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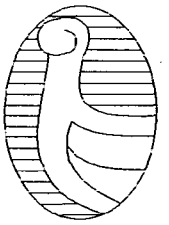

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SPATIAL ASPECTS OF VEGETATION DYNAMICS INDUCED BY HERBICIDE DISTURBANCES IN A HUNGARIAN LOESS GRASSLAND COMMUNITY

K. Virágh

Virágh, K. (1994): Spatial aspects of vegetation dynamics induced by herbicide disturbances in a Hungarian loess grassland community. - Tiscia 28, 3-13.

Abstract. Major floristic changes induced by leaf-herbicides selective to dicots and monocots and a comprehensive leaf-herbicide in an old perennial grassland community were studied for 10 years using permanent quadrates at 3 spatial microscales (at 400 cm², 1 m² and 5 m² plot sizes). Great impact of spatial scale upon the detection of dynamic phenomena and recognition of recovery tendency as well as the assessment of its degree was analyzed during the local secondary microsuccessions following herbicide-disturbances.
Similarity analyses and principal coordinates ordinations were applied to measure the rate of floristic change and to reveal trends in temporal variation of species composition, variability of regenerative trajectories, as well as to estimate the degree of recovery at 400 cm², 1 m² and 5 m² plot sizes.
The results indicated significant differences in the variation of floristic composition and in the rate of major floristic changes at small versus larger sizes of quadrates.
It was concluded that the different changes in spatial microheterogeneity of the originally homogeneous stand of the community caused by the herbicide-disturbances strongly affected the appropriate plot size for detecting grassland recovery-dynamics. The spatial heterogeneity changes induced by the herbicides were especially critical in comparison of the different treatments as well as in assessing the degree of recovery of the treated plots to control ones.
It was stated that the observable differences between floristic pattern at different spatial scales would be the result of different degrees of spatial heterogeneity within the community.
A change of spatial scale (the size of experimental plots) brought forth, in fact, a new perception of vegetation dynamic processes and the results also highlighted different aspects of species abundance hierarchy.

Keywords: herbicide-disturbances, spatial scales, temporal floristic pattern.

K. Virágh, Institute of Ecology and Botany, Hungarian Academy of Sciences, H-2163 Vácrátót, Hungary

Introduction

Spatial-scale dependence of grassland dynamics as well as the influence of disturbances on different biological organization levels and at different spatial scales have been well-documented recently (e.g.: Chaneton-Facelly, 1991; Collins and Gibson, 1990; Glenn-Lewin-Ver Hoef, 1988; Hogeweg et al., 1985; Sousa, 1984; Thórhallsdóttir, 1990; White and Pickett, 1985). This field study demonstrates spatial aspects of grassland dynamics in a community which was experimentally manipulated.

Leaf herbicides selective to dicots and monocots, as well as a comprehensive herbicide were applied using permanent plots in a species rich old perennial grassland community in Hungary to induce quick vegetation dynamic processes (Virágh, 1982). Major floristic and structural changes during secondary successions and regeneration capability of the community after herbicide disturbances were studied. Using herbicides as disturbance agents was very useful also from practical point of view. At present application of herbicides in sward-farming is a fairly general method for removal of weeds and

for improvement of the sward (selective extirpation), as well as for total destruction of the vegetation in order to re-new, re-sow the sward. So some questions mostly regarding recovery, important in my experiments, must be very important for practice and cannot be answered without taking the vegetation and population dynamic processes into account.

At a local scale my controlled disturbance experiments aimed to study the endogenous dynamics, temporal floristic fluctuation of a relatively intact loess steppe grassland community for a long time period and to examine how natural man-made disturbances impact the species composition and dynamic behaviour (resistance, recovery) of the studied community. Population dynamics, community regenerative and secondary microsuccessional processes following herbicide treatments of different types, intensity and frequency were analyzed for 10 years. The effect of herbicide treatments on the cenological similarity relations, as well as the utility of different resemblance indices and multivariate analyses in detecting vegetation temporal changes were reported by Virágh (1987a). The degree of community-recovery after disturbances and its resistance against drought were assessed by comparing control plots and herbicide-disturbed plots with respect to major floristic changes (Virágh, 1986; 1987a; 1987b), some textural and structural community attributes (Virágh, 1989a; 1991) and recovery patterns of populations (Virágh, 1989b). Determination of buried viable seed populations in the soil (Virágh and Gerencsér, 1989) was also included in the investigation.

In vegetation dynamic studies examining the effect of herbicide treatments, the selection of methods is critical. The result of methodological studies has been discussed in a previous article (Virágh, 1987b). In addition, due to the different effects of herbicides, choosing the appropriate size of experimental plots for comparing many treatments and for measuring the degree of recovery is also a very crucial point. The problems are the following:

The herbicides used caused different changes in microheterogeneity of the originally homogeneous stand. They altered the species hierarchy by changing the rank order of some previously dominant species and increasing the relative importance of subordinate species (Virágh, 1989a).

Selective herbicides, which killed the dicots represented by many species but with low abundance and the other killed the dominant and most abundant monocots, significantly changed the abundance-dominance relations among the species. The herbicides also produced smaller and larger bare-ground surfaces in different numbers, causing local spatial microheterogeneity differences in the study area. Later these topographical differences due to the herbicide-disturbances, could also increase with time because of the differential growth of surviving populations as well as the differential rate and manner of colonizations with various first colonizers.

So analyzing the impact of spatial scales applied upon the recognition of dynamic phenomena was significant in the differently disturbed community.

This paper analyses the temporal variation of species composition at 3 spatial microscales (at 3 plot sizes) and the effect of size of sampling plots on detection of recovery tendency. The significance of appropriate size of investigated plots in the comparison of the differently disturbed community for detecting community-recovery and measuring its degree is mainly emphasized here.

The study aims to answer to following questions:

1) How different view on dynamic phenomena (direction and rate of floristic change, the degree of responses to drought) and dynamic processes (seasonal dynamics and recovery) may be obtained by similarity analyses at different plot sizes in the intact and herbicide-treated community?

2) What is the effect of spatial sample-scales on temporal floristic patterns in the principal coordinates ordination space and the classification space?

3) What size of sampling plots can be acceptable for detecting grassland recovery in this differently disturbed community?

Material and Methods

Field experiments

Field study was carried out on a dry-situated hill, at the southern foot of the Bükk Mountains (NE-Hungary), about 200-300 m above sea level in Hungary. The mean annual temperature is 9 °C, the total precipitation is about 600 mm. The soil is brown forest soil of chernozem character, formed on loess. The study area is in a secondary steppe community: *Pulsatillo-Festucetum rupicolae*, formed a very long time ago in place of deforestation. It can be considered as the final stage (subclimax community) in a successional series of grasslands in the given area. Detailed description of this community and the sources of richness of flora are presented in previous papers: Virágh (1982) and

Virágh and Fekete (1984).

The research program was launched in 1979 and the experiments ran for 10 years in a fairly stable *Pulsatillo-Festucetum rupicolae* community. A homogeneous stand of this species rich community was selected for studies of local secondary succession, i.e., regeneration processes initiated by some herbicide treatments (Virágh, 1982; 1986).

The experiments carried out are briefly summarized bellow:

CONTROL experiment.

It represents vegetational changes without any treatment.

GABONIL experiment (4 l/ha dose, 7 l/ha dose)

Gabonil: MCPA+dicamba:

4-chloro-2-methyl phenoxyacetic acid+2-methoxy-3.6-dichloro-benzoic acid

The dicots, the less dominant group, were killed. Immediately after spraying, there was a possibility for expansion of grasses and later for the re-settlement of some dicots.

DALAPON experiment (12 kg/ha dose, 20 kg/ha dose)

Dalapon: 2.2-dichloropropionic acid

The dominant monocots were killed leading to large spots of bare ground on which some dicots well spreading by vegetative propagula became predominant and determined subsequent vegetation changes.

The monocots reappeared some years later.

GLYPHOSATE experiment (15 kg/ha)

Glyphosate:4-(phosphono-methyl)glycine

All the vegetation was killed. The bare ground was particularly recolonized from seeds and from the sedge by vegetative propagula. The secondary succession was mainly determined by the first colonizers.

It must be noted that the leaf herbicides used did not cause habitat changes or ground-surface changes in the field. They were applied in a relatively small plots of 1.5x1.5 m. The processes taking place in the small windows were governed by the surrounding vegetation. Thus, during the period of 10 years of study there was no succession in the general sense of the word, that is the sense of substitution of well-defined communities by others. As a consequence of the direct effects of herbicides, after the partial or complete killing of the vegetation, smaller and larger bare-ground surfaces appeared in the stand. These different types of localized secondary microsuccessions and regeneration processes were initiated. Only the species previously present in the community returned. But the development of vegetation proceeded step by step by the replacement of different well-defined coenostates.

Sampling

The experiments were arranged in a randomized block design with 5 replications per treatment. The field investigations were carried out twice a year in 1 m^2 permanent plots with 5 replications, covered with a grid of 4x4 cm, as well as 20x20 cm units. Presence - absence and percentage cover of each species, visually estimated, were mainly recorded in a set of 400 cm^2 contagious subquadrates (125 in total per treatment) and then the cover values were summed for 1 m^2 and 5 m^2 quadrates in each experiment.

