DIFFERENTIATION OF VEGETATION IN A SALINE GRASSLAND IN THE VICINITY OF INOWROCŁAW SODA PLANTS AT MĄTWY

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ABSTRACT

In the course of two growing seasons (1992 and 1993) there was investigated the zonation of vegetation with reference to soil conditions at the saline grassland in the vicinity of Inowrocław Soda Plants at Mątwy town. In data analysis there were used: classification method – hierarchical agglomerative cluster analysis and as well as two ordination techniques: Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA). As a result of the classification analysis five vegetation zones were distinguished, related to the following communities: community with *Festuca rubra*, *Potentillo-Festucetum arundinaceae*, community with *Euphorbia lucida* and *Phragmites australis*, *Triglochino-Glaucetum maritimae* and *Puccinellio distantis-Salicornietum brachystachyae*. The ordination techniques used in the analysis have demonstrated that out of the measured soil properties the most essential part, in the formation of the grassland vegetation zonation, played the content of chloride ions (which was used here as the main salinity measure), while moisture and pH were of minor importance. All the measured environmental factors accounted for only a low percentage (26.5% in 1992 and 17.2% in 1993) of the total vegetation variation, what might suggest that besides chloride ions another factor might have affected the development of zonation.

KEY WORDS: environmental gradient, halophytes, salinity, DCA, CCA.

INTRODUCTION

In the Kujawy region halophilous vegetation occurs both in natural habitats: along brine springs and salt plugs and also in the areas being under anthropogenic pressure such as salt mining, brine exploitation and soda industry. The example of a large industrial object, considerably influencing salinity of adjacent areas, is Inowrocław Soda Plants (Inowrocławskie Zakłady Sodowe) at Mątwy. In the immediate vicinity of the Plants, distinct zonation of grassland and pasture vegetation can be observed, showing in its spatial structure zones or patches dominated by halophilous species.

The carried out so far studies on halophytes in the Kujawy region concerned mainly phytosociology, ecology and protection of halophytes (Wilkoń-Michalska 1957, 1963, 1970, 1976, 1986, Nienartowicz & Wilkoń-Michalska 1993a, 1993b). The study introduced here presents the results of investigation, which aimed also at ecology of halophytes – exactly at the determination of relationships between the zonation of vegetation and soil properties. Basing on the results of the earliest studies there have been assumed, that the factors differentiating halophilous vegetation are salinity, moisture, and soil reaction. As the main measure of salinity there was adopted, after Wilkoń-Michalska (a.b.), the content of chloride ions in the soil.

MATERIAL AND METHODS

The study area

The research was carried out at one of the meadows situated in the immediate vicinity of the Soda Plants at Mątwy town, in north-western Kujawy (between 52° and 53° N, and 18° and 20° E). The general source of salinity for meadows and arable fields neighbouring the Plants are the sediment traps together with drainage ditches, and also Rąbin Ditch following southwards. Their origin came back to ca. 1900' s. In case of the studied here meadow the main source of salinity there was the sediment trap, which originated in the seventies (see Fig. 1), and exactly – one of the drainage ditches surrounding it. The surface of the meadow was plane, only slightly sloping down towards the source of salinity.

The sediment traps are to collect the industrial slime of sediments created during the process of soda production, which consist mainly of: $CaCO_3$, $CaSO_4$, $Ca(OH)_2$, $Fe(OH)_3$, silicates, aluminosilicates and oversedimentary liquid, which is a solution of KCl, NaCl, NH_4OH, Na_2SO_4, NaOH, $MgCl_2$, $CaCl_2$. In a consequence of inappropriate tightening of the bottoms of sediment traps there takes place infiltration of accumulated there sewage into the soil substratum. It has been ascertained (Kulesza et al. 1977) that the concentrations of

