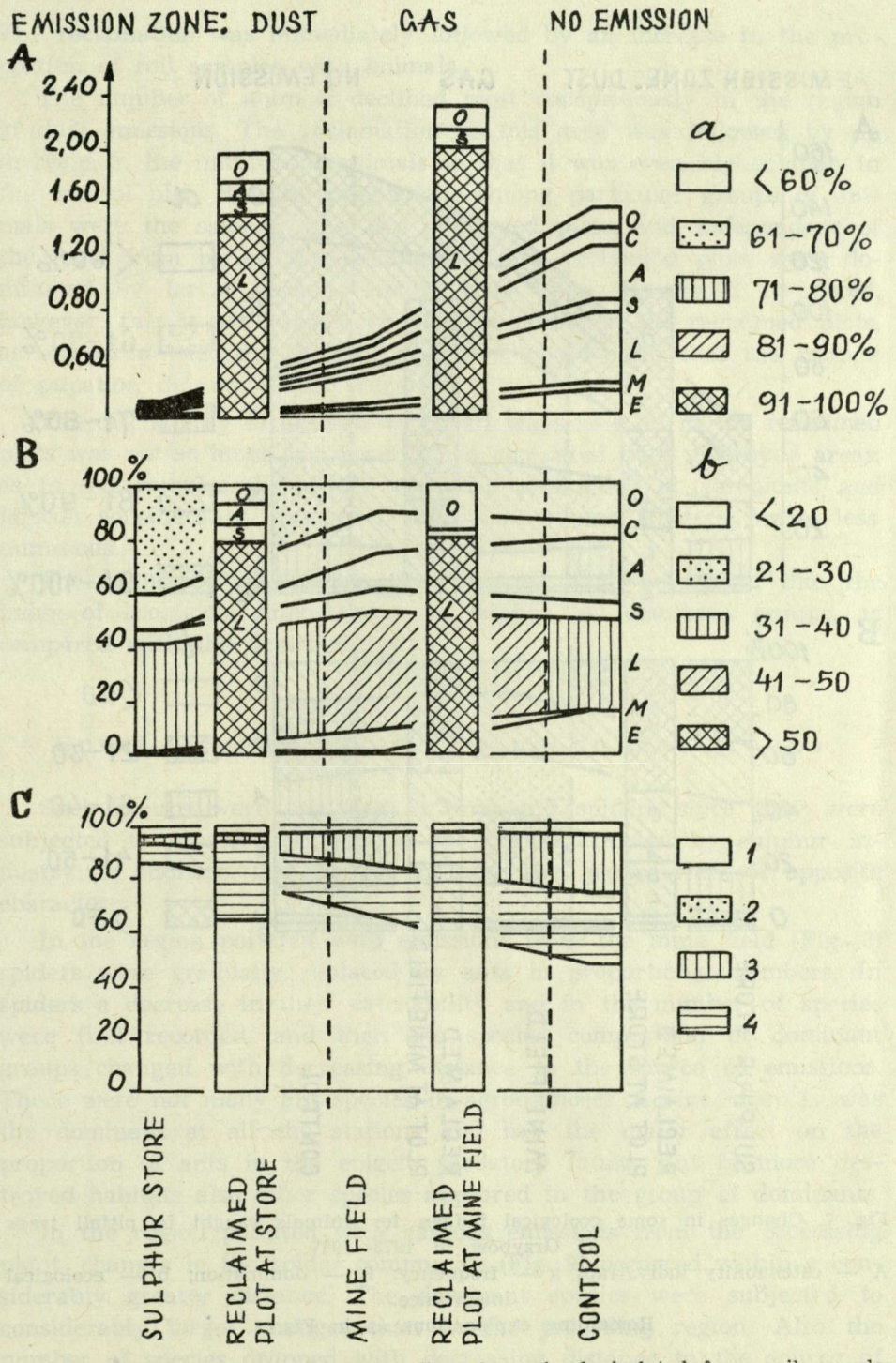

Fig. 6. Changes in some ecological indices for animals isolated from soil samples at Grzybów in 1973—1977. Explanations as in Fig. 1.