Remarks on the relevant plot sizes

-- Maximum value of the cover-based significant ISC and aggregation sums of most of the species was apparent at 400 cm^2 plot size on the study-site. The number of species combination was also the highest and the stand proved to be the most heterogeneous at this characteristic area for the most abundant species. The floristic changes on this spatial microscale indicated the effect of herbicides very sensitively.

-- At 1 m^2 plot size summation of the smaller scale dynamics was manifested. Variability among these plots, resulted from the plots differed in species composition and abundance, reflected the local spatial heterogeneity, characteristic for the whole stand.

-- Considering all of the species, the 5 m^2 size of plots contained a portion of the stand large enough to be floristically homogeneous and characteristic for the whole stand.

The area was sprayed at one occasion at the end of June, but the treatment by the two selective herbicides of larger dose was repeated again after a year. Dates of spraying were: June 1979, and June 1980, respectively.

The investigations were performed from 1979 to 1989. Floristic composition of treated quadrates was recorded before and after the treatments in June and in September from 1979 to 1983 and then 1987 and 1989. The control plots were also examined twice a year.

Data

The presence-absence and cover-scores were summarized in a species by quadrates data matrix (400 cm^2, 1 m^2, 5 m^2) for each point of time and each treatment. Such a matrix represents the operational unit (basic object) of multivariate

analyses. To facilitate the use of resemblance coefficients for comparing points of time, these matrices were often transformed into vector form. Consequently, in these cases only the temporal change within subquadrates or quadrates is manifested in the final results, and here the variation between the replicate plots does not influence similarity analyses, ordinations and classifications.

Methods

1) Similarity indices were used to analyze the effects of treatment and plot size on

a) the cenological similarity relations
b) the direction of secondary successions,
c) the rates of change,
d) the degree of community recovery,
e) the seasonal dynamics and
f) the responses to drought.

The year to year changes, as well as the changes referring to the first point of sampling date, namely the trend of changes during the investigated period were analyzed. Similarities between consecutive points of time, as well as similarities between each of the points of time and the initial sample time were calculated here by Sørensen index and Czekanowski's percentage similarity coefficient. These indices proved to be the most appropriate for revealing similarity relations involved in floristic data matrices (see Virágh, 1987a; 1987b).

The rates of change were calculated as floristic change and as cover-based change also by means of the two similarity indices mentioned earlier. These were suggested by Bornkamm (1981) and Armesto and Pickett (1986) for determining rates and magnitudes of vegetational changes.

Two referenced states were accepted for my comparative analyses:

a) pre-disturbed floristic state in every treatment and

b) control dynamics, the intact natural condition including normal temporal changes.

The value of similarity indices could indicate the degree of community-recovery to the original pre-disturbed or to the control compositional state.

The years 1982 and 1987 were dryer than usual. The effects of these extremely dry summers ("stress situation") could be measured in the deviations of values of Sørensen and Czekanowski's similarity coefficient.

2) Principal coordinates ordinations and clustering methods were applied to reveal trends in temporal variation of species composition and variability of regenerative trajectories as well as to estimate the degree of recovery at different spatial microscales (at 3 plot sizes).

3) Comparison of the dendrograms and the ordination results

a) Comparison of small and larger patterns in the same observational data set (a single experiment) was evaluated by using pairwise comparison of ordinations by Procrustes analysis (Schoenemann and Caroll, 1970; Gower, 1971, 1975; Sibson, 1978) and of classifications by using 7 coefficients (Podani , 1984).

b) The method of multiple comparison of classifications (Podani, 1982; Podani and Dickinson, 1984) of cover data of different data sets, originated from various treatments, was also used to reveal similarity relationships among the dendrograms obtained at different spatial scales and to examine the relative impact of treatments and plot sizes upon the vegetation pattern.

Results and discussion

Similarity analyses at 3 plot sizes

The results of similarity analyses (Fig. 1 and 2) demonstrated the differences in the temporal variation of floristic composition and in the rate of floristic change at small versus larger sizes of quadrates. Microheterogeneity differences smooth with time so the larger size of sample-quadrates significantly reduced the floristic variation and decreased the rate of observable changes in each treatment.

The detection of grassland recovery tendency and assessment of its degree in differently disturbed communities were also strongly affected by the size of sampling plots.

While all of the 3 plots sizes (400 cm^2 , 1 m^2, 5 m^2) had nearly the same results about the trend of floristic changes in the control experiment, but great differences appear in the herbicide treatments. Only 5 m^2 quadrates prove to be sufficiently large to reveal the tendency of recovery of the plots treated by Gabonil herbicide, eliminating the subordinate dicots, but after killing of the dominant monocots convergence in the species composition of Dalapon-treated plots to the pre-disturbed compositional state appears already at 1 m^2 quadrates (see Fig. 1).

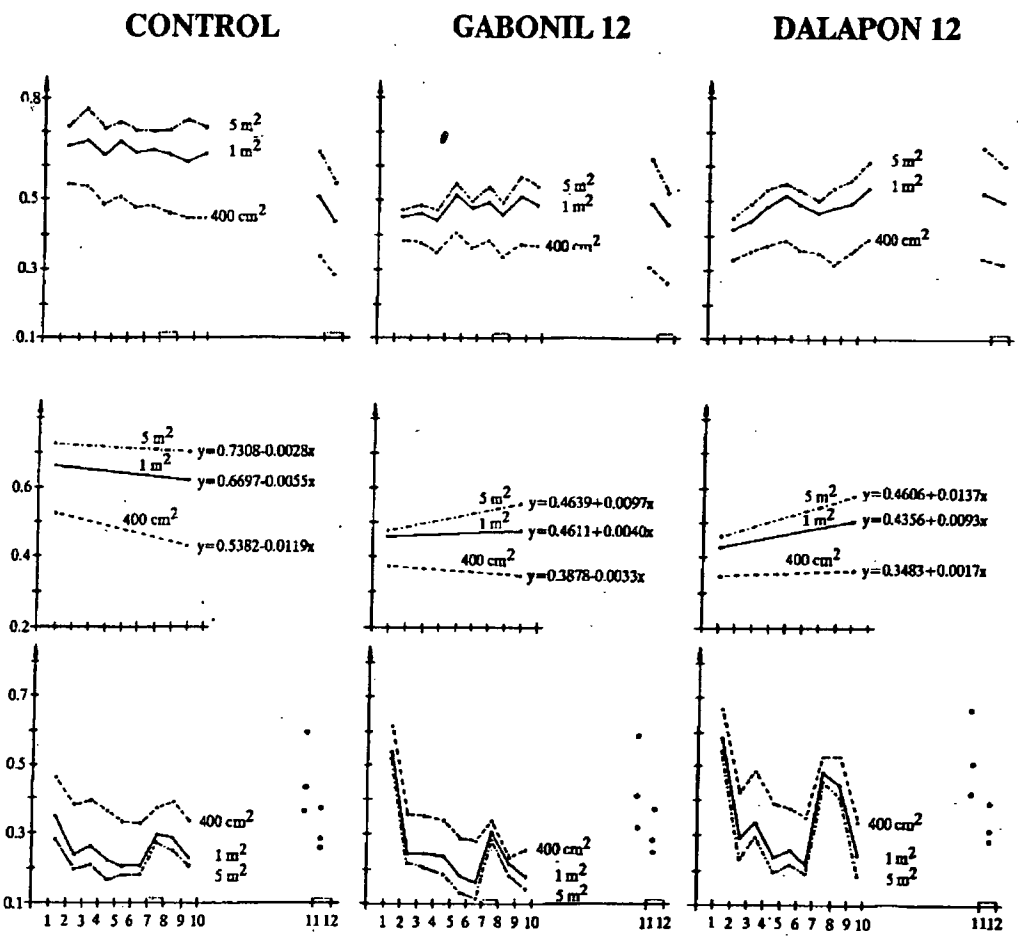


Fig. 1. Effect of plot size on the results of similarity analysis in 3 experiments. (Resemblance is measured by Czekanowski's similarity coefficient. 1: June 1979; 2: September 1979; 3: June 1980; 4: September 1980; 5: June 1981; 6: September 1981; 7: June 1982; 8: September 1982; 9: June 1983; 10: September 1983; 11: June 1987; 12: September 1987. Gabonil 4: Gabonil 4 kg/ha dose; Dalapon 12: Dalapon 12 kg/ha dose.) Upper row: trend of species cover changes (Similarities {Czekanowski index} between each of the points of time and thee initial sample time). Middle row: fitting of linear curve for cover changes. Lower row: rate of cover-based change (Dissimilarities between consecutive sample times)

The expression of seasonal dynamics was strongly decreased by increasing the size of sampling plots.

The effects of herbicides as well as the responses to drought were also dissimilarly manifested at the 3 spatial scales and they could be detected in various degree in each treatment depended on the plot sizes.

The expression of differences among the treatments was also very dissimilar at the 3 plot sizes investigated (Fig. 2). The quantitative differences (Czekanowski-index) in species composition of the treatments were significant in each size of sampling plots, however the qualitative compositional differences (Sørensen index) could especially be detected at 400 cm² quadrates and they could hardly be recognizable after 2 or 3 years following the treatments at 5 m² quadrates.