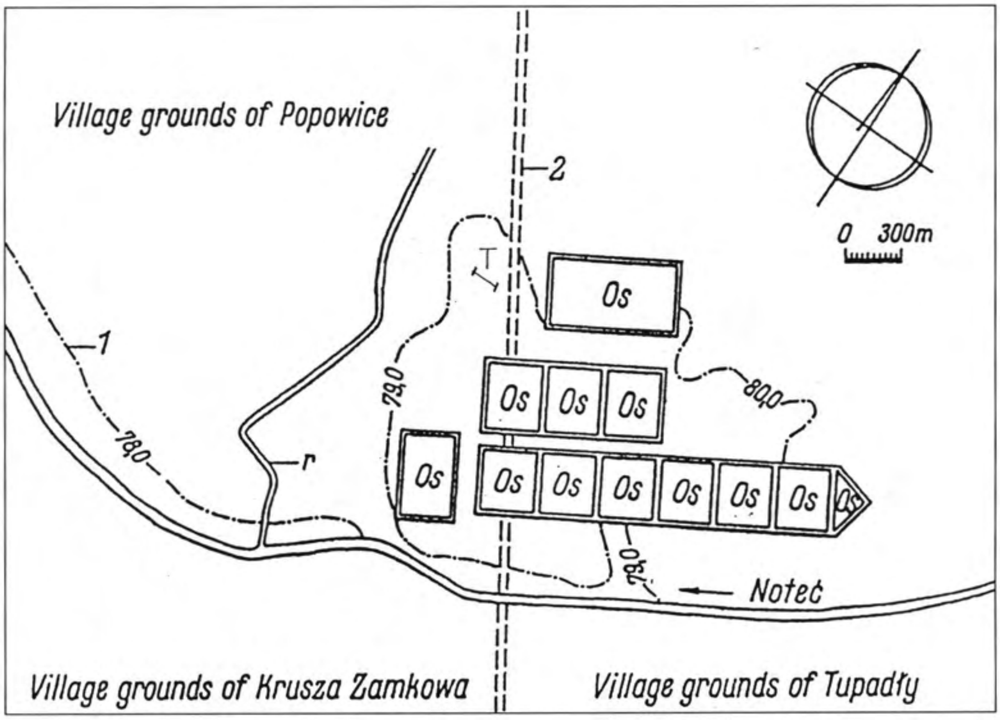

Fig. 1. Location of the study area: T – transect, Os – settling tanks, r – ditch, 1 – contour lines, 2 – run line of western salt fault

calcium and chlorides in the underground waters of that area are approximated the concentrations of those components in the settling tanks. Furthermore, salinity of this area is connected with changes of waters salinity and its level in the drainage ditches, as the waters flood the surrounding regurally, particulary after abundant rains, or after damages to the pipelines converging brine to the Plants. High concentrations, mainly of chloride and univalent ions, cause deterioration of soil structure and change in its chemical composition (alkalization, salinity). A consequence of those adverse phenomena are changes in the succesion of plant communities dominated by halophytes and an increase in the area of agriculturally useless lands (Wilkoń-Michalska 1957, Czerwiński at al. 1984).

Field works

The investigations were carried out on 16 July 1992 and 15 June 1993. In 1992 a transect of 87 m long and 1m wide was subjectively selected, so as to cover all variation in vegetation and soil conditions in the study grassland. The transect was laid down from an agriculture field towards a drainage ditch with saline water (Fig. 1). The transect was terminated at the place were on the soil innundated with brine there were no more plants growing. Along the transect there were taken 87 phytosociological relevés, each one the size of a square with a side of 1m. The phytosociological relevés were taken following the Braun-Blanquet approach (Braun-Blanquet 1964, Westhoff & van der Maarel 1978). The names of the species of vascular plants were given after Flora Europea (Tutin et al. 1964-1980). Affiliation of particular species to syntaxonomic groups were defined after Matuszkiewicz (1981).

At right verges of the squares, soil samples were taken at a depth of 0-25 cm so as not to damage the vegetation of a given path. In the first, homogeneous part of the transect soil samples for chemical analyses were taken for relevés 1, 6, 20, and starting from relevé 25 they were taken every one meter up to relevé 87. Samples for determining soil moisture were taken at points: 1, 6, 20, 35, 44, 52, 57, 64, 78, 81, 85.

In 1993 in consequence of deepening the drainage ditches saline waters considerably receded from the investigated area and thus there were expected changes in vegetation of the meadow. That is why phytosociological relevés were repeated for each of the 87 squares along the same transect. The transect was extended by 37 m considering an extension of the area overgrown with vegetation and terminated, like in the year before, where there were no more plants on the soil flooded with brine. At a right margin of each of the 124 squares, soil samples for chemical analyses were taken at a depth of 0-25 cm, and samples for determining moisture were taken every 10 m.

Laboratory analyses

In fresh soil samples the actual moisture was determined by the method of drying in 105°C temperature and expressed as percentage by weight.

For chemical analyses air-dry earthy parts of soil (Ø < 1 mm) were taken and the following parameters were determined:
– pH in destillated water by the potentiometric method,
– the chloride ion content by Mohr's method. The method consists in titrating the study solution with silver nitrate of determined titre (0.1 n) with the presence of potassium chromate as an indicator. The soil solutions, in which the chlorides content was determined, were prepared according to the method described by Adriani (1945). The results were expressed as percentage, i.e. there was given amount of gram of chloride ion in 100 g dry soil. The concentration of chloride ion in soil water was calculated using the formula: chloride ion content in the soil / soil moisture x 100%.

Multivariate analyses

In order to obtain a description of the transect vegetation and its relationship to the habitat, classification and ordination analyses were carried out. The cover/abundance values obtained with the Braun-Blanquet scale were transformed into ordinal scale values (van der Maarel 1979, Noest et al. 1989) in the following way: + - 2, 1 - 3, 2 - 5, 3 - 7, 4 - 8, 5 - 9. The phytosociological relevés were clustered using the hierarchical agglomerative cluster analysis: average linkage procedure, unweighted pair group (MVSP package, Kovach 1986-1993), and then subjected to ordination analysis. There were used both Indirect Gradient Analysis (IGA), performed on the vegetation data alone, in order to capture the overall variation present in the study vegetation and as well as to help in the identification of outliers, and Direct Gradient Analysis (DGA), performed on the vegetation and environmental data together, in order to explore relationships between the vegetation and habitat. Since data were collected along an environmental gradient, expecting the presence of a major coenocline, an unimodal model was accepted as an appropriate one (Pielou 1984; ter Braak 1987). For indirect Gradient Analysis Detrended Correspondence Analysis (DCA, Hill & Gauch 1980; ter Braak 1987) was applied, and for Direct Gradient Analysis – Canonical Correspondence Analysis (CCA, ter Braak 1990). The phytosociological relevés for which soil salinity analyses were not made enter gradient analyses as passive samples.

