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EVALUATION OF ALFA DIVERSITY OF AN ANTHROPOGENIC FOREST THREATENED BY PESTICIDE TOMB*

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Key words: alfa species diversity, antropogenic forest, pesticide tombs.

Abstract

This study was aimed at evaluating the point diversity of an anthropogenic forest threatened by a pesticide tomb. Herein, the concept of diversity is consistent with that of WHITTAKER (1977). A lack of significant differences in the diversity index, species abundance and species contribution between the phytocoenoses of the examined community with *Sambucus nigra-Picea abies* and that of *Sambuco racemosi-Pieceetum* indicates a modifying role of the pesticide tomb in species distribution within the analyzed phytocoenoses.

Diversity in species distribution of phytocoenoses *Sambuco racemosi-Piceetum* and *Sambucus nigra-Picea abies* in the ordination space determined by ecological index numbers points to a modifying effect of the pesticide tomb.

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OCENA α-RÓŻNORODNOŚCI ANTROPOGENICZNEGO LASU WOKÓŁ MOGILNIKA PESTYCYDOWEGO

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Słowa kluczowe: α-różnorodność gatunkowa, antropogeniczny las, mogilnik pestycydowy.

Abstrakt

Badania miały na celu ocenę α-różnorodności gatunkowej antropogenicznego lasu położonego w sąsiedztwie mogilnika pestycydowego. Wykazano brak istotnych różnic w zakresie indeksu różnorodności, bogactwa gatunkowego i udziału gatunków w fitocenozach badanych zbiorowisk *Sambucus nigra-Picea abies i Sambuco racemosi-Pieceetum*. Stwierdzono istnienie czynników modyfikujących siedliska badanych fitocenoz. Przypuszczalnie jest to wpływ mogilnika pestycydowego, który może powodować zmiany w składzie gatunków badanych fitocenoz w analizowanych zbiorowiskach roślinnych.

Introduction

One of key threats to the natural environment in Poland are hazardous wastes, especially those deposited in tombs. In Warlity Wielkie, near Ostróda, a pesticide tomb was in use until November 3, 2003. It is one of the 16 landfill sites of non-utilized pesticides in the province of Warmia and Mazury in the years 1960–1970. The tomb was used as a landfill of 54 tonnes of toxic substances disposed in 36 silos and 2 unprotected cavities.

Since 2003, complex analyses of edaphic and aquatic habitats have been carried out on this area (SKIBNIEWSKA et al. 2002, SZAREK et al. 2003, GRZYBOWSKI et al. 2004, GRZYBOWSKI et al. 2005, ZMYSŁOWSKA et al. 2005).

This study was aimed at evaluating the point diversity of an anthropogenic forest threatened by a pesticide tomb. Herein, the concept of diversity is consistent with that of WHITTAKER (1977).

Study Area

The forest area under study is situated within the Ostróda – Warlity Fishing Farm, approx. 800 m from the nearby village of Warlity Wielkie (Figure 1). The area covers 6.5 ha. The habitat type is typical former farmland forested area, artificially planted with trees.

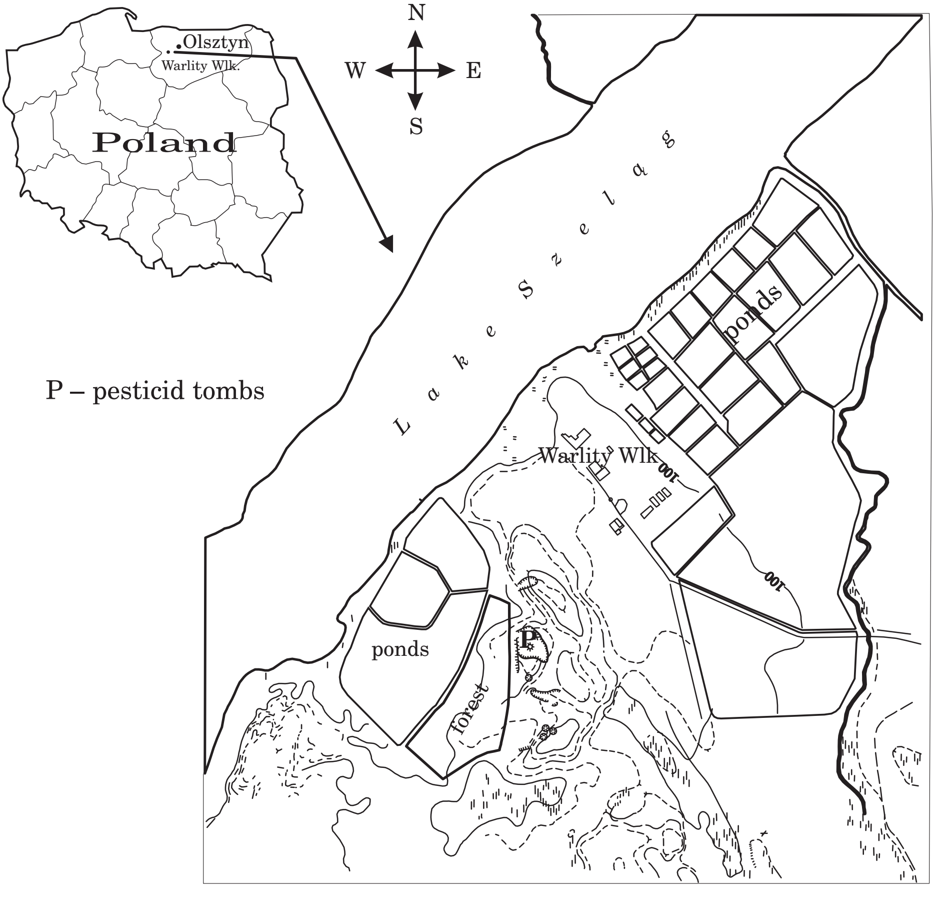

Fig. 1. Location of the study area

On the eastern side, the forest is adjoined by a hill on top of which in 1968–2004 a pesticide tomb was built. It covered an area of 0.7 ha. The pesticide tomb under study was situated in sandy formations and even a small leakage of the chambers posed a threat to contamination of ground waters and the neighboring ecosystems, including the forest (Figure 1). On the western wall, the forest is adjoined by three fishing ponds, followed by the largest lake in the basin of the Drwęca River – Szeląg Wielki.