Temporal floristic pattern at 3 plot sizes. The influence of plot size on vegetation pattern in time

Grassland dynamics in the principal coordinates ordination space and the classification space

Spatial sample scales also affected the observation of temporal patterns during the 10 years of study-period (Fig. 3).

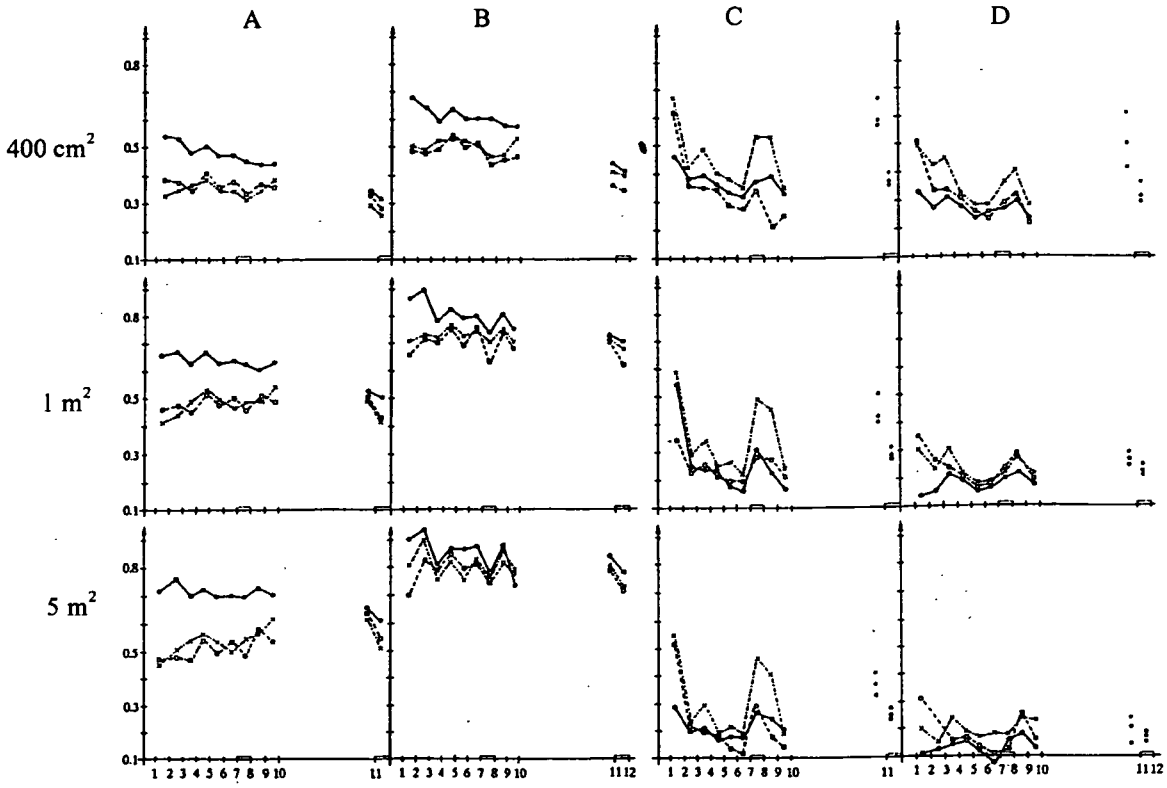


Fig. 2. Differences in trend and rate of cover-based change and floristic change between the treatments at 3 plot sizes. Trend of cover-based change [A] (Czekanowski's percentage similarity index) and of floristic change [B] (Sorensen index) and rate of cover-based change [C] (Czekanowski's percentage similarity index) and of floristic change [C] (Sorensen index); (control ———, Gabonil 4 ·····, Dalapon 12 – · – · – · –: See Fig. 1. for explanation of symbols and numbers.)

Pairwise comparison of ordinations of points of time (see Fig. 3) for different plot sizes reflected that the ordination results in Gabonil experiments were in a good agreement.

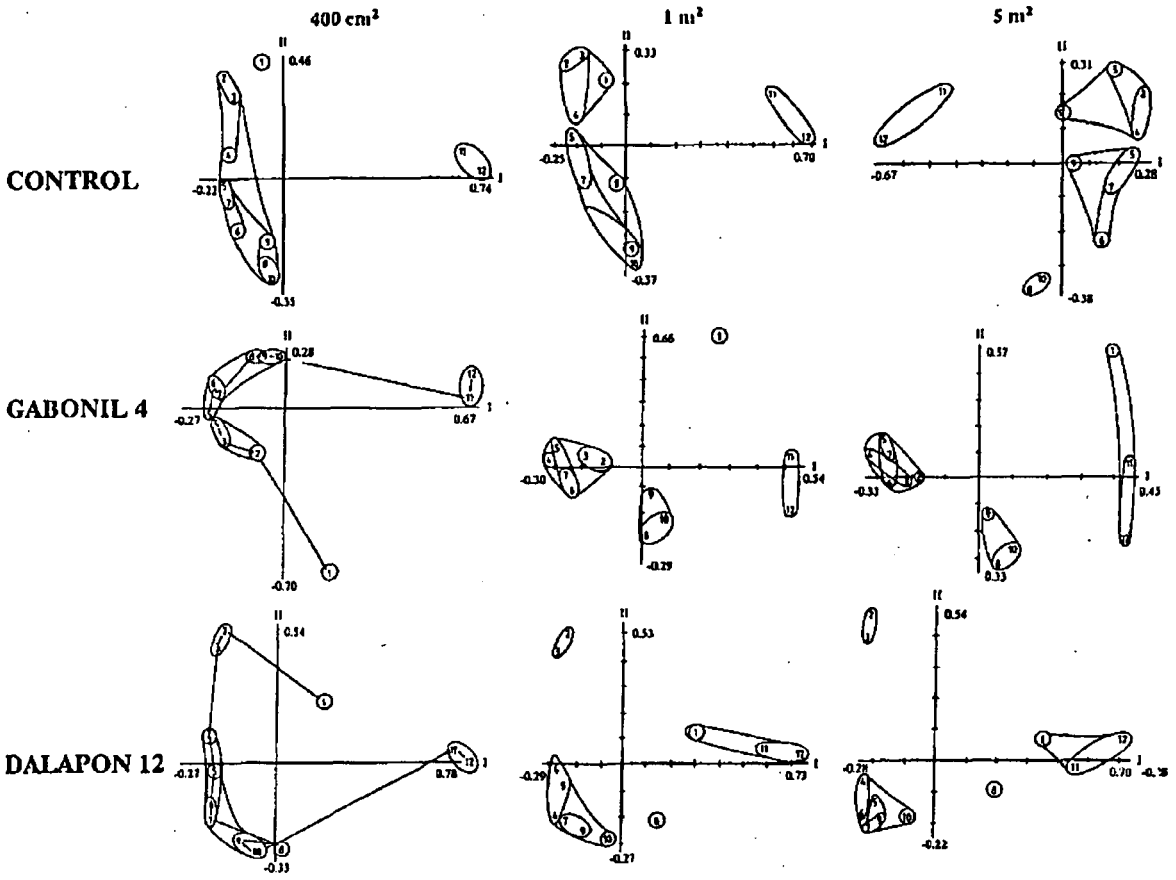
The control plots of different sizes tended to produce somewhat different ordination results, though the underlying trends in vegetation dynamics revealed were very similar. Here the results on temporal patterns were nearly the same at the 2 smaller plot sizes, but from these a more or less different pattern of points of time was detected at 5 m².

If the variation among the 5 replicates of 1 m² plots was also manifested (Fig. 4), the ordination showed that the variability among the 1 m² plots was much more considerable than that was among the points of time. In this case it may be advisable not to sum the data for 5 m² and the interpretation of recovery at population level can be only possible at 1 m² plot size.

This inconsistency among the results might occur because of the specific vegetation development of the five 1 m² quadrates probably induced by the changes in the dominance of some species.

The greatest difference was revealed between the ordinations in the case of Dalapon-treated plots. The pattern of points of time at 400 cm² plot size was strongly different from that was at the larger quadrates. The high inconsistency between the results at 3 sample-scales in this experiment might occur because of the rapid vegetative regeneration and the great expansion of some clonal dicots, indicating that the 400 cm² plots were not large enough to include the most predominant and abundant dicots after herbicide-disturbances.

The classifications also clearly showed the great impact of plot sizes on temporal vegetation pattern in each treatment (Fig. 5). The differences referring to the overall structure of dendrograms were well-reflected by the results of dendrogram-comparisons (Table 1), by which the separation of vegetation pattern of the 400 cm² Dalapon-treated plots from the others was the most strikingly expressed.



Pairvise comparison of ordinations

Procrustes analysis	sum of squares	
	400 cm^2 - 1 m^2	1 m^2 - 5 m^2
Control	0.062	0.129
Gabonil 4	0.028	0.020
Dalapon 12	0.140	0.026

Fig. 3. Effect of plot size on the result of principal coordinates ordination of points of time in 3 experiments. (Resemblance is measured by Czekanowski's similarity coefficient. See Fig. 1. for explanation of numbers.)

The effect of treatment and plot size on the classifications

When the classification results of 3 plot sizes were analyzed for all treatments simultaneously (Fig. 6), the sharp separation of Dalapon-treated plots from the control plots and Gabonil-treated ones, owing to the elimination of dominant monocots, could be well-detected. The result of multiple comparison of dendrograms also indicated that the dissimilarities in the pattern of points of time of the treatments were mainly caused by the herbicides (axis I accounted for 31% of the total variance) and by the spatial sample-scales in lesser degree (axis III: 13%).