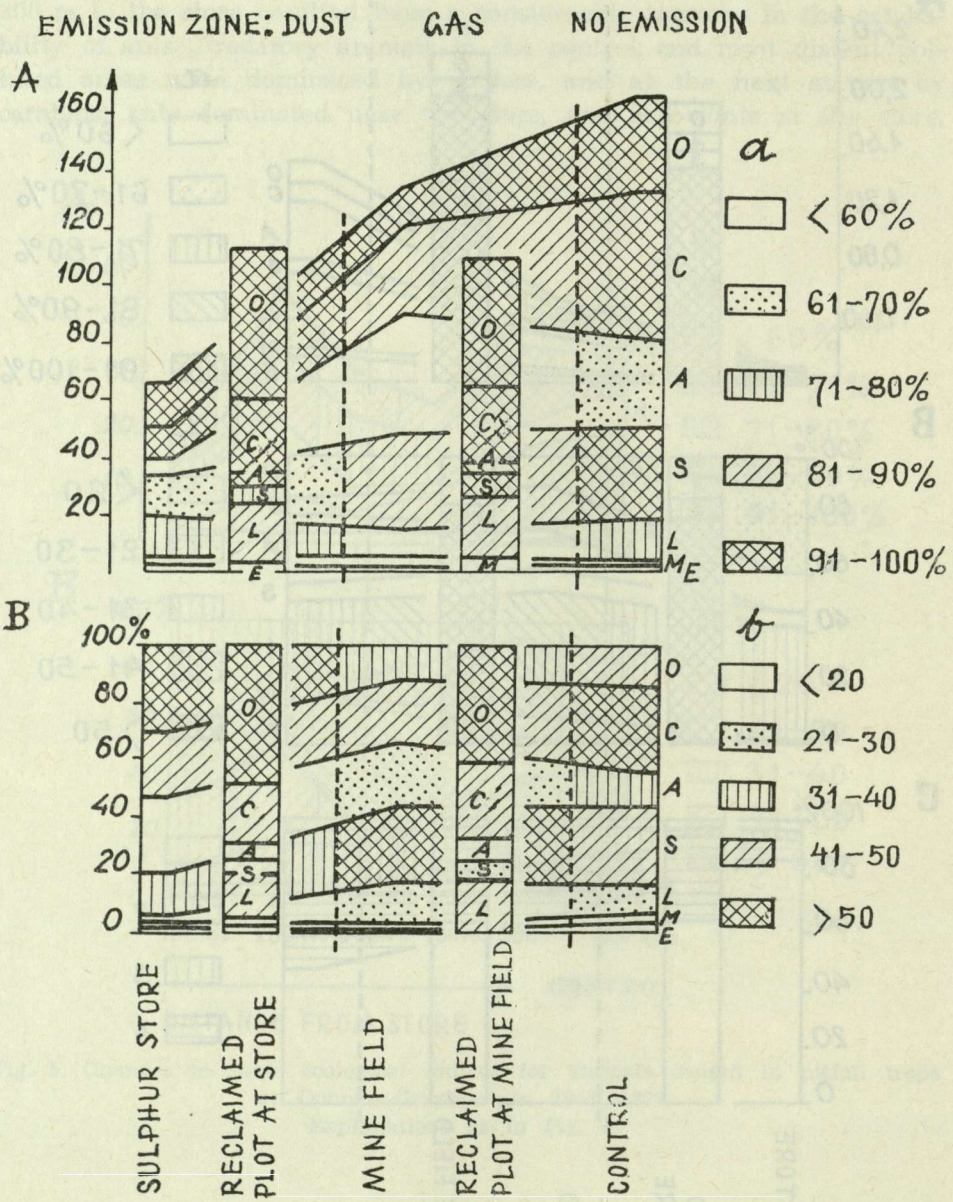

Fig. 7. Changes in some ecological indices for animals caught in pitfall traps at Grzybów in 1973—1977.

A — catchability indiv./trap; a — frequency; B — domination; b — ecological importance.

Remaining explanations as in Fig. 1.

The reclamation was immediately followed by an increase in the proportion of soil samples with animals.

The number of animals declined most conspicuously in the region of dust emissions. The reclamation of this area was followed by an increase in the number of animals so that it was even higher than in the control plot. But the proportions among particular groups of animals were the same in the two reclaimed plots, and independent of the level from before the reclamation. The reclaimed plots were dominated by larval insects, mainly crop pests. It should be noted, however, that insect pupae were almost absent in the reclaimed plots, as compared with the control, so that it could seem that the process of pupation did not occur there.