Material and Methods

A site survey was carried out in the summer of 2006–2007. The basis for the ecological characteristics were 16 phytosociological releves performed with the BRAUN-BLANQUET method (1964). The releves covered an area of 400–600 m^2 (Figure 2).

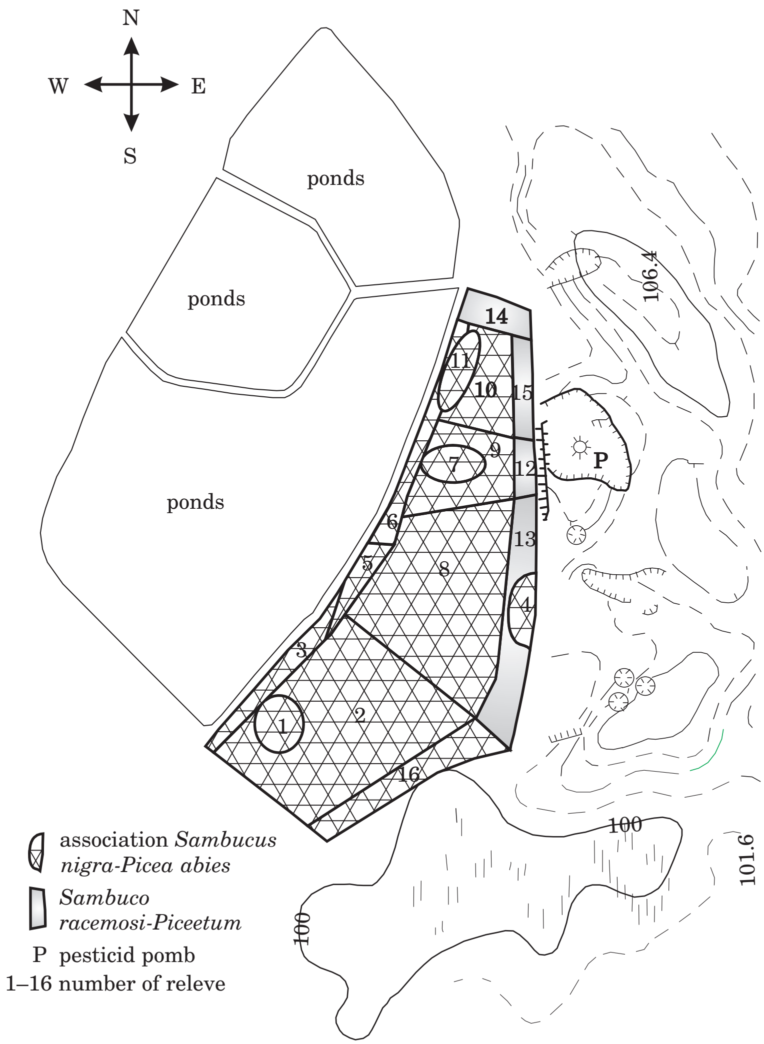

Fig. 2. Location of the phytosociological releves within the study area in the vivinity of the pesticide tomb

The nomenclature of vascular plants was adopted after RUTKOWSKI (2004). The names of bryophyte species were given according to *Die Moos – und Farnpflanzen Europas* (1995).

In this paper, use is made of a division of spruce forests proposed by SOKOŁOWSKI (1980). The remaining syntaxonomic units were adopted according to the common nomenclature by MATUSZKIEWICZ (2001).

For a numerical analysis of the phytosociological pictures, the quantitative degrees in the BRAUN-BLANQUET scale (1964) were transformed into the quantitative degrees in the scale proposed by JANSÉN (1975) following the recommendations of MAAREL VAN DER (1979).

To analyze the internal differentiation at the level of phytosociological releves, use was made of the *Complete Link* method belonging to the group of hierarchic agglomeration methods (GRZYBOWSKI, ENDLER 1999). To calculate the matrix of distances between sites, an Euclidian measure was used. The effect of the analysis is a dendrogram graphically depicting the significance of similarities between the phytocoenoses.

The evaluation of diversity was conducted based on a Shannon-Wiener index (SHANNON, WEAVER 1949). The Shannon-Wiener diversity index (H) is defined as a negative sum of the product of probability of subsequent species significance in a set (pi), a logarithm of that probability.

$$H = -\sum p_i \log p_i$$

with 2 adopted as logarithm base.

The probability of subsequent species significance in the set (p_i) is understood as a quotient n_i/N, where n_i is a coefficient of significance of a given species, ad N denotes the sum of significance coefficients of all species.

Species distribution in phytocenosis was described by means of a Pielou Evenness index (J) (MAGURRAN 1988). The Pielou Evenness index (J) is defined as a ratio of observed diversity to the maximal diversity at a given number of species s:

$J = \frac{H_{obs}}{H_{\max}}$ where the maximum diversity H_{max} after transforming the formula into the Shannon-Wiener diversity index:

$J = \frac{H_{obs}}{\text{lig } s}$, the value of Pielou Evenness reaches maximally 1 when the observed diversity equals the maximum diversity, namely when all species have equal contribution in the phytocenosis.

Calculations of diversity were conducted with the use of Multi Variate Statistical Package (MVSP) ver. 3.1.

To determine statistically significant differences in terms of species abundance, diversity index and contribution of species in phytocoenoses between the analyzed communites of *Sambucus nigra-Picea abies* and *Sambuco racemosi-Piceetum,* the mean values of all indices were calculated.