Appropriate scale for detecting grassland recovery

The results presented earlier clearly showed that the most influential factor on the vegetation dynamics was the effect of herbicide-disturbances but all observations about the floristic changes were strongly constrained by the size of sampling plots applied. Great impact of the size of investigated plots (spatial microscales) upon the detection of dynamic phenomena and recognition of temporal floristic patterns as well as recovery tendency was well-demonstrated.

It was concluded that when the recovery of differently disturbed plots, the convergence in

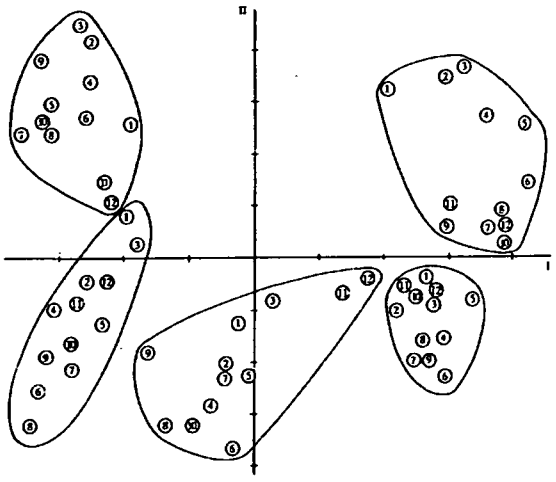


Fig. 4. Principal coordinates ordination of points of time in the case of 5 replications of 1 m^2 quadrat in the control experiment. (Resemblance is measured by Czekanowski's similarity coefficient. See Fig. 1. for explanation of numbers.)

species composition of treated plots to control ones was analyzed at community level (Fig. 7), in order to avoid the different spatial microheterogeneity effects caused by the herbicide-treatments, the results were necessarily referenced for 5 m^2 plot size, at which the summation of "patch dynamics" (microtopographical heterogeneity) would come to exist. Compositional recovery is well indicated by the result of ordination of points of time (Fig. 7).

In the comparison of 5 experiments (control and the 2 selective herbicides in 2 different doses), the ordination (Fig. 7) clearly shows homogeneity of the original community without treatments, as well as sharp distinction between the compositional temporal pattern of control and treated plots during the first 5 years of study. Relatively great impact of herbicide-doses upon the ordination results is also well-expressed. It was also apparent here that during the first 5 years the treated plots could not return to their pre-disturbed state. Despite of the results of 5 years, in the comparison of 5 treatments for 9 years, very high similarity values among the first and the last 2 coenostates (or points of sampling dates) can be well-reflected in the ordination space, indicating compositional recovery during 9 years.

Whereas, when all the vegetation was completely killed (Glyphosate experiment), the secondary succession was mainly determined by the first species occupying the bare ground. Here the 5 replications of 1 m^2 quadrate due to their differential initial composition after herbicide-disturbances were well-separated from each other (Fig. 8), indicating a specific way of vegetation development in each 1 m^2 quadrate. The five 1 m^2 Glyphosate-treated quadrates also became increasingly dissimilar floristically with time, probably due to the stochastic colonization and its differential rate and manner. So because of the strong spatial heterogeneity produced and also the specific way of vegetation development of the 1 m^2 individual quadrates induced by their various initial species composition in the very early colonization phase, it was necessary to examine floristic changes in each of the separated 1 m^2 quadrates independently.

Table 1. Dendrogram comparison by using 7 coefficients

	Descriptor	400 cm^2 - 1 m^2
Control	cladistic difference	12.65
	cophenetic difference	60.35
	cluster membership divergence	13.63
	number of changes in ultrametric relationship	31.00
	ultrametric dissimilarity	0.14
	mismatched edge difference	55.56
	absolute edge difference	200.96
	edge matching coefficient	0.50
Gabonil 4	cladistic difference	12.00
	cophenetic difference	46.33
	cluster membership divergence	17.08
	number of changes in ultrametric relationship	53.00
	ultrametric dissimilarity	0.24
	mismatched edge difference	71.39
	absolute edge difference	168.93
	edge matching coefficient	0.50
Dalapon 12	cladistic difference	14.56
	cophenetic difference	85.21
	cluster membership divergence	27.89
	number of changes in ultrametric relationship	77.00
	ultrametric dissimilarity	0.35
	mismatched edge difference	112.41
	absolute edge difference	227.99
	edge matching coefficient	0.70

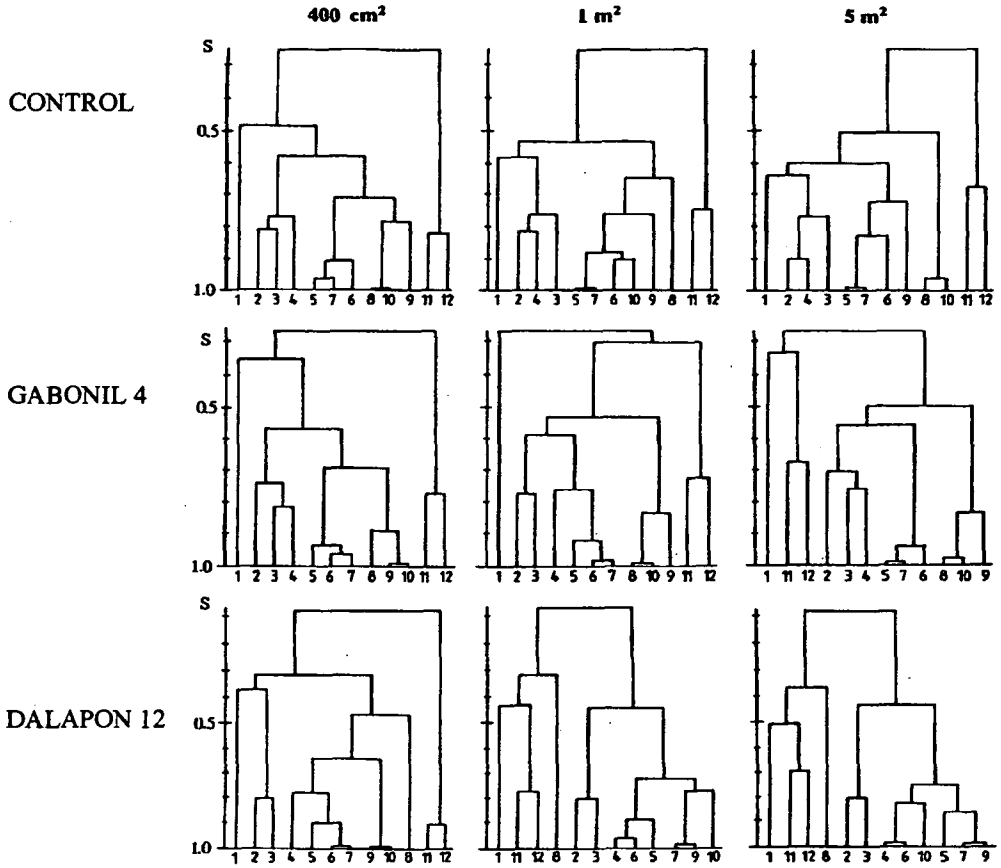
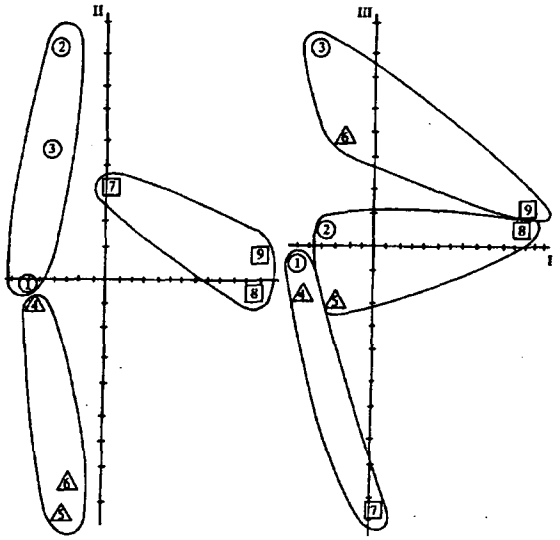


Fig. 5. Effect of plot size on the results of classification of points of time in 3 experiments. (See Fig. 1. for explanation of numbers.)



Squared distance matrix

1	2	3	4	5	6	7	8	9	
0.00	2.54	2.66	1.25	2.52	2.39	2.82	4.17	4.27	1
	0.00	2.87	2.57	4.06	3.74	3.09	4.39	4.31	2
		0.00	2.99	3.54	3.24	3.52	4.46	4.48	3
			0.00	2.6	2.44	2.84	4.15	4.30	4
				0.00	2.24	3.14	4.07	4.31	5
					0.00	3.70	3.81	4.01	6
						0.00	3.64	3.73	7
							0.00	1.46	8
								0.00	9

Symbols used in ordinations	400 cm²	1 m²	5 m²
Control	①	②	③
Gabonil 4	△4	△5	△6
Dalapon 12	□7	□8	□9

Fig. 6. Effect of treatment and plot size on the classifications. Principal coordinates ordination of classifications of 3 treatments at 3 plot sizes. (Resemblance is measured by Czekanowski's similarity coefficient.)