In order to ascertain a possible relative importance of the respective environmental variables in determining the vegetation variation along the transect, as well as relative amount of the variation present in the species data as accounted for by the measured environmental data, forward selection of explanatory variables (ter Braak 1990) was applied. For assessing the statistical significance of each variable upon inclussion in the regression model, the Monte Carlo permutation test (ter Braak 1990) was used with 99 unrestricted permutations of the constraining variable. Throughout the analysis relations between species and environmental variables were considered significant at $P. < 0.01$ Both DCA and CCA were done using the program package CANOCO version 3.10 (ter Braak 1987, 1990).

RESULTS

Soil characteristics

On the grounds of profile structure, soil of the considered here grassland was classified as anthropogenic saline soil (Systematics of Polish Soils 1989). The results of chemical analyses (Piernik 1994) show that during the investigation period in 1992, pH of the transect soil oscilated around value 7, moisture increased from 31% to 140% along the transect, and the content of chloride ions: from 0.27% to 10.88%.

During the investigation period in 1993, pH of the transect soil was fluctuating within interval 6.83 to 7.84 and was slightly higher than the year before. Moisture was increasing (irregularly) from 26% to 112%, the chloride ions content – from 0.09% to 3.32%. The values of both moisture and salinity were considerably lower than in 1992 (Fig. 2).

Zones of vegetation

Basing on the classification of the floristic relevés, four types of phytocoenoses were distinguished in both years of investigations: the community with *Festuca rubra*, *Potentillo-Festucetum arundinaceae*, community with *Euphorbia lucida* and *Phragmites australis*, *Triglochino-Glaucetum maritimae*. At the terminal part of the transect in 1992 vegetation with *Aster tripolium*, with *Aster tripolium* and *Salicornia europaea*, vegetation with *Salicornia europaea* were distinguished, whereas in 1993 year the community with *Atriplex hastata var. salina and Senecio vernalis*, and *Puccinellio distantis-Salicornietum brachystachyae* (Fig. 3A, Fig. 4A). In the ordination diagrams they are distributed along the first

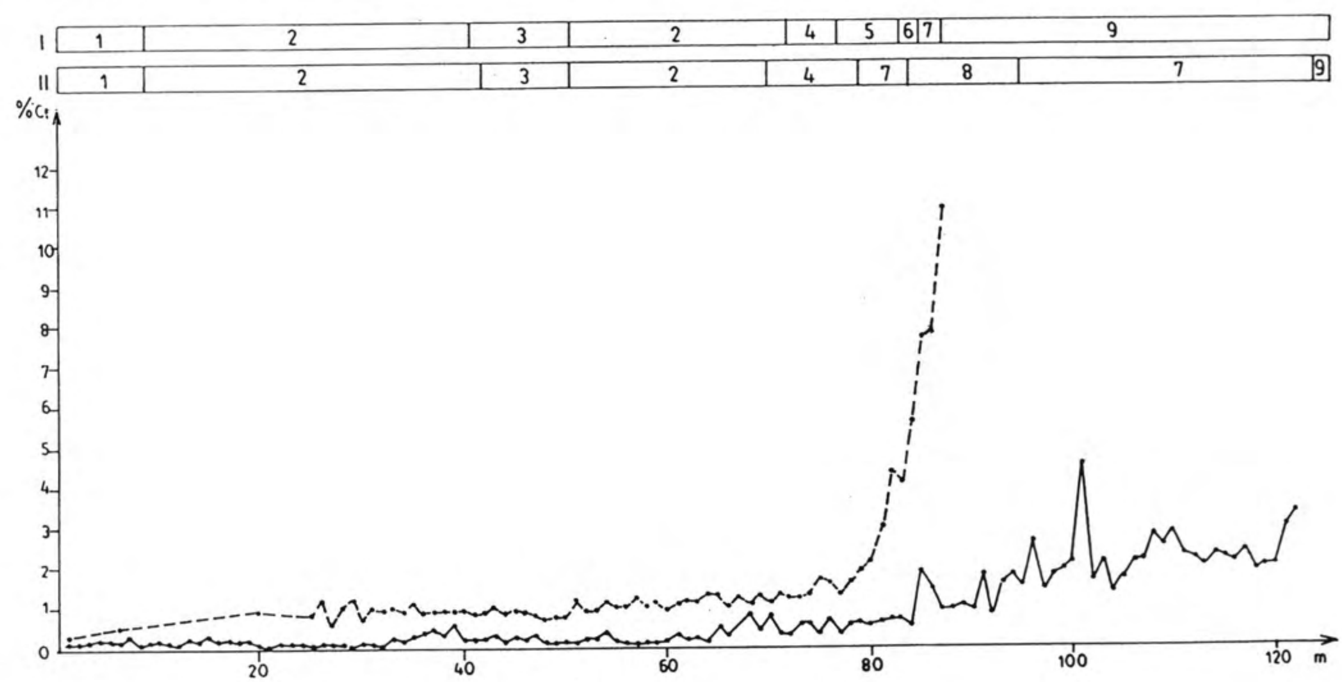

Fig. 2. Zonation of transect vegetation against a background of chloride ions content in soil
------ 16.07.92, ____ 15.06.93, I – communities distinguished in 1992, II – communities distinguished in 1993, 1 – community with *Festuca rubra*, 2 – *Potentillo-Festucetum arundinaceae*, 3 – community with *Euphorbia lucida* and *Phragmites australis*, 4 – *Triglochino-Glaucetum maritimae*, 5 – community with *Aster tripolium*, 6 – community with *Aster tripolium* and *Salicornia europaea*, 7 – *Puccinellio distantis-Salicornietum brachystachyae* (relevés with *Salicornia europaea*-1992), 8 – community with *Atriplex hastata* var. *salina* and *Senecio vernalis*, 9 – stagnant saline waters.