Next, it was determined whether the observed differences between mean values of indices were statistically significant. To this end, use was made of a non-parametric U-test from Statistica 7.1 package (StatSoft, Inc. 2005). To avoid a second order error (to adopt a null hypothesis – on a lack of differences between means; URLICH 2004), Student's t-test was applied additionally which assumes normal distribution of results or differences between results. The Student's t-test was computed by means of Statistica 7.1 package (StatSoft, Inc. 2005).

The U-test is a non-parametric equivalent of the Student's t-test (ŁOMNICKI 2003, STANISZ 1998).

Ecological preferences of species were determined with the use of index numbers by Zarzycki and Ellenberg (ELLENBERG 1974, ZARZYCKI et al. 2002), in addition ordination was performed based on Canonical Correspondence Analysis [CCA].

The CCA is a method postulated by Braak ter (1986, 1987,1988a,b). It enables determining the standard of variability of analyzed data, which is explained to the greatest extent by considered habitat variables. First, weighted means were computed for all indices characterizing preferences of all species present on phytosociological relevés: soil humidity (*W*), trophism (*Tr*), soil acidity (*R*), mechanical soil content (*D*), organic matter content (*H*) (ZARZYCKI et al. 2002) and nitrogen content of soil (*N*) (ELLENBERG 1974).

In CCA calculations use was made of Multi Variate Statistical Package (MVSP) ver. 3.1.

Results

On the examined area there were identified 161 species of vascular plants and 24 species of bryophytes.

Similarity between the relevés is depicted in a dendrogram (Figure 3) that differentiates the set of phytosociological relevés into two groups according to the phytosociological classification performed.

From the phytosociological viewpoint, the analyzed forest was classified to two syntaxonomic units: a community with *Sambucus nigra-Picea abies* and a community of *Sambuco racemosi-Pieceetum* Jut.-Trzeb. 1980 (Table 1, Table 2).

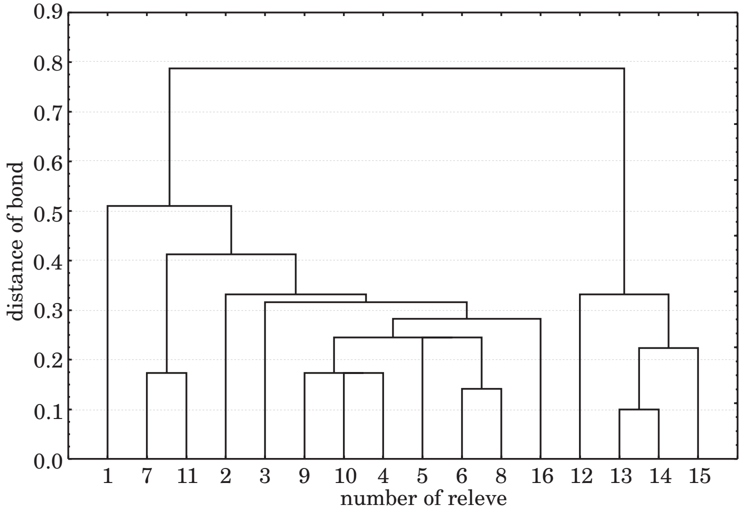

Fig. 3. Dendrogram of similarity between the releves of the studied forest area

Table 1

Community *Sambucus nigra-Picea abies*

Successive number		1	2	3	4
Number of releve		12	13	14	15
Date		06. 2006	06. 2006	06. 2007	06. 2006
Area of releve in m^2		200	600	400	400
Cover of plants layer (%) a		100	100	100	100
b		80	60	80	80
c		60	60	60	60
d		20	20	10	20
Total number of species in 1 releve		38	27	46	53
1		2	3	4	5
Ch. *Sambucus nigra-Picea abies*					
Sambucus nigra	b	3	4	3	1
Picea abies	a	5	5	3	5
Picea abies	c	.	.	+	+
Ch. *Myceli-Piceion*					
Mycelis muralis	c	1	.	2	1
Plagiomnium affine	d	2	1	1	.
Ch. *Vaccinio-Piceetea*					
Sorbus aucuparia	b	.	.	1	+
Calamagrostis arundinacea	c	.	.	.	1
Betula pendula	a	.	.	.	1
Ch. *Tilio-Piceion*					
Milium effusum	c	.	.	1	.
Dryopteris filix-mas	c	.	.	1	1
Aegopodium podagraria	c	3	2	2	4

cont. table 1

1		2	3	4	5
Ch. *Querco-Fagetea*					
Acer platanoides	a	1	.	3	2
Acer platanoides	b	.	.	2	.
Acer platanoides	c	1	.	1	1
Tilia cordata	a	.	.	1	.
Corylus avellana	b	2	1	2	2
Corylus avellana	c	.	.	1	1
Fagus sylvatica	c	.	.	+	+
Epilobium montanum	c	+	.	.	1
Poa nemoralis	c	1	2	.	1
Accompanying species					
Quercus robur	a	.	.	2	2
Quercus robur	b	.	.	1	.
Quercus robur	c	1	.	+	1
Pteridium aquilinum	c	.	.	2	1
Maianthemum bifolium	c	+	+	.	.
Rubus idaeus	b	2	.	2	2
Frangula alnus	b	.	.	+	2
Frangula alnus	c	.	1	2	+
Veronica chamaedrys	c	.	1	3	1
Urtica dioica	c	.	.	3	2
Fragaria vesca	c	1	.	2	.
Galeopsis tetrahit	c	2	.	2	2
Sambucus racemosa	b	1	1	1	+
Chelidonium majus	c	2	+	2	+
Equisetum pratense	c	+	1	1	1
Galium aparine	c	2	.	2	2
Poa pratensis	*c*	*1*	*1*	.	*1*
Geum urbanum	c	1	.	3	2
Anthriscus sylvestris	c	.	+	2	1
Arrhenatherum elatius	c	.	2	1	2
Avenula pubescens	c	1	.	1	2
Saponaria officinalis	c	+	+	+	.
Convolvulus arvensis	c	+	+	+	.
Lapsana communis	c	1	.	+	1
Melilotus officinalis	c	1	.	+	1
Stellaria media	c	.	.	2	2
Agrostis gigantea	c	.	1	.	1
Poa trivialis	c	1	1	.	.
Dactylis glomerata	c	.	.	1	1
Holcus mollis	c	1	.	.	2
Calamagrostis stricta	c	1	.	.	1
Plantago major	c	3	3	.	.
Leonurus cardiaca	c	+	+	.	.
Artemisia vulgaris	c	+	.	.	+
Myosotis sylvatica	*c*	.	.	+	+
Filipendula ulmaria	c	.	.	+	+
Galeopsis bifida	c	.	.	1	+
Cirsium vulgare	c	.	.	2	.
Geranium robertianum	c	.	.	2	.
Verbascum nigrum	c	.	.	.	2