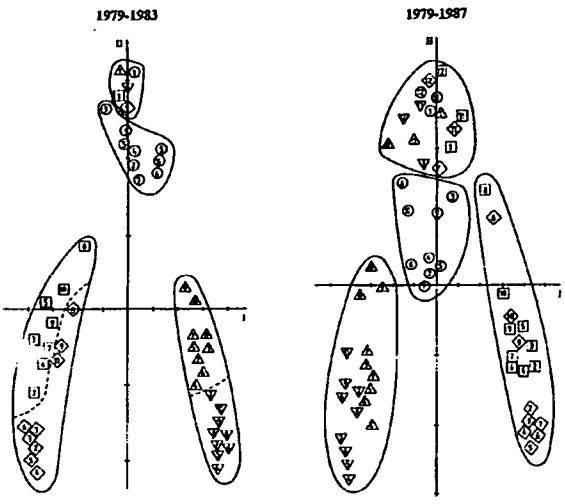


Fig. 7. Principal coordinates ordination of points of time of 5 treatments (control ○, Gabonil 4 Δ, Gabonil 7 ▽, Dalapon 12 □, Dalapon 20 ◇. Resemblance is measured by Czekanowski's similarity coefficient. See Fig. 1. for explanation of numbers.)

Concluding remarks

It was obvious that different changes in spatial microheterogeneity of the originally homogeneous stand of the community caused by the herbicide-disturbances were very important for interpreting the synmorphological phenomena and dynamic processes during the localized secondary microsuccessions.

The results of comparative analyses based on cenological similarities proved the great importance of the size of investigated quadrates chosen for detecting grassland recovery dynamics and supported the view that the recognition of vegetation dynamic processes is inherently spatial-scale dependent.

The results also suggested that it is likely that the differences observed between floristic patterns at the different spatial scales (microscale: 400 cm², local patch-scale: 1 m², stand-scale: 5 m²) might be the result of different effects of herbicide-disturbances and various degrees of spatial heterogeneity induced by herbicide treatments within the community.

It seems very possible that the relative importance of both deterministic and stochastic influential factors on floristic change also varied with spatial scale. Beside the herbicide effects, patterns on the smallest plot size were mainly determined by the spacing, interacting and size of individual plants. In contrast, patterns on larger scales were most influenced by the competitive interactions of the constituting species following disturbances and the local environmental factors.

These descriptive analyses yielded meaningful results on the temporal pattern of major floristic changes at community level. A change of spatial scale brought forth, in fact, a new perception of vegetation dynamic processes. However, it is also obvious, that many questions remain open and additional statistical tests and studies on population dynamics (Virágh, 1989) of the species are necessary. Detailed investigations of species

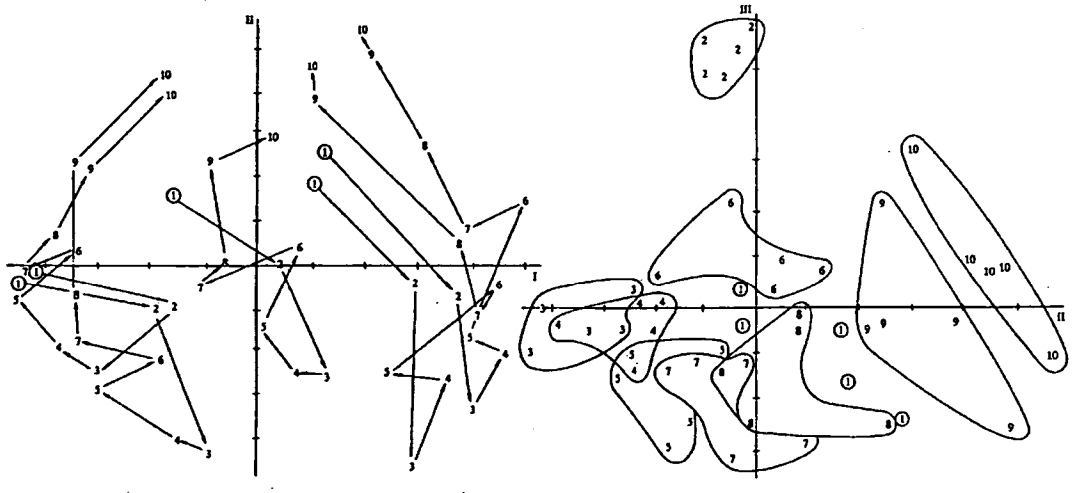


Fig. 8. Principal coordinates ordination of points of time in the case of 5 replications of 1 m^2 quadrat in the Glyphosate experiment. (Resemblance is measured by Czekanowski's similarity coefficient. See Fig. 1. for explanation of numbers.)

distributions and pattern abundance-dominance relationships by changing the size of study-area are also needed for understanding community changes and their appropriate interpretation at different spatial scales.

This is a preliminary experiment, which can be used later for generating some hypotheses. However, the results of this experiment can be useful for researchers who are further using herbicides or learning their effect.

Acknowledgements

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TISCIA 28, 15-19

MEASURES OF ASSOCIATION AND CORRELATION BETWEEN TWO COEXISTENT FORMS OF *CAREX SEROTINA* MÉRAT; PATTERN AND DISTRIBUTION OF DOMINANCE

I. Bagi

Bagi, I. (1994): Measures of association and correlation between two coexistent forms of ***Carex serotina*** *Mérat; pattern and distribution of dominance.-Tiscia 28, 15-19.*

Abstract. Two *Carex serotina* forms ('A' similar to forma serotina, 'B' similar to forma thalassica) occur together on the mud of a meander lake in the Tiszaalpár Basin.
The distribution of the forms in space seems to be independent of the location of the cenological sample in the lake bed. The frequencies of dominances show a close paralelism in the 2 - 10 % domain of dominances. The measures of association and correlation between the two forms refer to a close positive relation of the forms.

According to our current information, it is the first paper in which such a degree of phenotypical variability increase is reported, which had led to the discontinous segregation between two cooccurrent plant forms in a natural population.

Key words: ***Carex serotina****, mud vegetation, plant architecture, vegetation structure*

I. Bagi, Department of Botany, József Attila University, H-6701 Szeged, P.O. Box 657, Hungary

Introduction

Two different forms ('A' and 'B') of *Carex serotina* can be found on the mud of a meander lake in the valley of the River Tisza. The appearance of the 'A' form is similar to 'forma serotina', the 'B' form has an appearance which is similar to 'forma thalassica' of *Carex serotina* (Soó, 1973), (Fig. 1). There is no transition between the two forms, so they can be well distinguished in the field. The lack of transitional forms excludes the possibility of supposition according to which the forms would be regarded as representatives of *Carex serotina* at different ages, therefore, in different stages of their life history (Havlíčková, 1982; Soó, 1955). The phenotypical variability in this case is manifested in architectural characteristics, e.g. height of the plants, length and curvature of the leaves.

There are several, sometimes contradictory data on the intra- and interpopulation variability of the species of *Carex flava* agg. (*C. flava* L. var. *flava*, *C. flava* var. *alpina* Kneucker, *C. lepidocarpa* Tausch, *C. tumidicarpa* Anderss. and *C. serotina* Mérat) (Cretin and Bidault, 1974; Davies, 1953, 1955; Havlíčková, 1982; Schmid, 1982, 1984 a, b, 1986 a, b; Senay, 1950-51; Stoeva and Štěpánková, 1990, Wiinstedt, 1947). Most of these publications agree on the fact that the variability within a population of the *Carex flava* complex is very high. In some cases it is higher than the variability between the studied populations in relation to several studied morphological characteristics. There is a debate on the ratio of the ecological or/and genetical dependence of the variability of the characteristics: Schmid (1984 a,b) regards *Carex serotina* to have the lowest genetical variability within its populations and finds its characteristics to have the widest plasticity. Stoeva and Štěpánková (1990) found a higher variability of characteristics of *Carex serotina* which can be regarded as being less sensitive to environmental factors compared to other species of the complex. (It is undoubted that the plant architecture, on which this paper is based, is under strong environmental influence (Havlíčková, 1982).) Nevertheless, it should be noted that the comparison of populations has often occured between populations of localities which are far from each other, and the cenological-environmental conditions are seldom documented sufficiently, while the authors agree on the

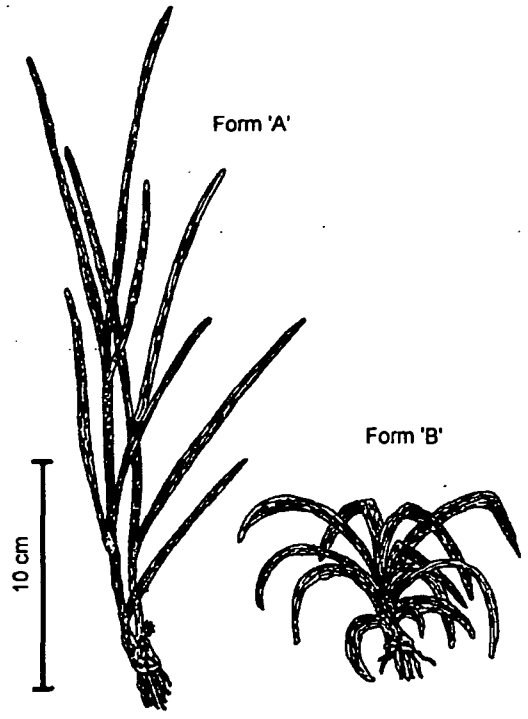

Fig. 1. Typical representatives of the two coexistent *Carex serotina* forms.

dominant significance of environmental conditions in the formation of the spectra of the phenotypical variables. The territory studied by us is exceptional because the forms, which are significantly different in their architecture, can be found in the same stand or cenological relevé.

