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An Assessment of the MTR Aquatic Plant Bioindication System for Determining the Trophic Status of Polish Rivers

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Abstract

Mean Trophic Rank (MTR), a new British biological macrophyte-based method for assessing trophic status of rivers was applied in Poland in 2000-2001. The occurrence and abundance of 86 aquatic plant species was recorded at 48 sites on 19 rivers in the lowland part of Poland. Forty-six of these species are MTR scoring taxa used in the British system, but another 40 species were recorded of which 11 species were selected as potential scoring plants for use in Poland. The revision of MTR scoring plants used in Britain was performed and resulted in the proposed elimination of 24 taxa as scoring species for Poland. The habitat conditions of the selected river sites were assessed and their diversity was observed in terms of eutrophication level. The MTR score was evaluated and its correlation with water trophic level was shown. The environmental preferences of the individual plant species according to water chemistry were estimated to give proposals of the MTR scoring species in Poland and the indicated preference was analogous to the original Species Trophic Rank (STR) score used in the UK. The MTR system was recommended for use in biological monitoring programmes.

Keywords: water assessment, macrophytes, bioindication, Mean Trophic Rank, monitoring.

Introduction

The usefulness of living organisms to detect environmental changes has frequently been confirmed in terrestrial as well as aquatic ecosystems [1, 5, 6, 11, 14, 27]. Habitat quality can be reflected in individual species abundance as well as by the structure and diversity of communities. Recently with increasing environmental endangerment and cumulative changes, the role of bioindication plays an increasing importance. These methods allow the evaluation of both individual environmental factors and also the investigation of the nature of ecological processes. Bioindication also enables retrospective assessments (paleolimnology) as well as predictive studies such as trends in successions. The advantages of biological methods compared to such techniques as water analysis are: the complex evaluation of habitat, potentially high precision, and cost-effectiveness.

Extensive data about biological monitoring comes from studies of aquatic ecosystems. Many groups of organisms are useful indicators of the presence and concentration of pollution, especially trophic pollution. Water monitoring utilizes various groups of organisms, like bacteria, algae, macrophytes, invertebrates and other animals [1, 6, 14, 27].

Aquatic macrophytes belong to the group of organisms with well identified ecological requirements [2, 5, 8, 15, 19]. It is understood that vascular plants are good indicators of more persistent and constant habitat features or perturbations. Several systems utilize the indicative value of individual macrophyte species to measure irradiation, water trophic status, or pH [11, 15, 17]. The habitat-plant interactions might indicate individual species as well with

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identifying the presence and abundance of plant communities like, for example, the phytosociological system, where identification of the certain syntaxa might be helpful in evaluating numerous habitat conditions, including trophic status [4, 9, 18, 21], the classification system for British rivers [12], or lake litoral assessment [3]. Water bioindication methods based on macrophytes seem to be well developed, although its application in regular biological monitoring is still limited, e.g. in the UK. Thus, water assessment systems are still based on the physical and chemical parameters with vascular plants until recently treated only as complementary methods in many European countries [15].

In recent years in Britain, the new Mean Trophic Rank methodology has been established to determine the degradation level of rivers [7, 13, 16]. This method focuses on the detection of the trophic status of water pollution from Waste Water Treatment (WWT) discharges and it is based on the occurrence and abundance of water and riparian macrophytes. It is emphasized that the system based on macrophytes be potentially widespread because it is a group of organisms which can be relatively easy for precise identification.

The MTR system was quickly established in the UK and has been generally applied in practice. The early incentive for the development of the MTR system was growing environmental European requirements such as Urban Waste Water Treatment and the Water Framework Directive. The new system has been highly appreciated by UK experts and it has been implemented by governmental institutions (e.g. Environmental Agency). Several studies aimed at implementation of the MTR achievements in other countries (e.g. France, Spain and Czech Republic) are in progress. The future development of MTR as well as similar systems can be expected because the development for effective and low cost water pollution detection systems is one of the priorities of European science (Water Framework Program 5). It is also emphasised that a uniform Pan-European methodology in water assessment should be urgently developed.