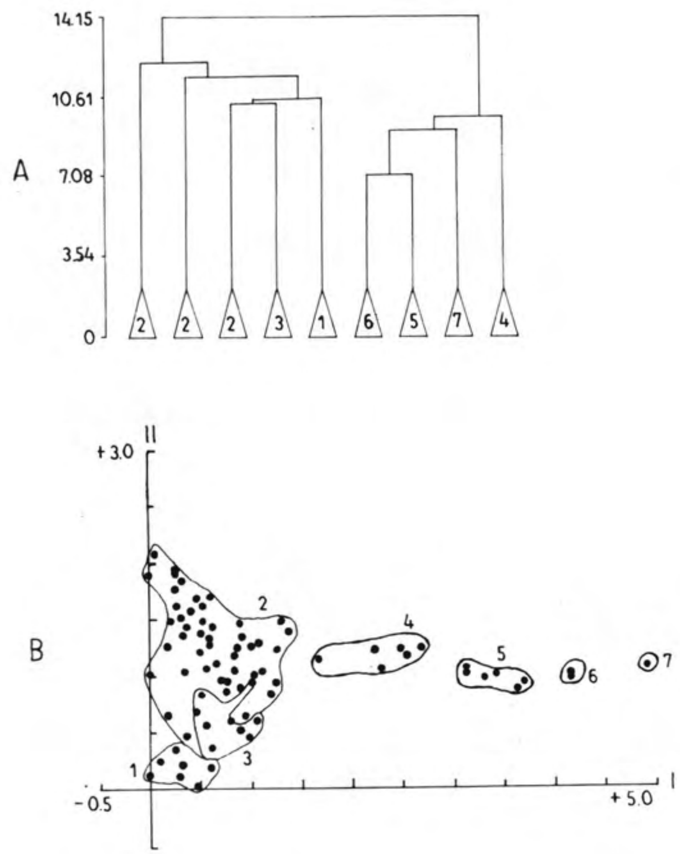

Fig. 3. Variation of transect vegetation in 1992:
A. dendrogram obtained with an agglomerative hierarchical clustering procedure (with Euclidean Distance as a resemblance measure) of 87 phytosociological relevés; groups indicated represent distinguished plan communities.
B. summary ordination diagram with axes 1 and 2 of a Detrended Correspondence Analysis (DCA).
Denotation of plant communities as in Fig. 2.

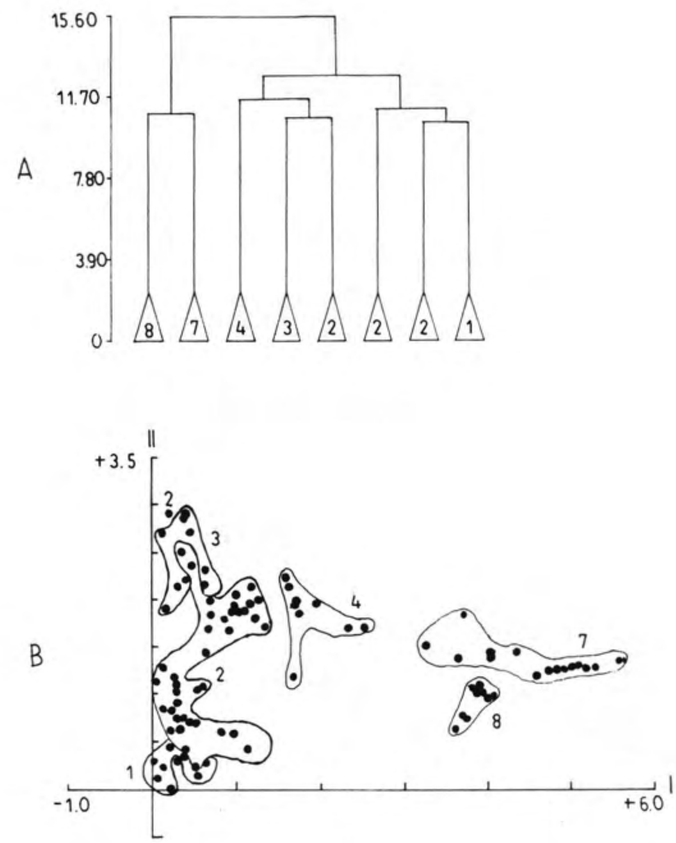

Fig. 4. Variation of transect vegetation in 1993:
A. dendrogram of an agglomerative hierarchical procedure (with Euclidian distance as a resemblance measure) of 124 phytosociological relevés; groups indicated represent the plant communities.
B. summary ordination diagram with axes 1 and 2 of a Detrended Correspondence Analysis (DCA).
Denotation of plant communities as in Fig. 2.

axis, which represented salinity gradient in accordance with the sequence of zones observed on the meadow (Fig. 3B, Fig. 4B). At the left hand side of the ordination diagrams there are placed relevés representing grass communities, at the extreme right there are the relevés from the sites nearest to the source of salinity, the remaining relevés take an intermediate position.