The cenological relations and the outlined edaphic conditions of the habitat have already been published (Bagi, 1988): It is characteristic of the cenological relations that the *Carex serotina* forms occur in a highly modified *Eleocharito-Caricetum bohemicae* community (Müller-Stoll and Pietsch, 1985; Pietsch and Müller-Stoll, 1968), which is influenced by *Bidentetea* elements due to the strong nutrient loading. The soil parameters refer to a high concentration of plant nutrients that originate from the hypertrophic water of the lake by an organogenic sedimentation process. The taxonomical consequences of the morphological dimorphism have also been mentioned (Bagi, 1989).

The subjects of this contribution are: first the documentation of the fact of the coexistence, moreover, the investigations of the parameters of coexistence of *Carex serotina* forms, the distribution of their dominance in cenological relevés, and their spatial allocation in the territory.

Materials and methods

Thirty-seven cenological relevés were recorded in the territory (cf. Bagi, 1988). The relevés almost entirely cover the lake bed. The size and shape of the plots where the cenologial relevés were taken conform to the patches with homogeneous vegetation (Fig. 2). As the cover values of the other species have no role in this paper (available in Bagi, 1988), the cover values (%) of the two *Carex serotina* forms are presented in Table 1.

The standard reference work is Goodall (1978) in relation to applied mathematical-statistical methods.

Table 1. Cover values (%) of the *Carex serotina* forms

relevé	1	2	3	4	5	6	7	8	9	10
Form 'A'	2	3	8	5	10	4	2	8	5	4
Form 'B'	4	10	5	0	1	5	2	+	1	4
relevé	11	12	13	14	15	16	17	18	19	20
Form 'A'	3	15	10	3	5	15	6	11	3	3
Form 'B'	3	4	0	3	5	2	+	0	+	0
relevé	21	22	23	24	25	26	27	28	29	30
Form 'A'	4	14	3	4	8	10	8	4	35	12
Form 'B'	+	+	2	2	10	5	4	10	3	3
relevé	31	32	33	34	35	36	37			
Form 'A'	14	17	1	5	4	4	10			
Form 'B'	4	1	4	7	8	10	3			

Results

Spatial relations

Investigations on the spatial distribution of *Carex serotina* forms (Fig. 2) refer to the following conclusions: Neither form 'A' nor form 'B' is bound unambiguously to a particular part of the lake; both forms may occur in high coverage both in the inner as well as in the outer parts. The distribution of the two forms seems to be random in scale of the cenological relevés involved by the perceptible patchiness of the vegetation. The water in the lake, however, is shallow; there are no important differences of reliefs between the lowest and the highest sampled plots (max. 20 cm).

Distribution of dominance

In spite of the fact that the summarized dominance value of the form 'A' is significantly higher (285) than the value of 'B' (127.5), the distribution of dominance values seems to be very similar in the most important 2-10 % domain (Fig. 3). The differences outside of this domain are resulted by the fact that dominance values of form 'A' are higher then 10 more frequently than 'B', and 'B' shows low dominance values more frequently than 'A'.

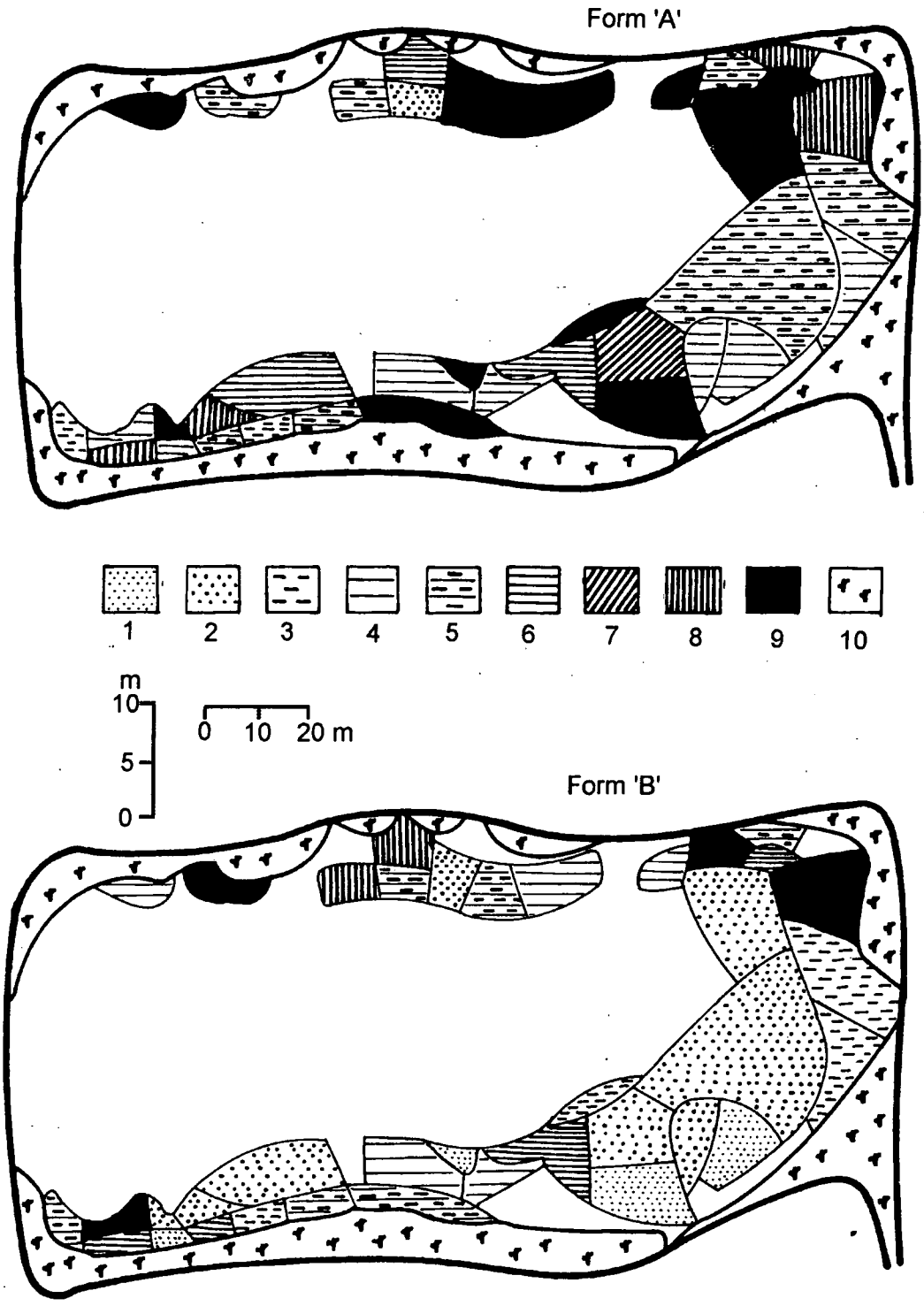

Fig. 2. Allocation of dominance values of the two *Carex serotina* forms. 1-9: cover values of the forms 'A' and 'B' in the relevés; 1: 0 %, 2: + - 1 %, 3: 2 %, 4: 3 %, 5: 4 %, 6: 5 %, 7: 6 %, 8: 7-8 %, 9: >=10 %, 10: *Phragmites - Typha* community. Note that the vertical and the horizontal scale are not identical.

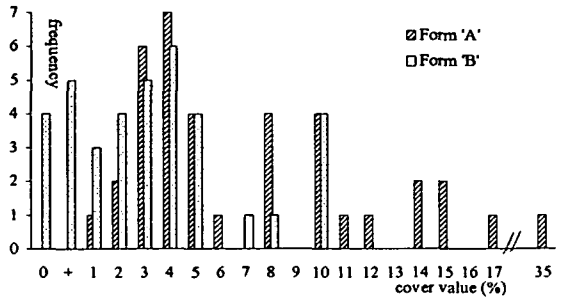

Fig. 3. Distribution of dominance values of the two *Carex serotina* forms.

Numerical approach to coexistence

The significance tests for "interspecific" association based on 2 x 2 contingency table of presence-absence data (one or two fictive "cenological" data pair(s) should be added to the data set depending on the kind of the test or index) refer to an association between the two forms. The χ^2-values are higher than what would be issued from the hypothesis which supposed total independence between *Carex serotina* forms. The χ^2-values are 1.6946 (n=38) and 3.8338 (n=39) by calculation according to Yates and Gilbert-Wells formulae, respectively (cf. Goodall, 1978), but these values are more or less lower than the critical $\chi^2_{0.05}$=3.841.

In case of the more effective Gilbert-Wells formula, the difference is only 0.0072. As the number of the cenological relevés is low, it is difficult to demonstrate the significant statistical association. (The chance of positive results is decreased by the introduction of fictive data.)