The aim of the study was thus the evaluation of the British system of river water assessment (MTR) in Polish conditions. Firstly, the accuracy of the MTR system in pollution assessment was evaluated; secondly the bioindicative capabilities of individual plant species was assessed; thirdly critical verification of the original British list was verified in relation to its applications in Poland; and finally, the proposals for a number of alternative species observed locally in Poland were proposed which, after extensive studies, could be included in the future list of indicative species.

Methods

Principals of MTR System

The Mean Trophic Rank (MTR) system in trophic status indication was elaborated to define a degree of degradation of running waters and especially to assess the degree of eutrophication. The MTR system is based on the presence and abundance of aquatic species. The system indicator lists 127 plants, including: 7 macroscopic algae, 23 bryophytes, 3 pteridophytes and 86 vascular plants (39 dicotyledons and 47 monocotyledons). The selected macrophytes have been assigned a number **STR** (Species Trophic Rank) in scale from 1 (for tolerance to eutrophic waters) to 10 (for un-enriched water) [7, 16].

The Mean Trophic Rank is calculated for the 100 m length of the river site. Only river macrophytes growing in the water are recorded (or those likely to be submerged for more than 85% of the time). The total percentage of

Table 1. Pearson linear correlation coefficient of MTR index and water chemical parameters.

Variable	MTR	pH	Alkalini.	Conduc.	$N-NO_3$	$N-NH_4$	N total	SRP	P total	BOD	Oxygen
MTR	1.000										
pH	0.193	1.000									
Alkalini.	-0.184	-0.123	1.000								
Conduc.	0.073	0.050	0.468*	1.000							
$N-NO_3$	0.156	-0.009	0.376*	0.307	1.000						
$N-NH_4$	-0.299*	-0.176	0.725*	0.422	-0.091	1.000					
N total	-0.368*	-0.261	0.474*	0.058	0.206	0.587*	1.000				
SRP	-0.260	-0.335*	0.725*	0.299*	-0.081	0.842*	0.520*	1.000			
P total	-0.294*	-0.392*	0.614*	0.218	-0.105	0.752*	0.522*	0.953*	1.000		
BOD	-0.125	0.116	0.318*	0.547*	-0.097	0.607*	0.270	0.428*	0.302*	1.000	
Oxygen	0.298*	0.318*	-0.556*	-0.039	-0.002	-0.540*	-0.374*	-0.648*	-0.669*	-0.136	1.000

*) $p < 0.05$. N = 48

Abbreviations:
MTR - Mean Trophic Rank; Alkalini. - alkalinity; Conduc. - conductivity; N- NO_3 - nitrate; N- NH_4 - ammonia nitrogen; N total - total nitrate; BOD - Biochemiacal Oxygen Demand, 5 days; Oxygen - dissolved oxygen

channel area covered by macrophyte species is estimated **(SCV** - Species Cover Value). The final **MTR** result is calculated by summing scores of cover for STR species and dividing these by the SCV for scoring species.

Field Surveys

The field surveys were carried out at 48 sites of different sections of 19 rivers in the lowland part of Poland. Most surveys were undertaken at sites in the **Wielkopolska Region** (Central-West Poland): Samica river with unnamed tributary, Flinta, Rudnica, Welna, Mogilnica, Mogilnica Wschodnia, Maskawa, Miloslawka with unnamed tributary, and Lutynia with unnamed tributary. Some of the surveys were undertaken at sites in the **Pomerania Region** (North-Wester Poland): Prostynia river, Rega, Wolczenica, Krepiela tributary and in the **Brodnica Lakeland** (Drweca, Skarlanka and Struga Brodnicka). The criteria for selection of the survey sites were to include the wide range of trophic status and other ecological parameters.