Succesively from the fore-part of the transect the first nine relevés represented the plant community with *Festuca rubra* (Piernik, Rutkowski 1994). There grew here mainly grassland species, including many grasses, such as *Festuca arundinacea*, *Deschampsia cespitosa*, *Elymus repens*. Facultative halophytes: *Carex distans* and *Melilotus dentata,* constituted a small admixture of vegetation. The major part of the transect was occupied by the zone of *Potentillo-Festucetum arundinaceae* character (relevés number 10-40 and 51-66 in 1992; 10-41 and 52-70 in 1993). In its composition grassland species dominated. Halophytes did not play an important part, though their share was much higher than in the former community. There were found here: *Carex distans, Glaux maritima* and *Atriplex hastata var. salina.*

The zone of *Potentillo-Festucetum arundinaceae* character was discontinued by the patches of vegetation with *Euphorbia lucida* and *Phragmites australis* (relevés number 41-51 in 1992 and 42-51 in 1993). Comparatively numerously there occur here grassland species, particularly those characteristic of the class *Molinio-Arrhenatheretea* and *Plantaginetea maioris.* Whereas halophytes played a minor role. There were met *Melilotus dentata*, *Carex distans* and *Glaux maritima.*

Of typically halophilous character there were relevés number 72-77 in 1992 and 70-79 in 1993 akin to *Triglochino-Glaucetum maritimae* community. However, the only community characteristic species occuring there, there was *Glaux maritima.* Considerable share there have grasses *Elymus repens* and *Phragmites australis.*

Phytocoenoses with *Aster tripolium* (relevés number 78-83; 1992) were poor in species. Besides the dominating *Aster tripolium*, a considerable percentage was constituated by *Glaux maritima*, *Salicornia europaea*, *Elymus repens* and *Phragmites australis*.

Relevés 84-85 (1992), characterized by a low vegetation cover – 25%, were phytocoenoses with *Salicornia europaea* and *Aster tripolium*.

In the last two metres of the transect (relevés 86 and 87; 1992) the only species growing there was *Salicornia europaea*, reaching merely 5% cover.

In the terminal section of the transect in 1993 (relevés 80-84 and 95-124) there developed the *Puccinellio distantis-Salicornietum brachystachyae* community. That community was characterized by the occurrence of *Salicornia europaea*, *Puccinellia distans*, *Aster tripolium Atriplex hastata var. salina* and *Glaux maritima* as well as other species, for instance *Carex otrubae* (*C. nemorosa*), *Chenopodium ficifolium* and *Chenopodium glaucum*.

Puccinellio distantis-Salicornietum brachystachyae community was discontinued by the patches of communities with *Atriplex hastata var. salina* and *Senecio vernalis* (relevés 85-94). A high degree of constancy there reached here *Puccinellia distans*.

The sequence of the vegetation variation along the transect in relation to soil conditions is presented in Fig. 2.

Relations between soil condition and variation of vegetation

In CCA ordination out of the four environmental variables involved in the analysis, i.e.: pH, moisture, chloride ion content in soil, chloride ion concentration in soil water, the last mentioned one was removed from the futher ordination analysis as it was strongly correlated with the chloride ion content in the soil (VIF – variance inflation factor value > 20; ter Braak 1987). In the data set of 1992 all the environmental variables left in the analysis (pH, moisture, chloride content in the soil) contributed significantly to the total variance of the floristic data, whereas in the data set of 1993 out of those three environmental factors, pH had to be deleted from the futher analysis, as its effect on the species was not significant at the conventional 5% level.

The total inertia (i.e. total variance in the species data) amounted 3.09 in 1992 and 5.42 in 1993. The current explanatory variables explained only 26.5% of the total vegetation variance in the species data of 1992 and 17.2% of 1993 (Tab. 1).

The largest contribution to the total variance of the floristic data had chloride ion content in soil: 17.5% of 1992's data set and 13.3% of 1993's data set; the contribution by soil moisture was 6.1% and 3.5% respectively; pH explained 2.9% of the total variance of the 1992's data set (Tab. 1).

The eigenvalues of the CCA ordination (Tab. 2) indicate that only the first axis (λ_1=0.55 with the data set of 1992 and λ_1=0.73 with the data set of 1993; scaling λ=1) displays the biologically relevent information and hence, is significant for explanation of the variance in the species data (Jongman, ter Braak, van Tongeren 1987). The first eigenvalue was significant at P< 0.01 significance level.

The correlation of the environmental factors with the CCA ordination axes (Tab.2) indicated that the first axis reflected mainly a gradient in chloride ion content in soil, the second axis – a gradient in moisture, and the third axis – a gradient in pH.

In the ordination diagrams (Fig. 5 and 6) most species concentrated in the centre of the diagrams and slightly spread along the first and second canonical axes. Species associated with the places of the highest salinity along the transect, such *Salicornia europaea*, *Aster tripolium*, *Puccinellia distans*, *Phragmites australis, Atriplex hastata var. salina, Senecio vernalis*, were clearly differentiated from the other species both along the first and the second axis.

DISCUSSION

Basing on the results of classification analysis, four vegetation zones were distinguished, unchanging during two successive vegetative seasons included in the study. They represented the following communities: the community with

TABLE 1. Result of the significance test (Monte Carlo permutation test) of explanatory environmental variables (for abbrevations see Fig. 5).

