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SOME PROBLEMS OF ZOOCOENOSIS RESTORATION IN DEGRADED FOREST HABITATS

ABSTRACT

Ecological aspects of the effect of forest management on zoocoenoses are analysed, as well as the possibility of the biological protection of forest sites from degradation is discussed.

Particular emphasis is put on the effect of clear-cutting, soil cultivation, changes in the tree layer on the communities of forest invertebrates. In addition, the results of the study on the restoration of soil invertebrate communities in reforested arable lands are presented.

INTRODUCTION AND DEFINITIONS

Forests together with their soil substratum are the main natural components of man's environment. The quality of the natural environment depends on the number and distribution of forests in the country, and not to a lesser degree on the economic activity of man in forests and outside forests, the latter having a considerable effect on this plant formation. At the same time, forests undergo natural succession controlled by general climatic and edaphic conditions, or by factors resulting from direct relationships among forest organisms. Assuming that the forest as a product of the activity of man exploiting natural forces is and will be in future the element of contemporary civilization, the development of which it promotes, the following classification can be suggested of factors responsible for the stability or variability of forest ecosystems and phytocoenoses);

— endogenous factors (e.g. natural succession processes occurring in forests, developmental trends in the tree stands, interaction effects);

— paraendogenous factors (any impact of human economic activity on forest ecosystems and phytocoenoses);

— natural exogenous factors (effect of macroclimatic changes on physiocoenoses, occurring without man's contribution);

— anthropoexogenous factors (all forms of anthropogenous pressure not related to forest management).

The force of action of any of these factors or groups of them on forest ecosystems is variable and depends not only on the absolute value of the factor but also on the natural quality of a given forest ecosystem. In Poland, three types of forest ecosystems can be distinguished taking as a criterion the degree of transformation as compared to the system which would exist at the absence of civilization. These are:

— strict reserves in or outside national parks, and not easily accessible forests (montane, marshy, and so on) with well preserved flora and fauna both corresponding to site conditions;

— forests developed as a result of the economic activity under forest conditions (here are included forests of the so-called group I, which are protected or used for recreation, and most forests of class II, economically used). Flora and fauna of these forest ecosystems is being impoverished;

— forests and plantations developed as a result of recultivation and reforestation, in which forest flora and fauna are being restored.

It can easily be noted that forest ecosystems of type I are characterized by lowest anthropogenous pressure and smallest synanthropization mainly due to exogenous factors. In forest ecosystems of type II synanthropization is increasing and their functioning is threatened with paraendogenous factors of a rather uniform intensity, as well as with anthropoexogenous factors of a regionally differentiated intensity. This results in a heavy degradation of soils and biocoenoses in these ecosystems.

The change in the way of soil management from agricultural to silvicultural implies that forest flora and fauna will be restored in the ecosystems of type III, however, the degree of synanthropization of this environment is the highest because of a deep transformation in the past. It is assumed that reforestation will account for a decrease in the degradation of these sites.

The present contribution is concerned with the effects of paraendogenous factors on forest ecosystems of types II and III. Also proposals for ecological engineering in the field of developing the communities of forest invertebrates are discussed.

Materials were collected by a research team of the Institute of Forest and Wood Protection, Agricultural University of Warsaw, studying the effects of forest management on insect communities for many years. About one million individuals of the forest fauna, mainly including soil insects, were examined from almost 300 study plots located in nine forest complexes. Methods and a part of the results have already been published [3—6, 8—21].

EFFECT OF FOREST MANAGEMENT ON ZOOCOENOSES

Among various forms of forest management affecting zoocoenoses, five are applied on largest areas: clear cutting, reforestation of agricultural land, soil cultivation in clear cuttings and reforestation areas with herb layer destruction, mineral fertilization of forests, and control of the species composition of stands. Four of the pressures listed above will be analysed here. The effect of mineral fertilizers will be omitted as there are not sufficient materials from Poland .