Field surveys were undertaken twice at each site, firstly in late vegetation phase, (August - beginning of September 2000), and secondly in the early vegetation phase (May-June 2001). The surveys were carried out by standard MTR method at sections of 100 m length at each river [16].

Botanical assessment includes the list of flora and abundance of each taxa according to a 9-point scale [16]. Identification of plant species was based on Rutkowski [22], Podbielkowski & Tomaszewicz [18], Rich & Jeremy [20], Stace [24] and Szafer *et al.* [25]. The original MTR botanical nomenclature was applied according of Stace [24].

Chemical Analyses

Water chemistry assessment based on samples collected at the 41 places - only one sample was gathered if two MTR sites were adjacent. Samples were filtered using Sartorius Cellulose membrane Nitrate filters with nominal pore width 0,45 mm. After filtering, samples were cooled and analysed in laboratory within a 12 hour period. Water samples were analysed for:

- pH - microcomputer pH analyzer (Elmetron CPI-551),
- conductivity - microcomputer conductivity meter (El metron CC-551),
- alkalinity - with Sulfuric Acid to an end point of pH = 4.5, pH analyzer (Elmetron CPI-551),
- soluble phosphorus - colorimetric with ascorbic acid (Hach DR/2000),
- total phosphorus - colorimetric method, acid persulfate digestion method (Hach DR/2000),
- nitrate - colorimetric method, cadmium reduction method (Hach DR/2000),
- ammonia nitrogen - colorimetric method, Nessler's method (Hach DR/2000),
- total nitrate - Kjeldahl's procedure,
- dissolved oxygen - Winkler's method,
- **BOD** - 5 days, Winkler's method.

Statistical Analyses

The collected data were entered into the Mean Trophic Rank Database held at CEH-Dorset', where the MTR scores were calculated automatically. Statistical analyses were performed using the statistical packages STATISTICA and CANOCO.

Firstly, the analyses of distribution of MTR values were performed with **Shapiro-Wilk** test [23]. Secondly, the relationships between MTR and water chemical composition was tested using Pearson's index (STATISTICA). The environmental preferences of individual species were examined using Canonical Correspondence Analysis (CCA). The analyses were conducted using the CANOCO program [26].

Results and Discussion

The Accuracy of MTR Scores in Poland

The 48 sites from the 19 rivers surveyed in lowland Poland showed MTR scores which ranged from 15.0 and 52.9 with a mean value 36.0. These values are relatively low, indicating considerable eutrophication in several rivers [16]. The lowest values (below 25) show that the rivers are badly damaged by eutrophication (hyper-eutrophic) and nutrient reduction measures are required. [7].

The data were normally distributed as proved by the Shapiro-Wilk test [23]. It must be emphasized that the Shapiro-Wilk test is the recommended tool for distribution testing due to its high power compared with other methods [23].

A correlation between MTR scores and some chemical water parameters was found using Pearson correlation coefficient (Tab. 1). The MTR score was correlated positively with soluble oxygen and negatively with total nitrogen, ammonia nitrogen and total phosphorous. Despite the small sample taken for analysis the relationship between these water trophic elements and MTR score was proved to be significant (for $p < 0.05$). In addition, soluble phosphorous was very close to being significantly correlated with the MTR values as well. A large sample population with the modified MTR species list is likely to precisely assess water trophic status in Poland.

Verification of the **MTR** Scoring Taxa List

The occurrence and abundance of aquatic plants were recorded at the 48 riverine sites in Poland. 86 taxa were recorded (Tab. 1, 2), including 79 vascular plant species, 2 Pteridiphytes *(Equisetum fluviatile* and *Thelypteris palustris),* 1 Bryophyte *(Fontinalis anypyretica)* and 4 taxa belonging to macroscopic algae *(Cham fragilis* and 3 taxa identified to the genus level).

Table 2. The list of Mean Trophic Rank indicative plants discovered in the surveyed riverine sites.