	1992		1993	
Environmental variables	significance level P	variation explained	significance level P	variation explained
Cl cont	0.01	17.5	0.01	13.3
Moist.	0.01	6.1	0.01	3.9
pH	0.01	2.9	0.13	–
Sum		26.5		17.2

TABLE 2. Eigenvalues and inter-set correlations of environmental variables (for abbrevations see Fig. 5) with axes of the Canonical Correspondence Analysis, and the fraction of the total variance extracted by the species axes.

	1992			1993	
Axes	1	.2	3	1	2
Eigenvalues	0.55	0.18	0.88	0.73	0.21
Fraction extracted	0.47	0.10	0.14	0.64	0.14
Cl cont	0.93	0.12	-0.80	0.90	0.68
Moist.	0.70	-0.55	-0.70	0.68	-0.52
pH	-0.23	0.29	0.65	–	–

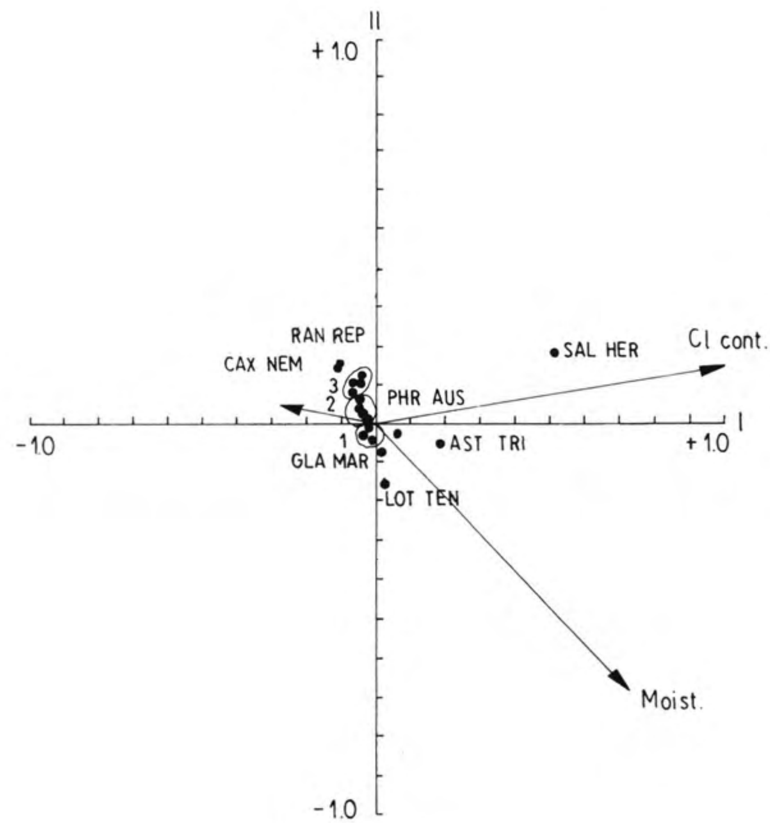

Fig. 5. Ordination diagram with axes 1 and 2 of a Canonical Correspondence Analysis (CCA) of the 43 species recorded in 1992 along the transect and applied environmental factors (represented by arrows): Cl cont-chloride ions content in soil, Moist-soil moisture, pH-soil pH; sal her-*Salicornia europaea*, ast tri-*Aster tripolium*, lot ten-*Lotus tenuis*, gla mar-*Glaux maritima*, cax nem-*Carex otrubae*, ran rep-*Ranunculus repens*, figures 1, 2 and 3 stand for the groups of species having the same co-ordinates; 1: *Cirsium arvense, Elymus repens* (a blue-green form), *Agrostis stolonifera, Plantago major ssp. intermedia, Carex distans, Picris hieracioides, Cirsium vulgare*, 2: *Atriplex hastata var. salina, Euphorbia lucida, Lotus corniculatus, Potentilla reptans, Achillea millefolium, Festuca arundinacea, Potentilla anserina, Elymus repens* (a green form), *Poa angustifolia, Sonchus arvensis, Centaurea jacea, Deschampsia cespitosa, Festuca rubra, Inula britannica, Tetragonolobus maritimus, Odontites verna ssp. pumila, Taraxacum officinale, Phragmites australis, Chenopodium album, Juncus compressus, Alopecurus pratensis, Plantago lanceolata, Poa pratensis, Ranunculus acer*, 3: *Melilotus dentata, Vicia cracca, Thalictrum flavum, Leontodon autuminalis, Dactylis glomerata, Plantago media.*