Every measure calculated from presence-absence contingency table data refer to a positive correlation and association of the two forms of *Carex serotina*: Association coefficient or percentage co-occurrence (Agrell, Whittaker-Fairbanks) is 0.8919, the coincidence index (Dice) is 0.9429, Fager's association-index is 0.8574, the ratio of the observed and the expected number of joint occurrences by Forbes is 1.00, the inverse measure of association (Margalef) is 0.00, the Hacker-index and the Sokal-Michener-index both are 0.8919, the relative point correlation coefficient (Cole) is 0.8702 and the Pielou-index is 1.00.

Measures for correlation of qualitative (i.e. dominance in percentage) data between the forms refer to close positive relationship, too: Ellenberg's "specifische Massen-Gemeinschaftskoefficient" is 0.8677, the index of interspecific overlapping (Morosita) is 0.6151, the information measure of association by Estabrook is 0.7194, and the most widely used Pearson correlation coefficient is 0.8858, ($P<0.001$), however, the normal distribution have not been tested.

Discussion and conclusions

The similar distribution of the two *Carex serotina* forms refers to their similar role in community structure. The close positive correlation between the forms can be explained by their similar environmental demands. As a consequence of the high level of sources of nutrients, it may be supposed that the interspecific effects are more relaxed and - in accordance with the niche variation hypothesis (van Valen, 1968) - development of higher phenotypical variability have occured within the population of *Carex serotina*. The higher variability aims at the reduction of intraspecific effects (see Bagi, 1992). Nevertheless, I have no information about a publication yet in which such a degree of phenotypical variability increase - which clearly manifested in plant architecture - is reported, which would lead to the discontinous segregation between cooccurrent plant forms in a natural population.

Acknowledgements

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TISCIA 28, 21-24

PHYTOPLANKTON COMMUNITY AND SAPROBIOLOGICAL CHARACTERISTICS OF LAKE LUDAŠ DURING THE SPRING SEASON

D. Branković and Lj. Budakov

Branković, D. and Budakov, Lj. (1994): Phytoplankton community and saprobiological characteristics of Lake Ludaš during the Spring season. - Tiscia 28, 21-24.

Abstract. This paper deals with the results on examinations of phytoplankton community and saprobiological characteristics of the Lake Ludaš, during the period from March to May (the spring), in the year of 1992. A hundred and eighteen species, varieties and forms of Cyanophyta, Pyrrophyta, Xantophyta, Bacillariophyta, Euglenophyta and Chlorophyta were recorded. All the examined samples were dominated by Chlorophyta. Bacillariophyta ranked the second place, while Xantophyta were present only in one of the samples with only one species. The density of phytoplankton community was changeable and varied from $0.85x10^3$ to $115.73x10^3$. Saprobity index, after Pantle and Buck, varied from 2.2 to 2.6, pointing out to ß-, ß-α- and α–mesosaprobity.

Key words: bioindicators, density of algae, phytoplankton, saprobity.

D. Branković, Lj. Budakov, Institute for nature protection of Serbia, Department in Novi Sad, Petrovaradinska tvrdjava 3, Novi Sad, Yugoslavia

Introduction

The Lake Ludaš is a protected area located in the northern part of Vojvodina Province - the north of Serbia, 12 km off Subotica. It is surrounded with the settlements Ludaš, Backi Vinogradi, Hajdukovo, Nosa, as well as single farms. The Lake Ludaš is a typical lowland lake and belongs to the aeolian type of lakes. The surface area of this lake is 330 ha. Two parts can be distinguished in the Lake Ludaš: the northern part, which is about 2 km wide and 1-1.2 m deep, and the southern part, which is narrower (200 m) and deeper (1.5-1.8 m) (Djukić et al.,1991).

The Lake Ludaš is supplied with the groundwaters, with the Kereš stream waters, and since 1981 it has been supplied with partly cleared waters from II section of the Lake Palić which flow into the northern part of the Lake Ludaš through the Palić-Ludaš Canal, causing higher nutrient loading of this part of the lake.

A few years ago, an irrigation system was built in the southern region of the Lake. During the watering periods, functioning of the system caused the withdrawal of lower quality waters from the northern into the southern part, so the quality of waters of the northern and the southern part became gradually equal (Djukić et al.,1991). Taking these facts into consideration, the aim of our examinations was to recognize the phytoplankton community and saprobiological characteristics of the whole Lake Ludaš as well as its parts during the spring season.

Material and methods

The samples for qualitative and quantitative analyses of phytoplankton were taken on three sampling sites in the Lake Ludaš towards the end of March, the begining of April and the middle of May in the year of 1992. During algological and saprobiological investigations, standard limnological methods were used (Hribar, 1978). Qualitative composition of the phytoplankton community was shown as a proportional participation of different algal groups in total number of taxa. Density of the phytoplankton community was shown as a number of

individuals per 1 cm^3, while relative abundance (quantitative composition) was shown as a proportional participation of algal groups in the total number of algae. Saprobity index was calculated after Pantle and Buck (1955) on the basis of phytoplankton indicator species.

Results

A hundred and eighteen species, varieties and forms of Cyanobacteria, Pyrrophyta, Xantophyta, Bacillariophyta, Euglenophyta and Chlorophyta were recorded during the investigation period. Chlorophyta were represented with 53 taxa (44.9%), Bacillariophyta with 31 (26.3%), Euglenophyta with 14 (11.9%), Cyanobacteria with 13 (11.0%), Pyrrophyta with 6 (5.1%) and Xantophyta with only 1 taxa (0.8%).

The results of qualitative analysis of phytoplankton (Fig. 1) show that Chlorophyta was dominant group during the spring season. Bacillariophyta ranked the second place and were followed by Euglenophyta, Cyanobacteria and Pyrrophyta. Xantophyta were present with only one species in only one sample.

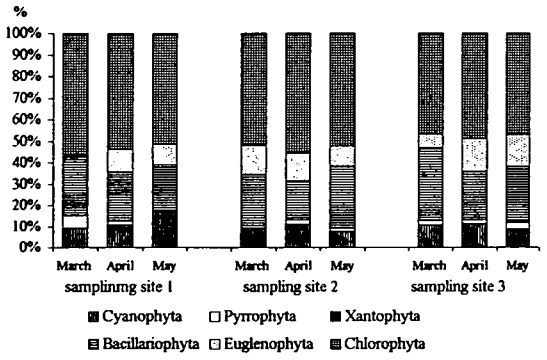

Fig. 1 Qualitative composition of the phytoplankton community (in %).

Density oft the phytoplankton community (Table 1.) varied from $0.85x10^3$ ind/cm^3 on the sampling site 2 in March, to $115.73x10^3$ ind/cm^3 on the sampling site 3 in May.

By relative abundance (Fig. 2), Chlorophyta represented a dominant phytoplankton group. Relative abundance of Chlorophyta varied from 45.3 to 55.4 %. They reached such high relative abundance thanks to massive development of the genera *Scenedesmus, Ankistrodesmus, Tetraedron, Crucigenia, Golenkinia* and *Pediastrum*.

Bacillariophyta represent another characteristic group of the Lake Ludaš phytoplankton community. Their relative abundance varied from 20.4 to 36.4 %. The genera *Stephanodiscus, Nitzschia, Ciclotella* and *Melosira* were the most abundant.

Table 1. Density of the phytoplancton community (x1000 ind/cm^3)

sampling site	1	2	3
March	9.54	0.58	19.76
April	32.43	14.37	27.62
May	48.32	54.26	115.73

Algae from the Cyanophyta group were less important member of the Lake Ludaš phytoplankton community, being present from 9.0 to 24.5 %. The species *Microcystis aeruginosa* Kutz., *Oscillatoria tenuis* Ag. and *Spirulina maior* Kutz. were most abundant.

In the Euglenophyta group, relative abundance of which varied from 0 to 12.7 %, the species *Euglena acus* Ehr., *E. viridis* Ehr. and *Lepocinclis ovum* (Ehr.) Lemm. were of the highest relative abundance.

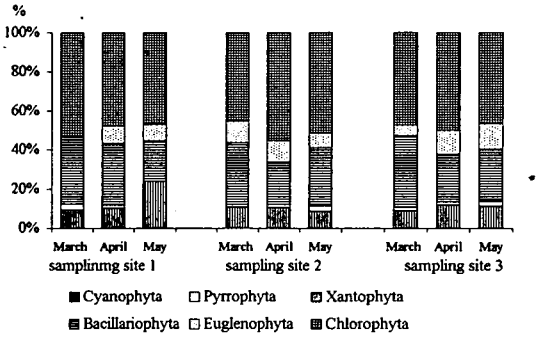

Fig. 2 Quantitative composition of the phytoplankton community (in %).

Indicators of the most polluted waters, such as *Euglena acus* Ehr., *E. viridis* Ehr., of α-mesosaprob degree, such as *Oscillatoria tenuis* Ag., *Cyclotella meneghiniana* Kutz., *Nitzschia palea* (Kutz.)W.Sm., *Stephanodiscus hantzschii* var. *pusilus* (Grun.)Krieg., *Lepocinclis ovum* (Ehr.)Lemm., *Cosmarium botrytis* Menegh. and of ß-mesosaprob degree, such as *Microcystis aeruginosa* Kutz., *Golenkinia radiata* Chod., species of the genera *Pediastrum* and *Scenedesmus* were recorded. Indicators of the oligosaprob degree were not recorded.