No	Plant name	STR (Species Trophic Rank)
1	*Potamogeton pectinatus*	1
2	*Cladophora agg.*	1
3	*Vaucheria sp.*	1
4	*Ceratophyllum demersum*	2
5	*Lemna gibba*	2
6	*Spirodela polyrhiza*	2
7	*Acorus calamus*	2
8	*Ranunculus sceleratus*	2
9	*Typha angustifolia*	2
10	*Typha latifolia*	2
11	*Myriophyllum spicatum*	3
12	*Nuphar lutea*	3
13	*Potamogeton crispus*	3
14	*Potamogeton friesii*	3
15	*Potamogeton lucens*	3
16	*Sagittaria sagittifolia*	3
17	*Sparganium emersum*	3
18	*Sparganium erectum*	3
19	*Alisma plantago-aquatica*	3
20	*Carex acutiformis*	3
21	*Glyceria maxima*	3
22	*Rorippa amphibia*	3
23	*Rumex hydrolapathum*	3
24	*Lemna minor*	4
25	*Lemna trisulca*	4
26	*Potamogeton perfoliatus*	4
27	*Ranunculus circinatus*	4
28	*Ranunculus peltatus*	4
29	*Veronica anagallis-aquatica*	4
30	*Carex riparia*	4
31	*Persicaria amphibia*	4
32	*Phragmites australis*	4
33	*Berula erecta*	5
34	*Butomus umbellatus*	5
35	*Elodea canadensis*	5
36	*Fontinalis antipyretica*	5
37	*Potamogeton natans*	5
38	*Carex acuta*	5
39	*Equisetum fluviatile*	5
40	*Iris pseudacorus*	5
41	*Hydrocharis morsus-ranae*	6
42	*Potamogeton praelongus*	6
43	*Eleocharis palustris*	6
44	*Hildenbrandia rivularis*	6
45	*Carex rostrata*	7
46	*Callitriche hamulata*	9

Table 3. The list non Mean Trophic Rank indicative plants discovered in the surveyed riverine sites.

No	Plant name
1	*Agrostis canina*
2	*Agrostis stolonifera*
3	*Alnus glutinosa*
4	*Alopecurus geniculatus*
5	*Callitriche cophocarpa*
6	*Callitriche platycarpa*
7	*Callitriche stagnalis*
8	*Caltha palustris*
9	*Carex elata*
10	*Carex paniculata*
11	*Carex pseudocyperus*
12	*Chara fragilis*
13	*Cicuta virosa*
14	*Galium palustre*
15	*Glyceria fluitans*
16	*Hottonia palustris*
17	*Juncus articulatus*
18	*Juncus effusus*
19	*Lycopus europaeus*
20	*Lysimachia vulgaris*
21	*Lythrum salicaria*
22	*Mentha aquatica*
23	*Myosotis scorpioides*
24	*Oenanthe aquatica*
25	*Persicaria hydropiper*
26	*Phalaris arundinacea*
27	*Ranunculus repens*
28	*Rumex obtusifolius*
29	*Salix alba*
30	*Salix cinerea*
31	*Salix fragilis*
32	*Scirpus sylvaticus*
33	*Scrophularia nodosa*
34	*Sium latifolium*
35	*Solanum dulcamara*
36	*Stachys palustris*
37	*Stratiotes aloides*
38	*Thelypteris palustris*
39	*Utricularia vulgaris*
40	*Veronica beccabunga*

There were 46 MTK scoring taxa among the plants identified (Tab. 1). The most frequent of these were vascular plants (41 species) and these represent almost half of the MTR scoring plant list for Britain. Bryophytes were poorly represented, although suitable habitat conditions are rare for this group of organisms in Central Poland (sand and silt substrate dominates).