Clear cutting

Clear cutting of trees and subsequent soil management coupled with the modification of microclimatic conditions bring about great changes in the forest soil fauna. Four phases of these changes have been distinguished: the phase of the degeneration of forest soil zoocoenoses during the period of clearings and one-year plantations; the phase of a crisis when the young plantations are 2—10 years old; the phase of regeneration during the period of thickets (11—25 years old), and the optimum phase in stands more than 25 years old. During the period of pole-sized stands, i.e. in tree stands more than 30 years old, forest fauna is almost stabilized and maintained with only small changes to the age of cutting.

Successive changes in soil zoocoenoses in clear cuttings cannot be considered as a succession because there is no complete species exchange in them, only proportions among particular species being modified.

In phase I (community degeneration) specialized forest-soil species are eliminated and replaced by eurytopic forms with considerable ecological plasticity. They have a clear-cut clumped distribution.

In phase II (crisis) numbers and species composition of zoocoenoses reflect a considerable alienation of the forest-soil fauna. Xerothermophilous communities are formed, predominated by phytophages and zoophages among which *Nopoiulus fuscus* is particularly abundant.

Phase III (regeneration) is characterized by the occurrence of instable communities of forest macrofauna, in which soil phytophages are gradually replaced by saprophages. The period of regeneration can be more prolonged, depending on the type of management in cuttings and thickets, and on the degree of site degradation.

Phase IV (optimum) is characterized by the occurrence of relatively stable communities of mesohygrophilous fauna predominated by saprophages.

The economic activity in forestry should create conditions for speeding up the development of phase IV. It has been suggested that the periodical elimination of forest species and maintaining soil zoocoenoses in a substitute form for one-fourth to one-third of the life-time of stands managed by clear cutting can result in a prolongation of the regeneration period of forest zoocoenoses, which would be harmful to soil-formation processes and would contribute to further site degradation.

Reforestation of agricultural land

About 0·7 million ha of primarily forest lands, subsequently used as arable lands for a longer or shorter time, have been reforested during the past 30 years. These are usually poor soils formed from loose sands, with a low biological activity and permanent water deficiency, where crop production was below the limit of economic effectiveness. If the projects to optimize the forest area in Poland were effected, forests developed on arable lands would occupy about 30% of the total forest area in the country after 2000, while now they occupy 14%. But these are forests of low timber production, and highly vulnerable to diseases and pests, this being the result of their poorly developed structure and function.

The colonization of arable land soils by macrofauna is effected in the process of secondary succession. Hence, the communities of soil macrofauna (pioneer, xerothermophilous) in 1—10-year-old reforestations are totally different from those in forest plantations on clear--cuttings of the same age. They are dominated by phytophages and zoophages. Between 21 and 45 years of stand age there occurs a main phase of the colonization of arable land soils by forest macrofauna; 11—30-year-old stands are dominated by instable "transitional" communities of field, shrub, and forest species.