cont. table 1

1	2	3	4	5
Bryophytina				
Brachythecium retabulum d	2	2	2	+
Eurhynchium hians d	.	.	.	3
Plagiomnium undulatum d	1	.	.	.
Eurhynchium praelongum d	.	1	.	.
Plagiothecium succulentum d	.	.	.	1
Eurhynchium striatum d	+	.	.	.
Eurhynchium schleicheri d	+	.	.	.
Sporadic species: *Moehriniga trinervia* 3 (+), *Ranunculus ficaria* 4 (+), *Scrophularia nodosa* 3 (+), *Silene latifolia* 1 (1), *Festuca arundinacea* 1 (1), *Cirsium arvense* 1 (1), *Galeopsis speciosa* 2 (1), *Vicia sativa* 2 (1), *Rumex acetosa* 2 (+), *Rumex sanguineus* 2 (+), *Valeriana officinalis* 3 (1), *Ranunculus acris* 3 (+), *Hypericum perforatum* 3 (+), *Levisticum officinale* 3 (+), *Verbascum thapsus* 4 (1), *Alliaria petiolata* 4 (1), *Rumex crispus* 4 (1), *Agrimonia eupatoria* 4 (1), *Conyza canadensis* 4 (1), *Epilobium angustifolium* 4 (+), *Senecio sylvaticus* 4 (+), *Euphorbia cyparissias* 4 (+).				

Table 2

Community *Sambuco racemosi-Piceetum* Jut.-Trzeb. 1980

Successive number	1	2	3	4	5	6	7	8	9	10	11	12	Constancy
Number of releve	1	7	11	2	3	9	10	4	5	6	8	16	
Date	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2006	06. 2007	06. 2007	
Area of releve in m^2	200	600	200	200	300	400	400	300	200	200	300	500	
Cover of plants layer (%) a	100	100	100	100	100	100	100	100	100	100	100	100	
b	70	60	60	70	70	60	40	60	60	50	60	40	
c	90	90	80	90	90	80	80	90	80	90	90	80	
d	30	30	30	20	30	40	50	30	20	40	40	40	
Total number of species in 1 releve	73	80	42	67	75	40	39	67	52	61	59	39	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ch. *Sambuco racemosi – Piceetum*													
Sambucus racemosa b	3	1	1	3	3	2	2	2	4	3	2	2	V
Ch. *Vaccinio-Piceion*													
Picea abies a	4	4	3	5	5	5	5	5	5	5	5	5	V
Picea abies c	.	+	1	+	.	2	1	.	1	+	+	+	IV
Mycelis muralis c	1	.	.	+	+	.	1	2	2	1	1	3	IV
Plagiomnium affine d	2	+	.	1	1	1	+	1	+	.	1	.	IV
Ch. *Vaccinio-Picetea*													
Sorbus aucuparia b	+	+	1	2	+	1	2	.	1	1	1	.	V
Calamagrostis arundinacea c	.	.	3	2	.	1	.	1	1	1	2	.	III
Pleurozium schreberi d	2	3	.	3	2	2	2	.	2	3	3	.	IV
Betula pendula a	.	.	4	.	+	1	.	.	+	.	.	.	II
Betula pendula b	.	1	.	.	.	1	1	.	.	.	1	.	II
Betula pendula c	.	.	.	.	.	1	1	.	.	.	.	.	I
Betula pubescens a	.	.	+	.	.	.	.	.	.	.	.	.	I
Betula pubescens c	+	.	.	.	1	.	.	.	1	1	.	.	II