The extent of the survey was quite limited and many species common to Poland were not recorded. Among the British MTR scoring plants which were not recorded during the field work, but present in Poland were 21 which could be included in the future Polish MTR scoring species list: *Alisma lanceolatum, Carex vesicaria, Catabrosa aquatica, Hippurus vulgaris, Juncus bulbosus, Lotus uliginosum, Menyanthes trifoliata, Myriophyllum altemiflorum, Nymphaea alba, Potamogeton gramineus, Potentilla palustris, Ranunculus aquatilis, Ranunculus flammula, Ranunculus fluitans, Ranunculus trichophyllus, Scirpus lacustris, Scirpus maritimus, Veronica catenata, Veronica scutellata, Viola palustris,* and *Zannichellia palustris.*

There is a large group of plants which are on the original MTR scoring species list but their presence in Poland has not yet been recorded: 8 species are not in the flora of Poland *(Apium inundatum, Apium nodiflorum, Callitriche obtusangula, Elodea nuttallii, Eleogiton fluitans, Lemna minuta, Oenanthe crocata, Oenanthe fluvitilis)* and another 11 species are very rare *(Groenlandia densa, Littorella uniflora, Montia fontana, Nasturtium officinalis Nymphoides peltata, Potamogeton alpinus, Potamogeton obtusifolius, Potamogeton potygonifolius, Potamogeton trichoides, Ranunculus hederaceus, Ranunculus omiophyllus).* There is a problem with the use of 3 subspecies of *Ranunculus* subgenus *Batriachium (R. penicillatus ssp. pseudofluitans, R. penicillatus ssp. penicillatus, R. penicillatus ssp. vertumnus)* and 2 species of *Potamogeton (P. pusillus, P. berchtoldii)* and whose use in Poland must be preceded by taxonomic verification and confirmation of occurrence because Polish nomenclature does not reflect the detail of the British system.

Among the 40 plants which are not included in the original MTR system (Tab. 2) a group of 11 species have been selected, as those which are recommend for future studies as potential indicating taxa and for which STR values have been proposed in this work (Tab. 3).

Table 4. The list of species recommended for future studies as potential indicating taxa in MTR system.

No	Species name	Proposed STR (Species Trophic Rank)
1	*Callitriche cophocarpa*	5
2	*Carex elata*	4
3	*Carex pseudocyperus*	5
4	*Chara fragilis*	7
5	*Cicuta virosa*	5
6	*Hottonia palustris*	5
7	*Oenanthe aquatica*	3
8	*Sium latifolium*	4
9	*Stratiotes aloides*	6
10	*Thelypteris palustris*	7
11	*Utricularia vulgaris*	6

Environmental Regulation of Identified Species

The environmental preferences of the particular plants according to water chemistry were estimated with the use of canonical correspondence analysis (CCA). The environmental scale of all species presented on one plot informs us about the variable inclination of identified taxa (Fig. 1). An especially large role in the spatial distribution of plants is played by oxygen, BOD, conductivity, and total nitrogen.

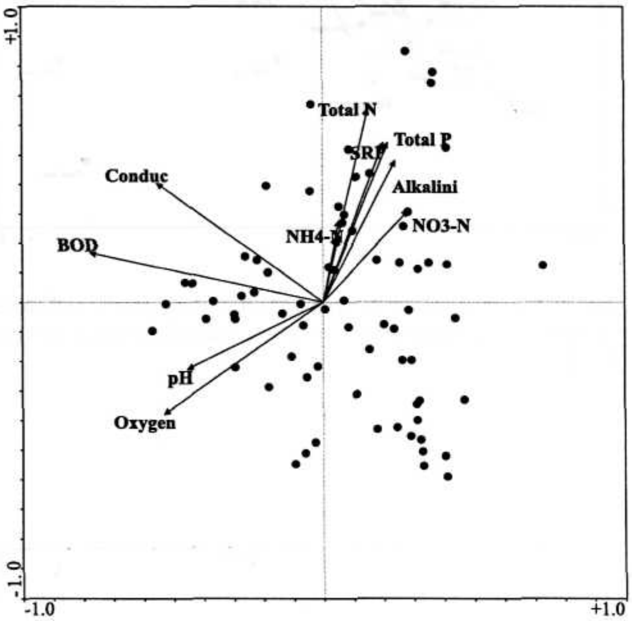

Fig. 1. The relationship between plant taxa and water chemical parameters - result of multidimensional analysis CCA.