The catchability of animals in pitfall traps (Fig. 7) in the reclaimed plots was not so much increased, when compared with destroyed areas, as in soil samples. In pitfall traps the proportion of aerobionts and larvae considerably increased, while ants and spiders were less numerous.

The frequency of animals in reclaimed plots was high, like the index of ecological importance, and higher for dominant groups, as compared with the destroyed plots.

Species composition of some animal groups

Such groups were analysed as ants and spiders since they were subjected to greatest changes in the region affected by sulphur industry; in addition, the changes in these two groups were of opposite character.

In the region polluted with emissions from the mine field (Fig. 8) spiders were gradually replaced by ants in proportional numbers. In spiders a decrease in their catchability and in the number of species were first recorded, and then the species composition of dominant groups changed with decreasing distance to the source of emissions. There were not many ant species in agrocoenoses. *Lasius niger* L. was the dominant at all the stations and had the major effect on the proportion of ants in the epigeic predatory fauna. But in more destroyed habitats also other species appeared in the group of dominants.

In the region polluted with gaseous emissions from the processing plant, changes in the spider community (Fig. 9) occurred within a considerably greater distance. The dominant species were subjected to considerably larger changes than in the preceding region. Also the number of species dropped with decreasing distance to the source of emissions.

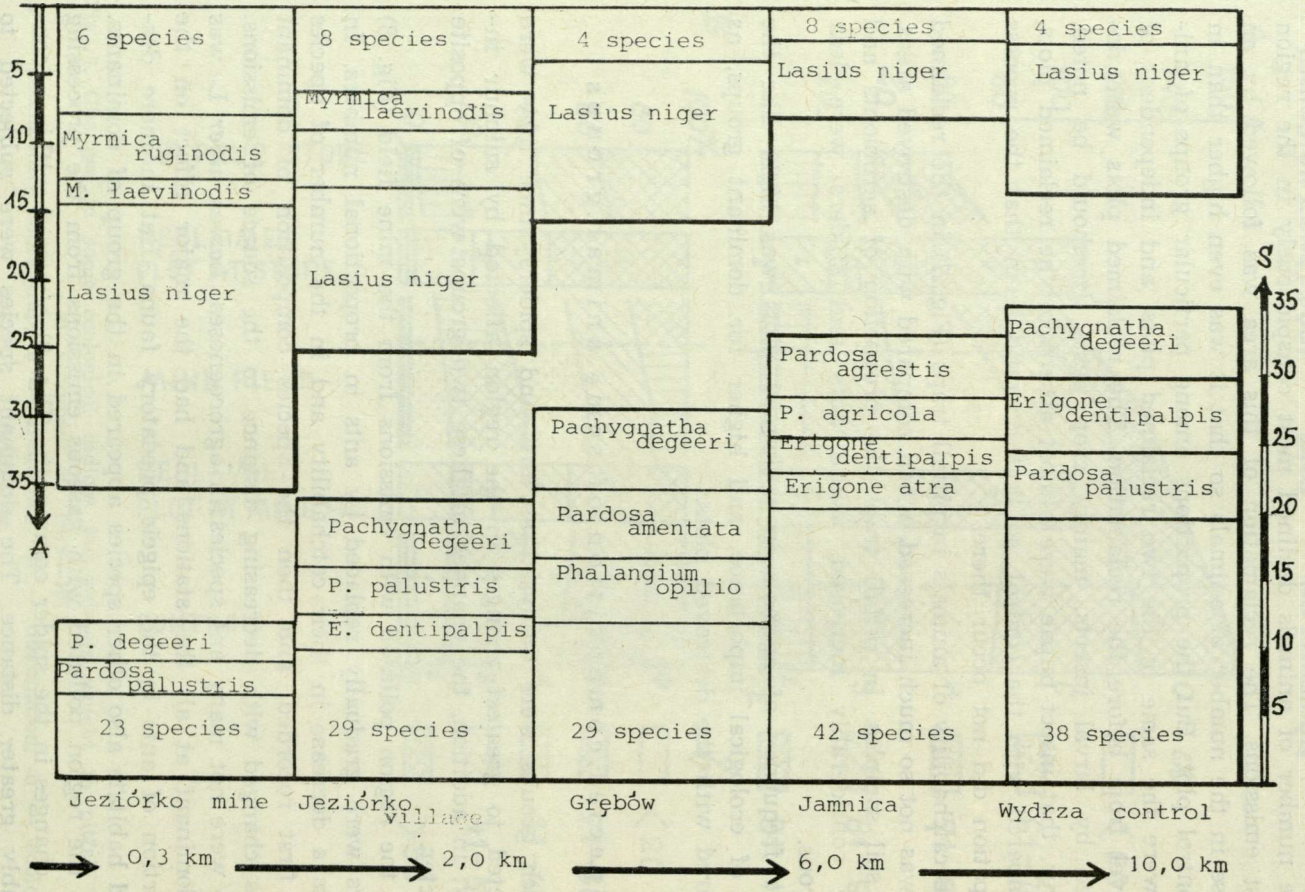

Fig. 8. Changes in the dominant ant (A) and spider (S) species in the region of the sulphur mine Jeziórko near Tarnobrzeg — number of individuals per trap at different distances to the source of emissions.

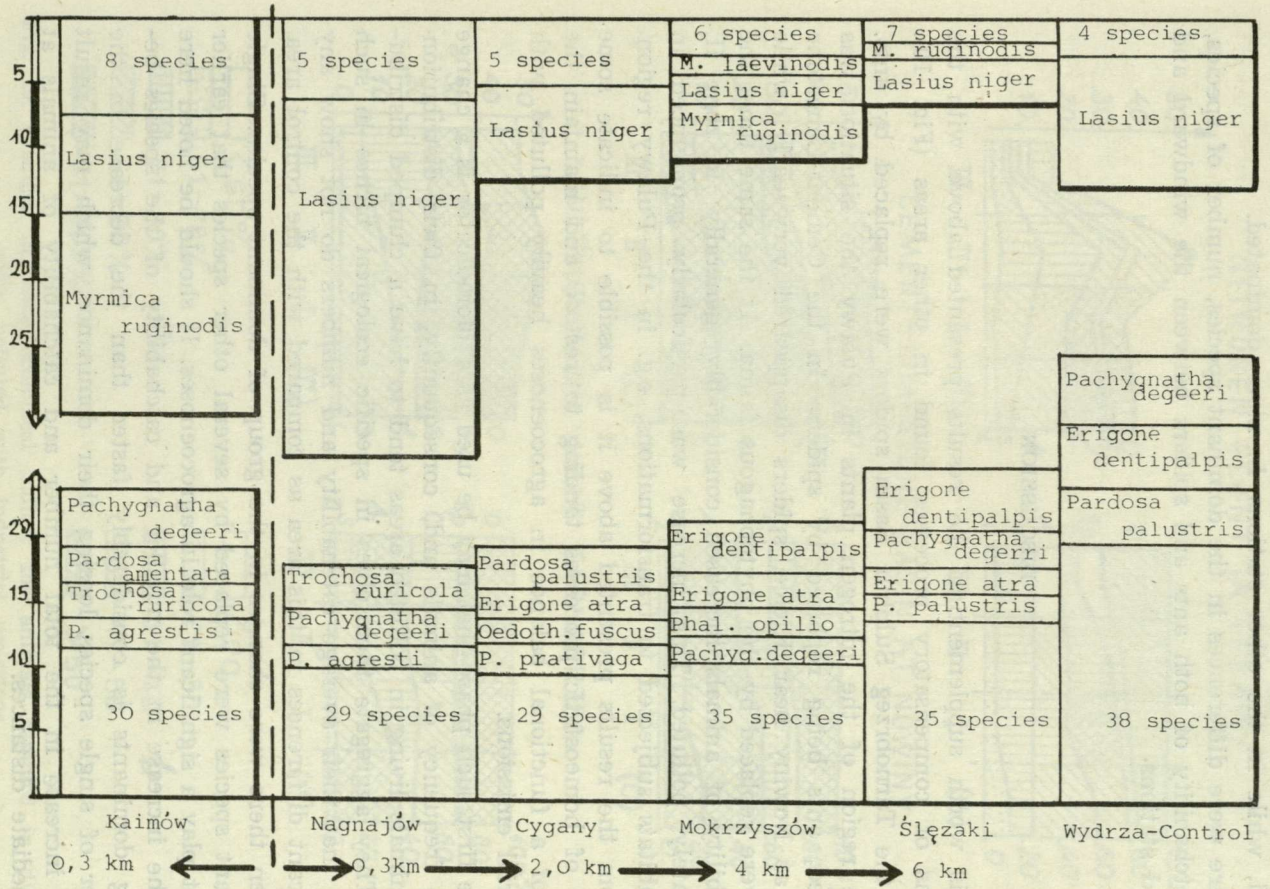

Fig. 9. Changes in the dominant ant (A) and spider (S) species in the region of the sulphur mine „Siarkopol" at Machów near Tarnobrzeg — number individuals per trap at different distances to the source of emissions.