Many taxa of the macrofauna reach the species composition and structure corresponding to those in forest soils only in 100-year-old stands. In macrofauna communities of arable land soils firstly epigeic predators reach the species composition characteristic of forest communities, while the formation of hemi- and euedaphic saprophagous communities, except for earthworms, is delayed about 20 years. So, in fact, only the soil macrofauna of 60—100-year-old stands on arable land soils have the species composition and domination structure similar to those in stands on forest soils. The delay as compared with forest soils is about 30—50 years. But generally the indices of domination are higher on arable land because of a lower diversity of macrofauna communities. In addition, standing crop biomass, stratified distribution, and population features of dominant species and of the whole macrofauna on arable land soils are different than those on forest soils. Except for young plantations the average standing crop biomass of macrofauna on arable land soils is lower than on forest soils by about 25%. This is a result of the lower content of organic matter in arable land soils, which has a limiting effect on saprophages. In general, the macrofauna of arable land soils occurs near to the surface and is more mobile than in forest soils, as well as it is more susceptible to changes in soil moisture, which results in more dynamic vertical migrations. The mean biomass of macrofauna individuals in arable land soils is smaller than in forest soils from the phase of thickets, and higher in the period of young plantations, thickets and small poles. This means that the arable land soils macrofauna communities differs in their functioning at the period when they apparently reach the structure corresponding to that in forest soils: macrofauna of arable land soils after the stabilization of their species composition is characterized by higher costs of living connected with a smaller biomass of macrofauna individuals and higher mobility of specimens. From the point of view of the functioning of reforested ecosystems this means energy losses as a smaller amount of nutrients is built up into the biomass and introduced into cycling than in forest soils. This is particularly the case of organic carbon, which in reforested soils mainly occurs in the top 5-cm layer of horizon. A_1, while in forest soils it is more concentrated at a depth of 20—25 cm. This suggests that nutrient cycling in reforested soils is different than in forest soils. In reforested soils the biomass of individuals of the same species is larger than in forest soils. As Szyszko [20] has pointed out, the presence of larger individuals in a population is characteristic of poor sites. This implies that reforested soils behave in a similar way as soils of poor sites, as if they represented earlier stages in the successional sequence of forest communities. Similar results were obtained in the study on sex ratio in *Carabidae*. Thus, the bioindication of reforested soils shows that synanthropic changes resulting from the temporary exclusion of soils from forest culture are very persistent.

Cultivation of forest and reforested soils, and herb-layer destruction

Progressive degradation of forest soils, shortage of staff, and growing possibilities of the utilization of heavy agricultural machinery encourage forestry not to take into account the natural layering of forest soils, and to shift to the methods of soil cultivation similar to those used in agriculture. Biological effects of this procedure are difficult to foresee, although it is certain that the return to edaphic conditions from before centuries becomes still more problematic in forests.

Soil cultivation on cuttings can determine the subsequent rate of forest fauna regeneration, and soil preparation for reforestation can have an effect on the subsequent rate of macrofauna succession. The smallest differences in macrofauna restoration processes between reforested and forest soils were observed when strip ploughing was used; they were a little larger when ploughing was shallow and complete, and the largest differences occurred after a complete and deep ploughing. Detrimental effects of deep ploughing on the reforestation of forest-soil macrofauna is reflected in the preference for xerothermophilous, eurytopic, and hemizoophagous forms, and in a decrease of the indices of diversity, thus, in an increase in the degree of synanthropization of this environment. This leads towards delaying macrofauna succession. Even epigeic carabids, which generally most rapidly stabilize their communities, are affected. Deep, complete ploughing delays this process by more than ten years.

Cuttings and soil cultivation are also followed by impoverishment of the forest herb layer, which in the stage of low and high poles passes through the phase of degeneration with the dominance of mosses. In damp pine forests and particularly in degraded mixed coniferous forests, the fauna composition is heavily affected by the elimination of the potential dominant such as the whortleberry. The presence of this dwarf shrub, with which about 300 insect species are associated [1, 2], enhances regulatory abilities of coniferous biocoenoses, lowers the degree of fauna synanthropization, has a decreasing effect on the mobility of epigeic insects, and a positive effect on the density of macrofauna and its deeper distribution, particularly, for saprophages in mineral soils. Consequences of the lack of this shrub in reforested arable land soils are particularly noticeable.

Changes in the species composition of stands

A comparison of various taxonomic groups of the entomofauna occurring in pure pine stands with those in mixed stands (on richer sites) or with those in pine stands with the deciduous undergrowth (on poorer sites) shows that man-made changes in the vegetation of forest biocoenoses affect entomocoenosis composition to the degree depending on the site quality. For instance, the numbers of *Carabidae* and *Ichneumonidae* on forest sites in multispecies stands are higher than in pure stands on the same sites. Also the proportion of polyphagous *Ichneumonidae* and parasites of dendrophilous insects is higher. However, the introduction of deciduous undergrowth to pine stands on poor coniferous sites, where the beech and oak naturally do not occur in the undergrowth, has an anthropogenous but positive character. Nevertheless, its effect on the diversity of insect communities is insignificant, mainly because of the reduction in the photophilous herb layer, with which many animal species are associated.