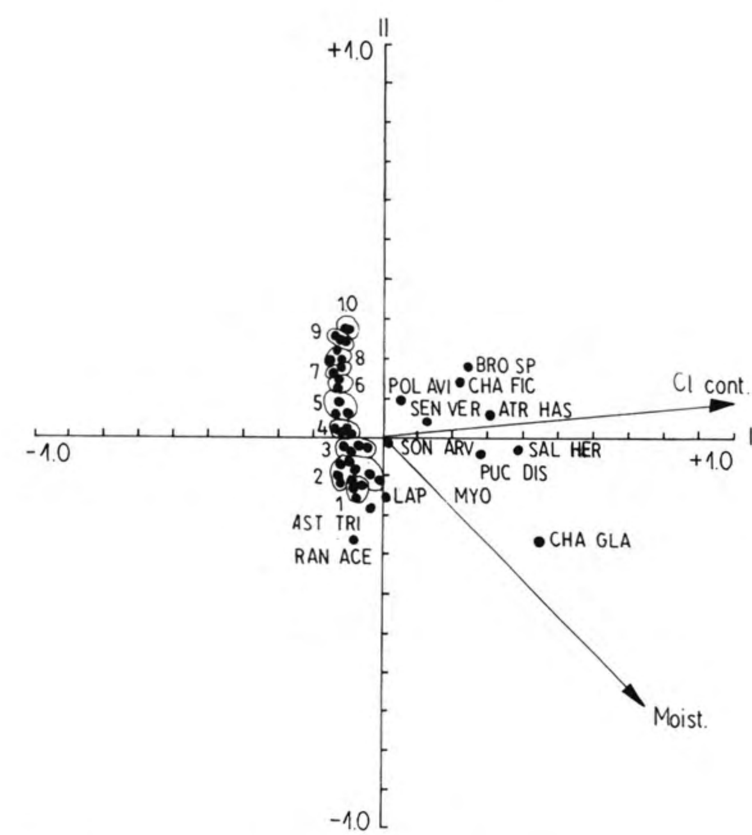

Fig. 6. Ordination diagram with axes 1 and 2 of the Canonical Correspondence Analysis of the 60 species recorded in 1993 along the transect and applied environmental factors (represented by arrows; for abbreviations see Fig. 5); sal her-*Salicornia europaea*, atr has-*Atriplex hastata var. salina*, puc dis-*Puccinellia distans*, cha gla-*Chenopodium glaucum*, cha fic-*Chenopodium ficifolium*, bro sp.-*Bromus sp*, pol avi-*Polygonum aviculare*, sen ver-*Senecio vernalis*, lap myo-*Lappula squarrosa ssp. squarrosa*, ast tri-*Aster tripolium*, ran ace-*Ranunculus acer*, 1: *Cirsium arvense, Glaux maritima, Plantago major ssp. intermedia, Phragmites australis, Lactuca serriola, Sonchus oleraceus*, 2: *Bromus hordeaceus, Potentilla anserina, Crepis tectorum, Agrostis stolonifera, Cirsium vulgare, Odontites verna ssp. pumila, Euphorbia lucida, Marticaria perforata, Atriplex nitens*, 3: *Elymus repens* (a blue-green form), *Cnidium dubium, Carex otrubae, Poa angustifolia, Potentilla reptans, Epilobium sp., Trifolium repens, Juncus compressus*, 4: *Achillea millefolium, Centaurea jacea, Inula britannica, Tetragonolobus maritimus, Taraxacum officinale, Conyza canadensis, Chenopodium album, Deschampsia cespitosa, Sonchus arvensis*, 5: *Epilobium palustre, Alopecurus pratensis, Cerastium fontanum ssp. triviale*, 6: *Ranunculus repens, Festuca rubra*, 7: *Festuca arundinacea, Elymus repens* (a green form), 8: *Carex distans, Plantago media, Lotus corniculatus, Dactylis glomerata, Vicia cracca*, 9: *Plantago lanceolata, Melilotus dentata, Poa pratensis*, 10: *Juncus bufonius, Leontodon autuminalis.*

Festuca rubra, Potentillo-Festucetum arundinaceae, the community with *Euphorbia lucida* and *Phragmites australis, Triglochino-Glaucetum maritimae*. The zone situated nearest to the source of salinity, dominated by obligatory halophytes, extended in size in the second year of the study – the regression of water flooding the meadow and probably decreasing of salinity afford posibilities for development of the community of *Puccinellio distantis-Salicornietum brachystachyae* character. All zones occuring on the meadow were presented in the investigated transect. This zonation is characteristic for most of the saline systems in the Kujawy region. Usually the community *Puccinellio-Spergularietum salinae* occurs also in the sequence of communities forming zonation, as the zone between *Puccinellio distantis-Salicornietum brachystachyae* and *Triglochino-Glaucetum maritimae*. On the investigated meadow this community didn't form a separate zone. It occurs only on the border of the meadow as in a small number of the patches. Among the halophilous communities occuring in the Kujawy there is also *Scirpetum maritimi* (it wasn't found on the meadow). This community grows, usually very fragmentarily, in salty pools or dithes with salty water. On the less salty soils in this region, besides *Potentillo-Festucetum arundinacea* distinguished on the meadow, community *Blysmo-Juncetum compressi* occurs. This community grows usually near the reservoirs on slimy, salty soils.

The order of soil salinity at depth of 0-25 cm recorded for the particular zones was similar to that reported by Wilkoń-Michalska (1963) for the corresponding plant communities from the Kujawy region, e.g. for *Salicornietum patulae* 0.3-20.6% Cl^-, for *Triglochin matitimum-Glaux maritima* 0.16-2.5%, for *Festuca arundinacea-Potentilla anserina* 0.04-0.56%. The salinity values recorded in the part of the transect adjoining a cultivated field were of a similar order to those reported by Cieśla (1981) for the soil of cultivated fields surrounding the Plants (at depth of 0-25cm: 0.011-0.224%Cl^-).