cont. table 2

1		2	3	4	5	6	7	8	9	10	11	12	13	14
Populus tremula	a	.	.	.	.	+	.	.	.	.	.	.	.	I
Populus tremula	b	+	.	.	.	.	.	.	.	.	.	.	.	I
Populus tremula	c	.	.	1	.	.	.	.	.	.	.	.	.	I
Ch. *Dicrano-Pinion*														
Pinus sylvestris	a	.	.	.	2	2	.	.	.	.	+	.	.	II
Dicranum polysetum	d	.	.	.	.	.	.	.	.	.	2	.	.	I
Ch. *Pino-Quercion*														
Veronica officinalis	c	1	1	+	+	+	+	+	.	1	1	1	.	V
Polytrichum formosum	d	1	.	.	.	.	1	.	.	.	.	2	.	II
Ch. *Alnetea Glutinosae*														
Alnus glutinosa	a	.	.	1	.	.	.	.	.	.	.	.	.	I
Salix cinerea	b	.	.	2	.	.	.	.	.	.	.	.	.	I
Ribes nigrum	b	.	1	1	.	.	.	.	.	.	.	.	.	I
Solanum dulcamara	c	+	.	.	.	+	.	.	.	+	+	.	.	II
Ch. *Tilio-Piceion*														
Milium effusum	c	.	.	.	1	.	.	.	1	.	1	.	2	II
Dryopteris filix-mas	c	1	1	1	1	.	.	1	1	1	.	1	1	IV
Aegopodium podagraria	c	.	.	.	.	.	.	.	2	.	.	.	1	I
Ch. *Querco-Fagetea*														
Acer platanoides	a	.	.	.	.	.	.	5	.	.	.	.	.	I
Acer platanoides	b	.	.	.	.	.	.	2	.	.	1	2	.	II
Acer platanoides	c	+	+	+	1	+	1	1	2	.	1	2	.	V
Tilia cordata	b	.	+	.	.	.	.	.	3	.	.	1	.	II
Tilia cordata	c	.	.	.	.	.	.	.	.	.	.	1	.	I
Corylus avellana	b	.	.	.	.	+	.	.	3	.	.	2	3	II
Corylus avellana	c	+	.	.	.	.	.	.	2	.	.	.	.	I
Fagus sylvatica	b	.	+	.	.	.	1	1	2	+	+	1	.	III
Fagus sylvatica	c	1	+	.	.	+	1	.	1	1	.	+	.	III
Euonymus europaeus	b	.	.	.	.	.	.	.	.	.	.	.	1	I
Moehriniga trinervia	c	1	1	.	.	.	.	.	.	2	.	1	.	II
Circaea alpine	c	.	.	.	+	.	.	.	.	.	.	.	.	I
Ranunculus ficaria	c	1	1	1	1	1	1	1	1	+	+	+	1	V
Epilobium montanum	c	1	.	+	1	1	+	+	.	+	+	.	.	IV
Scrophularia nodosa	c	.	.	.	.	+	.	.	.	.	.	1	.	I
Poa nemoralis	c	2	2	.	1	1	.	.	1	1	.	1	.	III
Acer pseudoplatanus	c	.	1	.	.	.	.	.	.	.	.	.	.	I
Ulmus glabra	a	.	.	.	.	.	.	.	.	.	.	2	2	I
Ulmus gabra	b	.	.	.	.	.	.	.	.	.	.	.	1	I
Accompanying species														
Quercus robur	a	.	.	1	.	.	.	.	.	.	.	.	.	I
Quercus robur	b	.	.	1	.	.	+	.	.	.	.	.	.	I
Quercus robur	c	+	+	.	+	+	2	1	1	.	+	1	.	IV
Oxalis acetosella	c	.	+	.	1	.	1	.	.	3	3	2	.	III
Pteridium aquilinum	c	1	1	2	1	1	.	2	+	+	1	1	1	V
Maianthemum bifolium	c	.	.	.	.	.	1	1	.	.	.	1	+	II
Festuca ovina	c	.	.	.	1	.	.	.	.	.	.	.	.	I
Rubus idaeus	b	3	3	3	3	3	3	.	2	1	3	3	2	V
Frangula alnus	b	+	+	2	.	+	.	.	.	+	1	2	2	IV
Frangula alnus	c	.	1	1	1	+	2	2	1	1	1	1	.	V
Veronica chamaedrys	c	+	1	2	+	+	.	.	+	1	1	2	.	IV
Urtica dioica	c	1	2	.	1	2	.	.	3	3	3	3	3	IV

cont. table 2

1		2	3	4	5	6	7	8	9	10	11	12	13	14
Fragaria vesca	c	1	2	1	1	1	1	.	1	2	3	3	+	V
Epilobium angustifolium	c	.	.	2	.	.	1	+	+	1	1	.	.	III
Galeopsis pubescens	c	1	.	1	4	3	.	2	.	.	.	.	.	III
Galeopsis tetrahit	c	.	.	2	2	.	.	2	4	.	.	.	.	II
Sambucus nigra	b	1	+	+	1	1	2	+	1	1	1	+	+	V
Stellaria media	c	3	2	.	.	3	1	2	2	2	1	3	2	V
Galium aparine	c	1	3	2	+	1	1	2	4	3	3	2	3	V
Dactylis glomerata	c	1	1	+	+	1	.	+	+	+	+	1	.	V
Holcus mollis	c	2	2	2	1	1	2	2	.	1	1	1	.	V
Saponaria officinalis	c	+	+	.	+	+	+	.	+	+	+	+	+	V
Chelidonium majus	c	.	+	.	1	4	.	.	2	+	1	+	3	IV
Poa trivialis	c	2	2	.	1	1	2	2	1	1	.	.	.	IV
Geum urbanum	c	2	+	.	.	1	+	1	2	.	+	1	2	IV
Arrhenatherum elatius	c	2	2	2	.	1	2	.	.	2	2	1	.	IV
Artemisia vulgaris	c	1	1	+	+	1	.	.	.	+	+	+	+	IV
Athyrium filix-femina	c	+	+	.	+	.	.	.	+	+	+	+	+	IV
Equisetum pretense	c	+	+	.	+	+	+	1	+	.	+	+	.	IV
Cardamine pratensis	c	+	+	+	+	+	+	.	.	+	+	+	.	IV
Berula erecta	c	+	+	.	+	+	+	.	.	+	+	+	.	IV
Anthriscus sylvestris	c	.	1	.	.	1	.	.	1	1	1	.	2	III
Avenula pubescens	c	2	.	.	.	1	.	.	1	1	.	.	2	III
Cirsium vulgare	c	.	.	.	+	+	.	.	+	1	.	1	.	III
Glechoma hederacea	c	1	1	.	.+	.	+	+	.	.	.	+	.	III
Filipendula ulmaria	b	1	.	1	1	1	.	1	.	+	1	1	.	III
Silene latifolia	c	1	1	1	1	+	.	.	+	.	+	.	.	III
Myosotis sylvatica	c	1	+	.	.	.	.	1	+	+	+	.	+	III
Alliaria petiolata	c	+	.	.	.	+	.	.	+	.	.	+	2	III
Medicago lupulina	c	+	+	.	.	+	.	.	.	+	+	.	.	III
Carex hirta	c	2	2	2	.	.	.	.	.	.	.	.	.	II
Calamagrostis stricta	c	.	2	.	1	1	.	.	.	.	1	.	.	II
Poa palustris	c	2	2	.	.	1	.	.	.	.	.	.	.	II
Achillea millefolium	c	1	1	.	.	.	.	.	1	.	1	.	.	II
Senecio sylvaticus	c	+	1	.	1	.	.	.	.	.	.	.	.	II
Anthoxanthum odoratum	c	2	2	.	.	1	.	.	.	.	.	1	.	II
Poa pratensis	c	.	2	.	.	.	2	.	1	.	.	.	2	II
Convolvulus arvensis	c	.	+	.	.	+	.	.	.	.	.	.	+	II
Viola arvensis	c	+	.	.	+	+	.	.	.	.	.	.	.	II
Geranium robertianum	c	.	.	.	.	1	.	.	.	2	1	.	.	II
Agrostis gigantea	c	.	.	.	.	1	.	.	.	.	1	1	1	II
Rumex acetosella	c	.	.	.	+	+	.	.	.	.	+	.	.	II
Plantago major	c	.	.	3	.	.	+	3	.	.	.	.	1	II
Eupatorium cannabinum	c	1	.	.	1	.	.	.	.	1	1	.	.	II
Circaea lutetiana	c	.	.	.	.	+	.	.	.	+	+	.	.	II
Rumex sanguineus	c	.	.	.	+	+	.	.	.	+	.	.	+	II
Crataegus monogyna	b	.	+	.	.	+	.	.	.	.	+	.	.	II
Crataegus monogyna	c	1	+	.	.	.	.	.	1	.	.	.	.	II
Rosa canina	b	.	3	.	.	+	.	.	.	.	.	2	.	II
Myosotis arvensis	c	+	.	.	.	.	.	.	+	.	.	+	.	II
Phalaris arundinacea	c	.	.	2	1	.	2	.	.	.	.	.	.	II
Cirsium arvense	c	.	.	.	+	.	.	.	+	.	.	1	.	II
Agrimonia eupatoria	c	.	1	.	.	.	.	.	+	.	+	.	.	II