The deciduous undergrowth in damp pine forests has mainly an effect on the spatial distribution of insects, e.g. *Staphylinidae* and *Ichneumonidae*. This results from the differentiation of light and humidity conditions on the forest floor, as well as in the herb and shrub layers because of the presence of undergrowth, which in turn influences the distribution and behaviour of insects, e.g. the mobility of *Carabidae*. It has been observed that in the presence of undergrowth insects are spatially differentiated as they occupy most suitable parts of the phytoameliorated stands. Photophilous species, which include many insects usually promoted by human activity, e.g. non-forest *Staphylinidae* species and *Carabidae* of the spring type, are reduced. The proportion of mesohygrophilous species characteristic of broadleaf forests slightly increases. The role of deciduous admixtures as food resources for intermediate and substitute hosts of parasitic insects on the damp-coniferous-forest site has been confirmed only to a low degree for polyphagous species and not confirmed for specialized oligophages.

So, intended and non-intended effects of man-produced changes in the stand composition on entomocoenoses are an extremely complex phenomenon, easily observed on richer sites and almost impossible on poor sites.

The presented description of factors responsible for synanthropization of the forest fauna also indicates the directions of ecological engineering which should be applied to counteract the processes of forest site degradation. In practice this will be an enrichment and diversification of species composition in order to speed up the succession and regeneration of zoocoenoses. The efforts can also be directed towards changes in the fauna activity in various layers of soil or phytocoenoses. This activity can be performed as some forms of hylotechnical treatments possible in types II and III of forest ecosystems:

— improvement of soil cultivation on clear-cuttings or on reforested lands;

— formation of forest zoocoenoses through establishment of the optimum species composition of the stand, protection and cultivation of the herb layer;

— formation of forest zoocoenoses through the introduction of selected animal species.

The ways of the improvement of soil management to stop synanthropization processes should go through the protection of its natural stratification under forest conditions and through an intensive enrichment with slowly decomposing organic materials (e.g. pine bark) under arable land conditions. Our experiments show that such treatments can account for a decrease in the variability of saprophage numbers during the stand development, and for speeding up the regeneration of forest-soil-fauna communities under conditions of clear-cutting management and in the succession of plant and animal communities in ecosystems of type III.

The principle of the adjustment of stand species composition to site conditions has to be rigorously followed on the sites of deciduous and mixed coniferous forests. This is the best form of the development of their zoocoenoses if these rich sites had been degraded under monocultures. The presence of broadleaf species considerably improves the regulatory abilities of biocoenoses.

Deciduous admixtures on poor sites of damp and dry coniferous forests have a different role; it is insignificant for the homeostatic ability of zoocoenoses, but of great importance for the acceleration of succession, improvement of soil-formation processes, and nutrient cycling. It results, among other factors, from the stimulating effect of undergrowth on the occurrence of animal species enhancing rather humidification than mineralization processes.

The herb layer is an important component of the phytocoenosis as it controls the composition of zoocoenoses on poor sites, so it should become an object of hylotechnical treatments.

The introduction of some animal species can be most effective in type III of forest ecosystems, less effective in type II. Introduction may be effected in order to control the proportions among other components of zoocoenoses (zoophagy, competition) or the course of soil-formation processes (saprophagy). All direct and indirect treatments to improve zoocoenoses must be based on O d u m's [7] thesis that the optimum diversity of forest ecosystems is a function of the quality and quantity of energy flow, while the positive correlation between diversity and stability is of derivative character.

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NIEKTÓRE PROBLEMY KSZTAŁTOWANIA ZOOCENOZ W ZDEGRADOWANYCH ŚRODOWISKACH LEŚNYCH

STRESZCZENIE

Na ekosystemy leśne wpływają czynniki:
— endogeniczne (pochodne naturalnych leśnych układów ekologicznych),
— paraendogeniczne (wynikające z gospodarczej działalności człowieka w ekosystemach leśnych),
— naturalne-egzogeniczne (pochodne naturalnych zmian makroklimatu i układów fizjocenotycznych),
— antropoegzogeniczne (presje antropogeniczne nie związane z gospodarką leśną).