The most pronounced changes in ants were noted at distances of 6 and 4 km to the plant. Here the number of dominant species increased, while in the other stations *L. niger* dominated.

There were differences in the dominant species, number of species, and catchability of both ants and spiders between the windward and leeward stations.

DISCUSSION

It is worth supplementing the results presented above with the patterns of compensatory processes found in other areas (Fig. 10).

In the Tarnobrzeg Sulphur Basin spiders were replaced by ants. In the region of the nitrogen plants in Puławy the situation was reversed, ants being replaced by spiders. In the Cement-Limestone Basin at Nowiny near Kielce, spiders disappeared very early, while ants were replaced by the phytophagous fauna. At the same time, the catchability of animals increased considerably, generally, in zone II, moderately polluted. This increase was particularly pronounced in the habitats subjected to transformations, e.g. in the Puławy region.

From the results presented above it is possible to indicate some phases of homeostatic processes tending to restore and maintain the state of a functional balance in agrocoenoses heavily polluted with industrial emissions.

The first such phase that may be used as a bioindicator is a change in the frequency of animals and, consequently, in their distribution. The animals living in polluted areas tend to have a clumped distribution. They aggregate themselves in specific ecological niches in such a way that their average catchability and numbers do not show any significant differences in this area as compared with the control area.

Then there were changes in the group of dominant species. Single dominant species were replaced by several other species that earlier did not play a significant role in agrocoenoses. It should be noted here that the increase in the number and catchability of the species becoming dominants is considerably faster than the decrease in the number of single species loosing their dominance, which may result in an increase in the total number and catchability of animals at intermediate distances.

A further increase in the rate of pollution or in the time of exposure to heavy pollution was followed by the disappearance of susceptible species and, hence, by a decrease in the total number of species.