The following plots present separately MTR scoring and non-scoring taxa and for each of the group's 2 plots were prepared:

- with all measured water parameters (Fig. 2, Fig. 4),
- with biogens only (Fig. 3, Fig. 5), for better under standing of preferences according to basic trophic el ements.

BOD and conductivity were strongly correlated with the development of the British MTR scoring taxa (Fig. 2). The strongest correlation was found between species abundance and biogenic elements (Fig. 3) showed by: *Ranunculus scleratus, Potamogeton pectinatus, P. crispus, Veronica anagalis-aquatica, Acorus calamus, Persicaria amphibia* and *Lemna gibba.* All these species are also known to indicate eutrophic conditions (STR 1-4). The reaction of other species was not so apparent.

The group of 18 species was selected among plants found in Poland which are not included as the original MTR scoring taxa list (scrubs and plants regarded as terrestrial were excluded). Strong relationships between alkalinity, pH and oxygen and abundance of these plants were found (Fig. 4). On the other hand the influence of biogenic compounds was smaller, especially low in case of

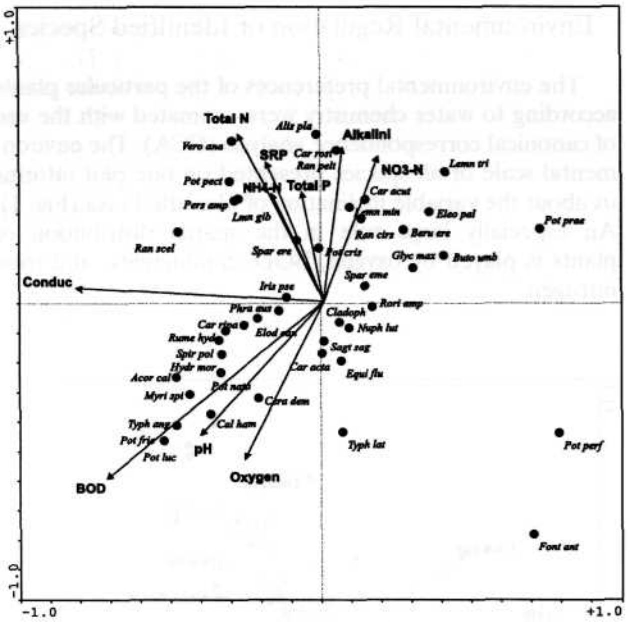

Fig. 2. The relationship between MTR scoring plants and some chemical water parameters - result of multidimensional analysis CCA.

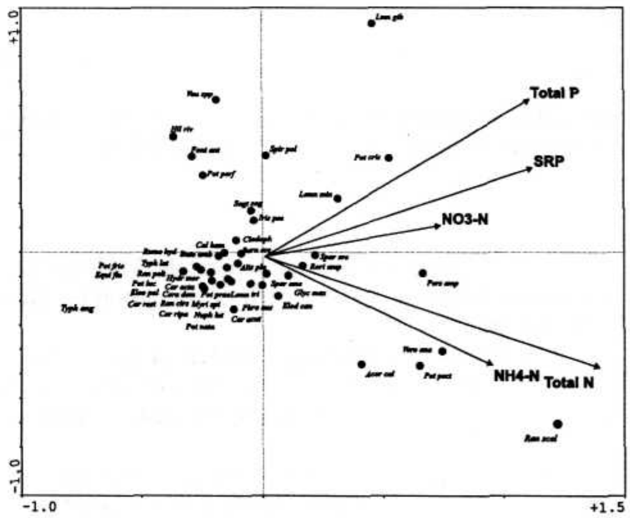

Fig. 3. The relationship between MTR scoring plants and content of water nutrients - result of multidimensional analysis CCA.

phosphorous. Several other species showed more distinctive correlations with water pollution: *Thefypteris palustris, Callitriche cophocarpa, Veronica beccabunga, Cicuta virosa, Chora fragilis, Hottonia palustris, Stratiotes aloides* (Fig. 4, Fig. 5). It must be emphasised that the size of analysed samples was relatively small and it is recommended that these particular species require more extensive studies before use as the MTR scoring species.