W pracy omówiono oddziaływanie ważniejszych czynników paraendogenicznych (rębnia zupełna, zalesienia gruntów porolnych, uprawa gleby i niszczenie runa leśnego, kształtowanie składu gatunkowego drzewostanów) na ekosystemy leśne i ekosystemy zalesień oraz propozycje działań z zakresu inżynierii ekologicznej nastawione na kształtowanie zespołów bezkręgowców, głównie w środowisku glebowym.

Są 4 fazowe zmiany w zoocenozach glebowych następujące na zrębach zupełnych: degeneracyjne (trwające 1—2 lata), kryzysowe (trwające 8 lat), regeneracyjne (mające miejsce w drzewostanach 11—25 letnich) prowadzące do czwartej fazy „optymalnej" w drzewostanach starszych od 30 lat kiedy następuje stabilizacja fauny leśnej. Cyklicznie powtarzające się eliminacje gatunków leśnych i utrzymywanie zoocenoz w formie zastępczej przez 1/4—1/3 część okresu życia drzewostanów prowadzić może do przedłużenia regeneracji zoocenoz leśnych.

Zasiedlanie zalesionych gleb przez zwierzęta glebowe następuje na drodze sukcesji wtórnej. W zalesieniach 1—10 letnich występują zespoły pionierskie, kserotermofilne, a w drzewostanach 11—30 letnich zespoły niestabilne składające się z różnych form życiowych zwierząt. Między 21 a 45 rokiem życia drzewostany są zasiedlane przez zwierzęta leśne: najpierw przez powierzchniowe drapieżce, później przez hemi- i euedaficzne saprofagi, które stabilizują skład gatunkowy dopiero w drzewostanach 60—100 letnich. W pierwszym pokoleniu zalesień makrofauna glebowa różni się jednak od makrofauny gleb leśnych mniejszą biomasą, szeregiem cech populacyjnych oraz większą aktywnością, a zatem większymi kosztami utrzymania. W glebach porolnych występuje też odmienny obieg biogenów niż w glebach leśnych.

Uprawa gleby, niszczenie runa i ubożenie składu gatunkowego drzewostanów opóźniają tempo procesów regeneracyjnych i sukcesyjnych a zwiększają stopień synantropizacji fauny. Gospodarcza ingerencja człowieka w stosunki florystyczne biocenoz leśnych wpływa na faunę w stopniu proporcjonalnym do jakości siedliska.

Zahamowanie degradacji siedlisk może być osiągane przez doskonalenie uprawy gleby (ochrona naturalnej warstwowości lub wzbogacanie w materiał organiczny), kształtowanie zoocenoz przez ustalenie optymalnego składu gatunkowego drzewostanu, ochronę i kultywację runa (zwiększenie potencjału regulacyjnego biocenoz szczególnie na siedliskach lasów i borów mieszanych, pomyślne kształtowanie procesów glebotwórczych, szczególnie na siedliskach ubogich) oraz przez introdukcję wybranych gatunków zwierząt (szczególnie w zalesieniach).

НЕКОТОРЫЕ ПРОБЛЕМЫ ФОРМИРОВАНИЯ БИОЦЕНОЗОВ В НАРУШЕННЫХ ЛЕСНЫХ БИОТОПАХ

РЕЗЮМЕ

В работе рассмотрены экологические аспекты воздействия лесного хозяйства на зооценозы и возможности биологической охраны лесных биоценозов от нарушения.

Особое внимание посвящено воздействию на сообщества лесных беспозвоночных полной вырубки, возделывания почвы, изменения растительного покрова и видового состава древостоя. Представлены также результаты исследований процессов реституции сообществ почвенных беспозвоночных в лесонасаждениях, посаженных на бывших сельскохозяйственных угодьях.