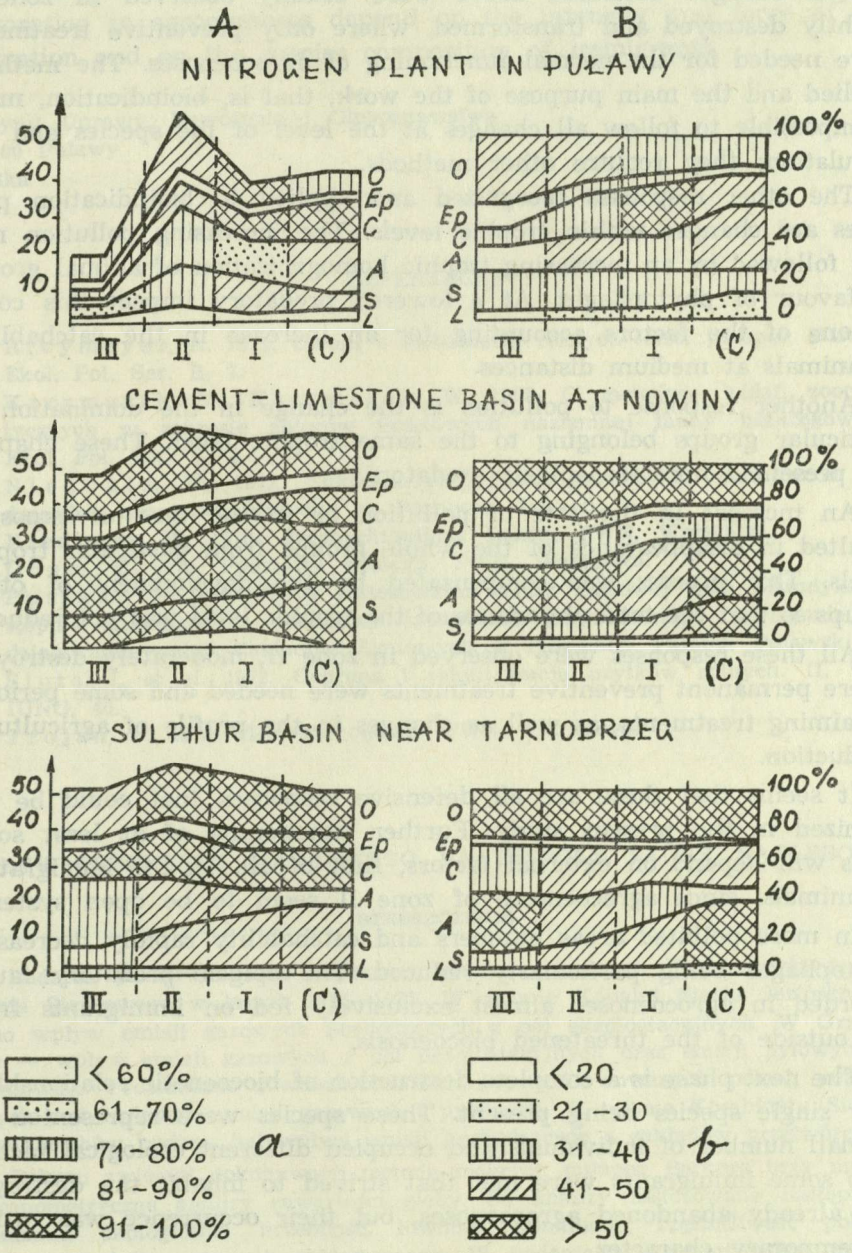

Fig. 10. Changes in some ecological indices for animals sampled in different zones polluted with industrial emissions.

A — catchability indiv./trap; a — frequency; B — domination; b — ecological importance.

I, II, III, (C) (control) — zones.

Animals: Ep — epigeic phytophages, C — carabids, A — ants, O — other insects, L — insect larvae, S — spiders.

The changes described above were usually observed in zone I, slightly destroyed and transformed, where only preventive treatments were needed for the normal functioning of agrocoenoses. The methods applied and the main purpose of the work, that is, bioindication, made it impossible to follow all changes at the level of the species and the population; they require other methods.

The other responses recognized and applied to bioindication purposes are changes within trophic levels. The increasing pollution rate was followed by an increasing trophic homogenization of animal groups in favour of phytophages. At a lowered predatory impact this could be one of the factors accounting for an increase in the catchability of animals at medium distances.

Another response to pollution is the change in the domination of particular groups belonging to the same trophic level. These changes are presented here for epigeic predators.

An increase in the rate of pollution or in the time of exposure resulted in disappearance of the whole groups from particular trophic levels. This process was compensated by the development of other groups so that the total abundance of the trophic level was not reduced.

All these responses were observed in zone II, moderately destroyed, where permanent preventive treatments were needed and some periodic reclaiming treatments, as well as changes in the profile of agricultural production.

It seems that these are all defensive responses that could be recognized in the present study. Further functioning of at least some links will depend on external factors, first of all, on the immigration of animals, since agrocoenoses of zone II seem to be open systems.

In more polluted areas numbers and catchability rapidly decreased, phytophages being particularly reduced. The epigeic predatory fauna recorded in agrocoenoses almost exclusively fed on immigrants from the outside of the threatened biocoenosis.

The next phase is a complete destruction of biocoenotic relationships, only single species being present. These species were represented by a small number of individuals and occupied different ecological niches. Also some immigrants were met that strived to inhabit the destroyed and already abandoned agrocoenoses, but their occurrence was rather of temporary character.

Each reclaiming treatment conducted in the destroyed areas was immediately followed by responses in the animal world. Even the fields reclaimed but still subjected to high pollution were resettled. In the first stages of this resettlement, however, animal communities differed from those living there before the destruction as well as in

the destroyed areas. It seems that the rate and the degree of fauna restoration in agrocoenoses depend on the intensity and force of immigration and on the species composition of immigrants.

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WPŁYW PRZEMYSŁU SIARKOWEGO NA ZESPOŁY FAUNY NAGLEBOWEJ

STRESZCZENIE

Badania przeprowadzono w trzech różnych obiektach Tarnobrzeskiego Zagłębia Siarkowego w latach 1973—1977. W rejonie Kopalni Siarki Jeziórko badano wpływ emisji gazowych pochodzących z pól eksploatacyjnych. W Grzybowie — wpływ emisji gazowych z pól eksploatacyjnych oraz emisji pyłowych ze składowisk. Prowadzono również badania na zrekultywowanych polach pozostających pod wpływem emisji gazowych i pyłowych. W rejonie Kombinatu Siarkowego Machów badany był wpływ emisji pochodzących z zakładów przetwórczych.