cont. table 2

1		2	3	4	5	6	7	8	9	10	11	12	13	14
Potentilla argentea	c	.	1	.	.	.	.	.	.	.	+	+	.	II
Knautia arvensis	c	.	+	.	.	.	.	.	+	.	+	1	.	II
Ajuga reptans	c	+	.	.	1	.	.	.	+	.	.	.	.	II
Ranunculus repens	c	1	1	.	.	.	.	.	.	.	.	.	.	I
Matricaria inodora	c	1	1	.	.	.	.	.	.	.	.	.	.	I
Elymus repens	c	.	2	.	.	.	.	.	.	.	.	.	.	I
Trisetum flavescens	c	.	2	.	.	.	.	.	.	.	.	.	.	I
Alopecurus pratensis	c	.	2	.	.	.	.	.	.	.	.	.	.	I
Festuca pratensis	c	.	2	.	1	.	.	.	.	.	.	.	.	I
Avena fatua	c	.	2	2	.	.	.	.	.	.	.	.	.	I
Lolium multiflorum	c	.	.	2	.	.	.	.	.	.	.	.	.	I
Festuca gigantea	c	.	.	.	1	.	.	.	.	.	1	.	.	I
Deschampsia caespitosa	c	.	.	.	.	1	.	.	1	.	.	.	.	I
Trifolium arvense	c	.	.	.	.	1	.	.	1	.	.	.	.	I
Syringa vulgaris	b	.	.	.	.	.	.	.	3	.	.	.	.	I
Syringa vulgaris	c	.	.	.	.	.	.	.	2	.	.	.	.	I
Bromus hordaceus ssp. Hordaceus	c	.	.	.	.	.	.	.	2	.	.	.	.	I
Ulmus minor	a	.	.	.	.	.	.	.	.	.	.	.	2	I
Ulmus minor	b	.	.	.	.	.	.	.	.	.	.	.	1	I
Bryophytina														
Brachythecium retabulum	d	1	.	2	2	1	2	+	2	2	.	2	1	V
Rhytidiadelphus squarrosus	d	2	2	1	1	+	1	2	.	.	.	1	.	IV
Brachythecium oedipodium	d	.	.	.	.	2	.	3	.	.	+	.	.	II
Scleropodium purum	d	.	1	.	.	2	.	.	.	.	+	.	.	II
Eurhynchium hians	d	.	.	.	.	.	.	.	1	.	.	.	2	II
Plagiomnium undulatum	d	+	.	.	.	.	.	.	1	+	1	.	.	II
Plagiothecium denticulatum	d	1	.	+	.	.	+	.	.	.	.	.	.	II
Brachythecium starkei	d	.	.	.	+	.	.	.	.	.	1	.	.	II