The DCA and CCA ordination analyses revealed that the deliminated vegetation zonation were differentiated to the highest degree in relation to the increasing soil salinity gradient. An analogous relationships and arrangement of plant communities along soil salinity gradient were obtained by DCA analysis for the plant communities occuring on saline soils in other regions of Poland (Nienartowicz and Wilkoń-Michalska 1993a, 1993b).

The results of the CCA analysis showed that the measured environmental factors explained only a small percentage of variation of the transect vegetation. Among them the most important was chloride ions content in soil, moisture explained only an inconsiderable fraction of the vegetation variation, and pH was almost of no significance for the elucidation of the study problem. A considerable amount of the variation (73.5% and 82.8% in 1992 and 1993) remains unexplained, what might implie that the measured environmental variables were not crucial for typological and spatial differentiation of the vegetation, and hence that unexplained variation was due to the effect of some overlooked, unmeasured factors, or spatial structure. The grazing by hares and wilde birds could be a such factor (Bakker 1989), this meadow was not exploited by grazing by cattle or geeses and hay-making in the period of investigations. Another explanation for that lack of close correlation between spatial variation of vegetation and spatial variation of environmental conditions might be random fluctuations in environmental condition which are not followed by immediate response of species occurring there, i.e. not simultaneous alteration of spatial environmental conditions and vegetation. Time of investigations could be also the reason why a high percentage of the total vegetation variation remains unexplained. The investigations were carried out at the begining of halophilous communities growth, whereas optimum of their growth is observed in the second half of August and the first half of September.

Differences that were obtained for data from 1992 and 1993 years could result from lability of moisture and chloride ions content in soil. Those values show actual condition at the given day and can show only general trends in vegetation variation. Species are sorted out along salinity gradient according to their physiological limits of salt tolerance, but rather maximum than mean or minimum salinity ultimately determines species distributions (Burhill & Kenkel 1991).

Resulted from CCA samples and species dispersion, smaller than from DCA, particullary along the first ordination axis, might insinuate that other ions, besides chloride one, decisive for soil salinity in that area: Ca^{2+}, Na^+, K^+, Mg^{2+}, cations and SO_4^{2-} and HCO_3^- anions (Cieśla at al 1981) might have affected the development of vegetation zonation. The chloride ions content in soil and their concentration in the soil solution may be subject to considerable fluctuation, since they are not exchangeably adsorbed by the soil sorptive complex (only in small measure by humus) and can be easly leached by rainfall water. Moreover, they are characterized by a high mobility they migrate deep into soil profile faster than the water molecules due to the repulsive action of negatively charged soil particles on the anions and as well as to the faster motion of anions in the narrow pores compared with water movement (Smith 1972). The use of Cl^- ions content as the main measure of salinity failed to explain fully the vegetation zonation in the grassland under study.

The zonation of halophilous vegetation in the Kujawy, as well as in other inland saline habitats, has a different character than in the coastal saline systems. Whereas species of coastal marshes must adopt to predictable tidal rythms that impose strong environmental gradients (Haines, Dunn 1985), those of inland habitats are subject to highly variable soil-salinity concentrations and periods of desiccation (Ungar 1974). Inland halophytes are also subject to occasional submergence following spring runoff or heavy rains. The environment of inland saline habitat is therefore somewat less predictable than that of most coastal salt marshes, both sesonally and from year to year. In the Kujawy the zonation is observed very often on the very small areas (Wilkoń-Michalska 1976) and could be called "microzonation" in comparison with coastal zonation. However the sequence of dominating species, common in both systems, along salinity gradient is rather similar.

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ZRÓŻNICOWANIE ROŚLINNOŚCI NA ZASOLONEJ ŁĄCE W SĄSIEDZTWIE INOWROCŁAWSKICH ZAKŁADÓW SODOWYCH W MĄTWACH

STRESZCZENIE

Przez dwa sezony wegetacyjne (1992 i 1993) badano różnicowanie się roślinności w odniesieniu do właściwości gleby na zasolonej łące w sąsiedztwie Inowrocławskich Zakładów Sodowych Mątwach. W analizie zebranych danych posłużono się metodą klasyfikacyjną (hierarchcal agglomerative cluster analysis) oraz dwoma technikami porządkującymi: Detrended Correspondence Analysis (DCA) i Canonical Correspondence Analysis (CCA). W wyniku analizy klasyfikacji wyróżniono pięć pasów roślinnych, nawiązujących do następujących zbiorowisk: zbiorowiska z *Festuca rubra* , *Potentillo-Festucetum arundinaceae*, zbiorowiska z *Euphorbia lucida* i *Phragmites australis*, *Triglochino-Glaucetum maritimae* i *Puccinellio distantis-Salicornietum brachystachyae*. Zastosowane techniki ordynacyjne wskazały, że spośród uwzględnionych właściwości glebowych, największy wpływ na kształtowanie się pasowego układu roślinności badanej łąki miała zawartość jonu chlorkowego w glebie (użyto ją jako główną miarę zasolenia), podczas gdy wilgotność i pH miały mniejsze znaczenie. Wszystkie mierzone czynniki środowiska tłumaczyły tylko niewielki procent (26.5% w 1992 roku i 17.2% w 1993 roku) ogólnej zmienności roślinności. Może to sugerować, że oprócz jonów chlorkowych inne czynniki wpływają na powstanie zonacji roślinności na badanym terenie.

SŁOWA KLUCZOWE: gradient środowiskowy, halofity, zasolenie, DCA, CCA.