Połowu zwierząt dokonywano metodą mokrych pułapek Barbera oraz metodą biocenometryczną analizy zawartości gleby. Do analizy zastosowano następujące wskaźniki ekologiczne: liczebność, łowność, dominacja, częstotliwość połowu, łączny wskaźnik znaczenia ekologicznego. W badaniach skoncentrowano się na drapieżnej faunie epigeicznej — biegaczach, mrówkach i pająkach — jako elemencie wskaźnikowym zmian. Z fauny glebowej uwzględniono: larwy owadów, wije, równonogi i dżdżownice.

Badania wykazały, że wpływ poszczególnych rodzajów emisji jest silniejszy niż zmiaony czynników atmosferycznych w kolejnych latach. Oddziaływanie emisji związków siarki uwidoczniło się w zmianach relacji pomiędzy poszczególnymi

grupami zwierząt, a szczególnie w zmniejszaniu się wartości wskaźników ekologicznych w przypadku pająków na rzecz wzrostu ich wartości u mrówek w miarę pogłębiania się stopnia niszczenia środowiska. W obrębie analizowanych grup następowała również wymiana gatunków dominujących. Analogiczną strefowość zmian zanotowano w próbach glebowych, przede wszystkim zmniejszanie się ilości prób, w których znajdowano zwierzęta, jak również ustępowanie poszczególnych grup fauny glebowej.

Rekultywacja terenów poeksploatacyjnych i ich rolnicze zagospodarowanie znalazły odbicie we wzroście wartości wskaźników ekologicznych drapieżców fauny epigeicznej. W przypadku zwierząt glebowych zanotowano wzrost ilości prób ze zwierzętami, przede wszystkim larw owadów.

Te różnice w wartościach wskaźników ekologicznych u wymienionych grup zwierząt z pułapek Barbera i prób glebowych w poszczególnych strefach zniszczenia i odbudowy środowiska są tak znaczne i charakterystyczne, że mogą być wykorzystane zarówno jako wskaźniki zasięgu oddziaływania toksycznych emisji związków siarki, jak również jako wskaźniki stopnia odbudowy tych środowisk przez rekultywację.

ВЛИЯНИЕ СЕРНОЙ ПРОМЫШЛЕННОСТИ НА СООБЩЕСТВА ЭПИГЕИЧЕСКОЙ ФАУНЫ

РЕЗЮМЕ

В 1973—1977 г.г. в Тарнобжеском серном бассейне были проведены исследования, целью которых было выявление влияния газовых эмиссий из эксплоатационных полос, пылевых эмиссий из складских хранилищ и эмиссий перерабатывающих заводов на эпигенческую фауну, где исследования сконцентрировались на жищниках (жужелицах, муравьях и пауках) как индикатовах происходящих изменений, и почвенную фауну, среди которой принялись во внимание личинки насекомых, равноногих, многоножек и дождевых червей.

При анализе материала применился ряд экологических показателей: численность, ловность, диминирование, частота встречаемости, объединенный показатель экологической значимости.

Исследования показали, Зто влияние каждого рода эмисси является более сильным, чем смена метеорологических факторов в очередных годах. Воздействие соединений серы проявилось в изменениях соотношения между группами животных, особенно в падении величин экологических показателей у пауков в пользу их роста у муравьев в зависимости от увеличения степени уничтожения естественной среды. В пределах анализированных групп происходила также смена доминирующих видов. В почвенных пробах аналогичным образом уменьшалось количество проб, содержащих животных, а отдельные группы исчезали из почвенной фауны вообще.

На рекультивированных территориях, используемых снова как сельскохозяйственные угодья, наблюдался рост экологических показателй у хищников эпигенческой фауны. В почве возрастало количество проб, содержащих животных, а прежде всего личинок насекомых.

Различия в величинах экологических показателей у исследованных групп эпигеических и почвенных животных так велики в зависимости от зоны уничтожения и восстановления среды, и так характерны, что могут быть использованы как индикаторы воздействия токсических эмиссий сиединений серы, а также в качестве показателя степени восстановления среды путем рекультивационных мероприятий.