Sporadic species: *Trientalis europaea* 4 (+), 5 (+), *Hylocomium splendens* 2 (+), *Hieracium vulgatum* 4 (+), *Viburnum opulus* 11 (+), *Campanula rotundifolia* 1(+), 2 (1), *Crataegus laevigata* 1 (+), *Chenopodium album* 1(+), *Ranunculus acris* 1(+), *Chenopodium polyspermum* 1 (+), 4 (+), *Vicia tetrasperma* 1 (+), *Valeriana officinalis* 1(+), 2 (+), *Trifolium pratense* 1 (+), 2 (+), *Trifolium repens* 1 (+), 2 (+), *Hypericum perforatum* 2 (1), 10 (+), *Hieracium pilosella* 2 (+), 4 (+), *Lathyrus pratensis* 2 (+), *Vicia cracca* 2 (+), 7 (1), *Plantago lanceolata* 2(+), *Coronilla varia* 2 (+), *Hieracium murorum* 3 (1), *Galeopsis bifida* 4 (1), *Sisymbrium altissimum* 4 (1), *Juncus effusus* 4 (+), *Hypericum maculatum* 4 (+), *Vicia grandiflora* 4 (+), *Galium mollugo* 5 (1), 8 (+), *Agrostis stolonifera* 5(1), *Cirsium oleraceum* 5 (+), 11 (1), *Succisella inflexa* 5 (+), *Lapsana communis* 5 (+), 8 (+), *Arctium tomentosum* 5 (+), 9 (+), *Sium latifolium* 5 (+), *Solidago graminifolia* 5 (+), *Linaria vulgaris* 6 (+), *Vicia hirsuta* 7 (1), *Lamium album* 8 (1), *Rhamnus catharticus* 8 (+), *Rumex acetosa* 8 (+), *Euphorbia cyparissias* 8 (+), *Verbascum thapsus* 8 (+), *Atriplex patula* 8 (+), *Conyza canadensis* 8 (+), *Plantago major* ssp. *intermedia* 8 (+), *Polygonum minus* 8 (+), *Scabiosa canescens* 8 (+), *Galeopsis speciosa* 9 (1), *Heracleum sphondylium* ssp. *sphondylium* 12 (1), *Plagiomnium cuspidatum* 12 (1), *Cirriphyllum piliferum* 7 (+), 11 (+), *Mnium stellare* 7 (+), *Eurhynchium angustirete* 4 (+), *Ditrichum pusillum* 6 (+)

Both the communities are anthropogenic in character. The prevailing part of species building the identified phytocoenoses are anthropophytes.

Diversity of samples representing a community was interpreted after WHITTAKER (1977) as an internal α-diversity, also referred to as point diversity.

The results obtained (Table 3) demonstrate that species abundance of the *Sambucus nigra-Picea abies* (Table 1) community ranges from 27 to 58 species in a phytocenosis. In addition, in that community the value of Shannon index fluctuates between 4.6 and 5.8. The results indicate a correlation between the value of diversity index and the number of species and the Pielou Evenness index. The highest value of diversity index was reported for the relevés with the highest number of species (No. 14, 15).

Table 3

Diversity indices of an *Sambuco racemosi-Piceetum* and *Sambucus nigra-Picea abies* communities

No. Releve	Shannon-Wiener Index (H)	Mean	Pielou Evenness (J)	Mean	Num. Spec.	Mean
Sambuco racemosi-Piceetum						
1	6.06		0.979		73	
7	6.201		0.978		81	
11	5.371		0.978		45	
2	5.944		0.976		68	
3	6.095	5.72325	0.975	0.975417	76	60
9	5.334		0.977		44	
10	5.25		0.974		42	
4	5.942		0.973		69	
5	5.621		0.972		55	
6	5.834		0.972		64	
8	5.843		0.977		63	
16	5.184		0.974		40	
Sambucus nigra-Picea abies						
12	5.15		0.974		39	
13	4.624	5.28075	0.972	0.97625	27	44.25
14	5.596		0.977		53	
15	5.753		0.982		58	

In the community of *Sambuco racemosi-Piceetum* species abundance ranges from 40 to 81 species in a phytocenosis (Table 2), and the value of Shannon index from 5.2 to 6.2. The results point to a correlation between the value of diversity index and species number and the value of Pielou Evennes index. The highest value of diversity index was observed for relevés with the highest number of species (No. 7, 3, 1), and the lowest one – for those with the lowest number of species (No. 16, 10, 9, 11).

Table 4

U-Mann-Whitney test and Student's *t*-test

U-Mann-Whitney. Grouping. var. stadium, marked results are significant at p <.05000										
Specification	Rank sum	Rank sum	U	Z	*p* level	Z	*p* level	No. cases per group	No. cases per group	2*1str.
Index (H)	117.0000	19.00000	9.00000	1.819017	0.068910	1.819017	0.068910	12	4	0.078022
Evenness (J)	101.0000	35.00000	23.00000	-0.12127	0.903479	-0.12244	0.902548	12	4	0.952747
Num. Spec.	117.0000	19.00000	9.00000	1.819017	0.068910	1.819017	0.068910	12	4	0.078022
Student's *t*-test; grouping: stadium (sheet1) group 1: 1 group 2: 2										
Specification	mean	mean	*t*	Df	P	no. cases per group	no. cases per group	SD	SD	F quotient
Index (H)	5.72325	5.28075	1.944655	14	0.072187	12	4	0.35724	0.50689	2.013291
Evenness (J)	0.97542	0.97625	-0.48962	14	0.631987	12	4	0.00243	0.00435	3.205392
Num. Spec.	60.00000	44.25000	1.909717	14	0.076876	12	4	14.35270	14.03270	1.046128

Simultaneously, attention was paid to various representation of species in a phytocenosis: relevé No. 8 had higher diversity than relevé No. 6 despite a lower number of species. Similar relations were observed between relevés No. 2 and No. 4 (Table 1). It results from more even spatial distribution of species in phytocoenoses No. 8 and No. 2 as compared to phytocoenoses No. 6 and No. 4. This is also indicated by a higher value of evenness indices for phytocoenoses No. 8 and No. 2 as compared to those No. 6 and No. 4.

The mean value of the diversity index and the mean number of species were higher in the case of *Sambuco racemosi-Piceetum* community, as compared to the *Sambucus nigra-Picea abies* one (Table 1). In turn, the mean values of the Pielou Evenness was higher in the community of *Sambucus nigra-Picea abies* in respect of the mean value of that index reported in the community of *Sambuco racemosi-Piceetum* (Table 3).

The U-Mann-Whitney test and Student's t-test carried out in the study confirmed that the observed differences in the diversity index, species abundance and species contribution in phytocoenoses between communities of *Sambuco racemosi-Piceetum* and those of *Sambucus nigra-Picea abies* were statistically significant (Table 4).

Variables applied in the CCA explain only ca. 43.6% of the total diversity of plants (Table 5). Canonical coefficients of all habitat variables evaluated by a measure of Variance Inflation Factor [VIF < 20 (BRAAK TER 1986)] are stable and suitable for interpretation.