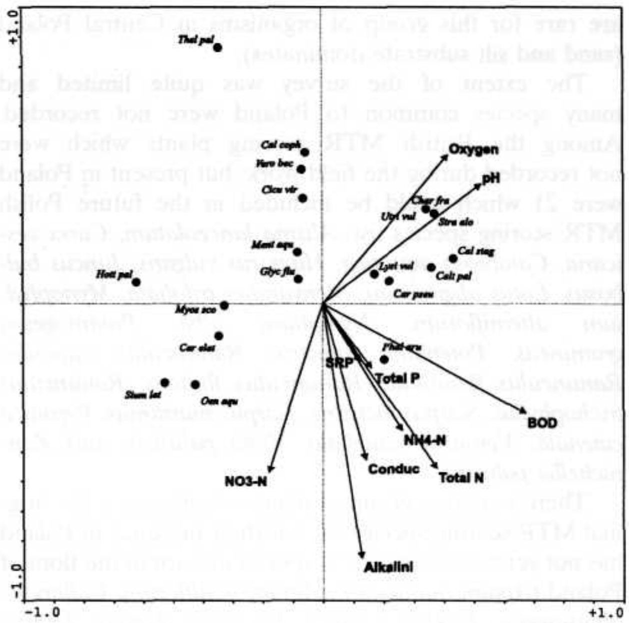

Fig. 4. The relationship between MTR non-scoring plants and some chemical water parameters - result of multidimensional analysis CCA.

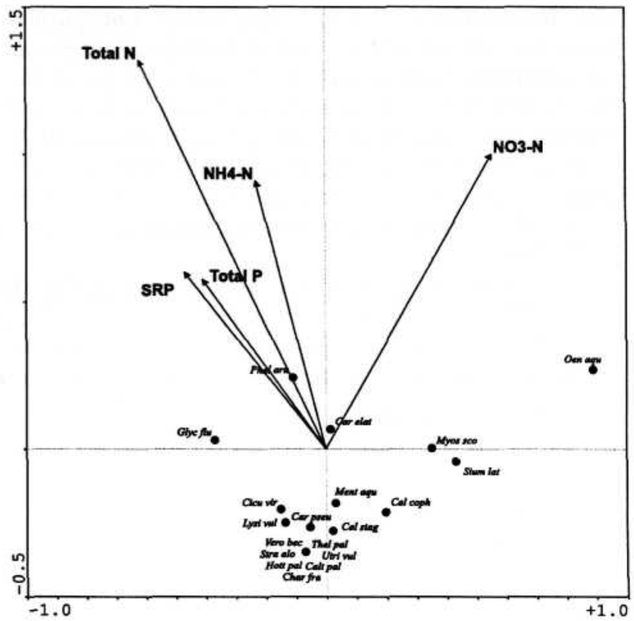

Fig. 5. The relationship between MTR non-scoring plants and some chemical water parameters - result of multidimensional analysis CCA.

Conclusions

Surveys of the occurrence and abundance of aquatic plants at the 48 riverine sites in Poland recorded 86 plants were identified, including 46 MTR scoring taxa used in the British system. A group of 11 species were selected from potential scoring plants for future studies. Among the 40 plants which are not included in the original MTR system from the British MTR scoring plants (which were not recorded during fieldwork), the application in Poland for 24 species is dubious.

The habitat conditions of the selected river sites were assessed and their large diversity was observed in terms of eutrophication level. The correlation between MTR score and water trophic status was shown in these Polish rivers. The MTR system, which includes results of further research on specified species, is recommended for biological monitoring in Poland.

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