Table 5

CCA ordination of the phytocoenoses threatened by a pesticide tomb

Variable	Weighted mean	Weighted SD	Variance Inflation Factor VIF
W	3.299	0.079	2.362
Tr	3.548	0.151	14.355
R	3.574	0.145	11.007
D	3.826	0.082	2.144
H	3.125	0.044	2.44
N	6.683	0.506	5.574

Specification	axis 1	axis 2	axis 3	axis 4	axis 5	axis 6	total interia
Eigenvalues	0.285	0.211	0.188	0.134	0.12	0.109	2.401
Percentage	11.862	8.801	7.844	5.578	5.005	4.523	–
Cum. Percentage	11.862	20.663	28.507	34.086	39.09	43.613	–
Cum. Constr. Percentage	27.199	47.379	65.364	78.154	89.63	100	–
Spec.-env. Correlations	0.98	0.977	0.988	0.924	0.967	0.982	–
Sum of all eigenvalues	–	–	–	–	–	–	2.401

Note: only the first 6 axes are environmentally constrained

Phytocoenoses of both communities are observed to separate along I axis gradient (Figure 4). On the right side of the ordination space with a higher contribution of erytopic cosmopolitan species, phytocoenoses adjoining the tomb can be distinguished (13, 16, 12, 14, 15, 4). All relevés of *Sambucus nigra-Picea abies* are observed herein (12, 13,14, 15). On the left side of the ordination space with a higher moisture content there are grouped phytocoenoses bordering with a drainage ditch being the closest to the fishing ponds (3, 5, 6, 11) and those located in the central area of the forest examined (1, 2, 7, 8, 9, 10).

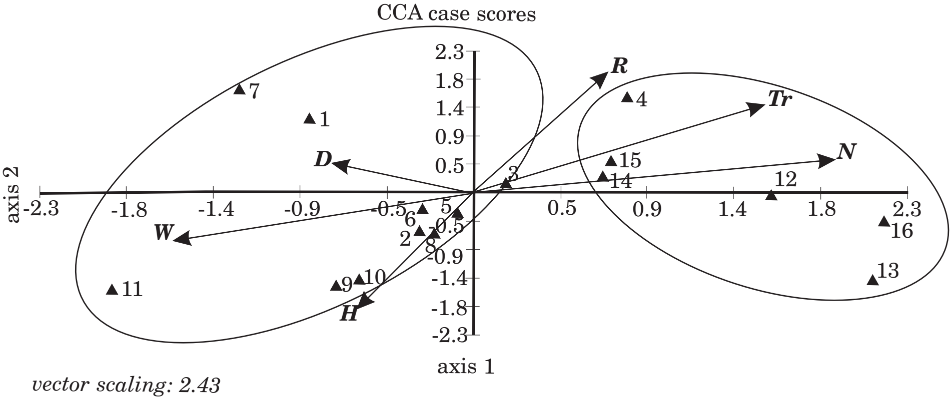

Fig. 4. CCA ordination diagram of the phytocenoses threatened by a pesticide tomb: 1–16 – releve; *W* – soil moisure value, *Tr* – trophy value, *R* – soil acidity (pH) value, *D* – soil granulometric value, *H* – organic matter content value, *N* – nitrophylity value

Discussion

The communities with *Sambucus nigra-Picea abies* usually occupy fertile, humus, damp and not very insolated habitats (ENDLER 1987). Soils they grown on are of character of artificially transformed soils with various degree of the soil-forming process advancement, or soils with a changed soil profile, as was the case of the examined habitat (GRZYBOWSKI et al. 2006). Phytocoenoses of *Sambuco racemosi-Pieceetum* are reported most often at forest ducts and on felling sites (SOKOŁOWSKI 1980). On the examined area, they also occurred close to a forest duct leading from a tomb to ponds (Figure 2). They requirements for soil and moisture content are medium, they are found most often on fresh, fertile argillaceous soils (SOKOŁOWSKI 1980). The analysis of the point diversity at a level of phytosociological relevés (Figure 2) confirmed the accuracy of the adopted phytosociological division, consistent with concepts of GRZYBOWSKI et al. (2006).

Investigations of species diversity carried out in the communities of *Sambuco racemosi-Piceetum* and *Sambucus nigra-Picea abies* did not demonstrate any statistically significant differences in terms of the diversity index, species abundance and species contribution. It has been confirmed by the ecological characteristics of the community with *Sambucus nigra-Picea abies* and community of *Sambuco racemosi-Pieceetum* (GRZYBOWSKI et al. 2005), which demonstrated that the phytocoenoses assayed were alike in terms of habitat factors.

Analyses of the preferences of species occurring in the phytocoenoses of *Sambuco racemosi-Piceetum* and *Sambucus nigra-Picea abies* distributed along a gradient determined by edaphic index numbers enabled selecting groups of phytocoenoses located in the very direct proximity of the pesticide tomb. This confirms results of investigations into the content of heavy metals in selected plant species in an environmental gradient around a pesticide tomb (GRZYBOWKI et al. 2005a,b) in which higher contents of heavy metals were observed in species growing in phytocoenoses adjacent to a pesticide tomb. Also soil analyses pointed to increasing effects of the tomb on soils of phytocoenoses located in its close vicinity (ZMYSŁOWSKA et al. 2005).

Conclusions

1. A lack of significant differences in the diversity index, species abundance and species contribution between the phytocoenoses of the examined community with *Sambucus nigra-Picea abies* and that of *Sambuco racemosi-Pieceetum* indicates a modifying role of the pesticide tomb in species distribution within the analyzed phytocoenoses.

2. Diversity in species distribution of phytocoenoses *Sambuco racemosi-Piceetum* and *Sambucus nigra-Picea abies* in the ordination space determined by ecological index numbers points to a modifying effect of the pesticide tomb.

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