Saprobity index, calculated on the basis of phytoplankton species as indicators, is given in Table 2. It varied from 2.2 to 2.6.

Table 2. Saprobity index after Pantle and Buck

sampling site	1	2	3
March	2.3	2.2	2.2
April	2.5	2.2	2.2
May	2.6	2.2	2.4

Discussion

In the lake Ludaš during the spring season in the year of 1992, 118 taxa (species, varieties and forms) of algae were recorded, which differed regarding the literature data (Seleši, 1981; Djukić et al., 1991). Seleši (1981) recorded 100 taxa during the spring season in the 1970-1981 sampling period, while Djukić et al. (1991) recorded 61 taxa in the period of 1981-1990.

There were some insignificant differences in qualitative composition of algae between our and the literature data. In respect to Seleši (1981), the proportional participation of Cyanophyta, Xantophyta, Euglenophyta and Chlorophyta was almost the same. The proportional participation of Pyrrophyta was 3.1% higher, while the proportional participation of Bacillariophyta was 4.7% lower.

Differences in the total number of taxa and in the proportional participation of some groups of algae between our and the literature data could be explained by different sampling spots and number of samples, as well as by expressive anthropological influence resulting in unstability of this water ecosystem.

Concerning the monthly and sampling spot variation in both qualitative and quantitative composition of the phytoplankton community (Fig. 1 and Fig. 2), the only noticed regularity was domination of Chlorophyta and subdomination of Bacillariophyta in all the samples. Any other regularity was not noticed, which could also be explained by the ecosystem unstability as a consequence of anthropological influence.

The density of phytoplankton community (Table 1.) varied from 0.85×10^3 ind/cm^{3}l to 115.73×10^3 ind/cm^3. The smallest number was recorded in March on the sampling site 2 and the highest number in May on the sampling site 3. The noticed regularities were the number of algae increasing towards the end of the spring and generally the highest number on the sampling site 3 through all those months.

Bioindicators of polysaprob, α-mesosaprob, and ß-mesosaprob degree were recorded, while indicators of the oligosaprob degree were not, which corresponds to the literature data. Namely, on the basis of the investigation in the period of 1978-1987, Djukić et al. (1988) recorded that the polysaprobic and eutrophic species almost disappeared from the bottom fauna of this Lake, and concluded that this Lake was gradually transformed from an eupolytrophic into a dystrophic lake.

As shown in Table 2., the saprobity index varied from 2.2 to 2.6, pointing out to ß-mesosaprob, ß-α-mesosaprob, and α-mesosaprob degree. The saprobity index was somewhat higher in the northern part of the Lake, pointing out a higher nutrient loading in this part of the Lake. This is understandable because partly cleared waste waters of Subotica and the waters from the Kereš stream, which are of poor quality, flow into the northern part of the Lake. Our results correspond to the results recorded by Djukic et al. (1991), and were given on the basis of phytoplankton, periphyton, zooplankton and zooperiphyton indicator species, and to the results recorded by Gajin et al. (1992), and were given on the basis of bacterioplankton.

Investigations of a lot of authors (Božinović et al., 1990; Djukić et al., 1988; Djukić et al., 1991; Gajin et al., 1992; Maletin and Budakov, 1983; Pujin, 1988; Ratajac, 1988; Seleši, 1981; Seleši, 1988) pointed out the poor quality of the Lake Ludaš waters and unstability of this ecosystem as a consequence of intensive human influence

Apart from the poor water quality, and on the basis of these investigations, it could be concluded that the quality of waters in the northern and southern part of the Lake Ludaš became gradually indentical, which probably resulted from functioning of the irrigation system, as well as disappearance of the reed belt between the northern and the southern part of the Lake.

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TISCIA 28, 25-28.

QUANTITATIVE PRESENCE OF MACROPHYTES IN BASIC CHANNEL NETWORK OF HYDROSYSTEM DANUBE - TISZA - DANUBE

M. Vučković, S. Stojanović, Ž. Stanković, M. Žderić, P. Kilibarda, Lj. Radak and S. Radulović

Vučković, M., Stojanović, S., Stanković, Ž., Žderić, M., Kilibarda, P., Radak, Lj. and Radulović, S. (1994): Quantitative presence of macrophytes in basic channel network of Hydrosystem Danube - Tisza - Danube. - Tiscia 28, 25-28.

Abstract. Quantitative presence of aquatic vascular plants is given at certain sections of Hydrosystem Danube - Tisza - Danube in Backa: channels Vrbas - Bezdan, Backi Petrovac - Karavukovo and Jegricka. Among submerged plants which are not rooted, species *Ceratophyllum demersum* is the most frequent in all sections. From submerged plants that are rooted, *Myriophyllum spicatum* and *Vallisneria spiralis* have the greatest quantitative presence. Floating non rooted hydrophytes are small floating flowering plants and water ferns. *Spirodela polyrrhiza, Lemna gibba, Salvinia natans* and *Azolla caroliniana* have high coverage values at certain spots. From group of floating rooted hydrophytes, most numerous are *Trapa natans, Nymphaea alba, Nuphar luteum* and *Nymphoides flava*. Due to great surface and big floating leaves, they are covering large areas of water mirror, especially in channel Vrbas - Bezdan. Among numerous emerged macrophytes giving coast zone of all channels, highest participation is of *Phragmites communis, Typha angustifolia* and *Glyceria maxima*. It is concluded that differences in floristic structure and quantitative presence of various life forms of aquatic plants in investigated sections of Hydrosystem Danube - Tisza - Danube are due to different age of channels (30 to 200 years), different physico-chemical conditions of aquatic environment, purpose functions of channels, pollution degree and application of different protection measures.

Keywords: Hydrosystem Danube - Tisza - Danube, hydrophyta, floristic structure, ecological groups, quantitative presence.

M. Vučković, S. Stojanović, Ž. Stanković, M. Žderić, Lj. Radak, S. Radulović, Faculty of Science, Institute of Biology, Trg Dositeja Obradovica 2, Novi Sad, Yugoslavia, P. Kilibarda, Danube Water Authority, Mihajla Pupina 25, Novi Sad, Yugoslavia

Introduction

Hydrosystem Danube - Tisza - Danube is one of the most important hydrotechnical objects at Vojvodina area. Total length of channel network is 960 km, from which about 400 km is in Bačka. Channel network consists of new channels, radically or partially reconstructed old channels and water flows included in a new system. Hydrosystem as a whole is a complex solution of numerous watereconomy problems at Vojvodina area - drainage, water supply of irrigation and distribution systems, industry development, fishery, swamp settlements sanation, navigation, recreation etc.

Channel network is a specific category of artificial aquatic ecosystems, where macrophyte vegetation is important component. Namely, aquatic plants are natural phytosanators, participating in water selfcleansing process, but on the other hand, high quantitative presence of aquatic plants is of important influence to organic production - plant mass, contributing to high level of eutrophication and overgrowth of these water biotopes.

Important data on water vegetation of Basic channel network of Hydrosystem Danube - Tisza - Danube are given in papers Slavnić (1956), Čanak

et all. (1969), Vukoje (1986), Stojanović et all. (1991, 1992, 1993), Butorac et all. (1991,1992), Vučković et all. (1993), Stanković et al. (1991, 1993).

In this paper, floristic structure and quantitative presence of vascular plants is given for channels Vrbas - Bezdan, Bački Petrovac - Karavukovo and Jegrička, in purpose of better knowledge of recent condition of aquatic vegetation at Basic channel network which is not sufficiently investigated from this point of view.

Material and methods

Investigations were carried out in 1991 -1993 period.

Plant species were determined according to Flora of SR Serbia (Josifović, 1970-1986) and Iconografia Florae Partis austro-orientalis Europae Centralis (Jávorka and Csapody, 1975).

Phytocenological surveys, on the basis of which phytocenological tables were constructed and total covering value of plant species determined, were taken according to method of Braun-Blanquet (1964).

General characteristics of investigated sections of DTD hydrosystem channels

Channel Vrbas - Bezdan (Fig. 1/I) is one of the oldest sections of Basic channel network, constructed in 1793 (before 200 years). In hydrotechnical sense, it consists of two gradual basins (bjefs). Channel is main, 80.9 km in length, with water mirror width 25-30 m, and 2.2 - 3.2 m deep. Water supply is from Danube over pump station in Bezdan, and in favourable hydrological conditions also over Baja channel, which flows in at Szebes-Fok. Having in mind waste waters and concentrated pollution sources, this channel is one of the most protected objects of Hydrosystem DTD, which ensures satisfactory water quality.

Channel Bački Petrovac - Karavukovo (Fig. I/II) belongs to group of navigable channels of Basic channel network DTD. Among other purpose functions, through this channel one-way navigation occurs (approx. 20 objects per year). This is one of more recent sections, constructed about 30 years ago (1960-1965). Total length of channel is 52 km, water mirror width is 40-50 m, with depth of 1.8 - 2.5 m. Water supply is from channel Bečej - Bogojevo at Bogojevo, or from Danube at Bezdan (through channel Odžaci - Sombor). At this section there is no important pollution source, which ensures good water quality.

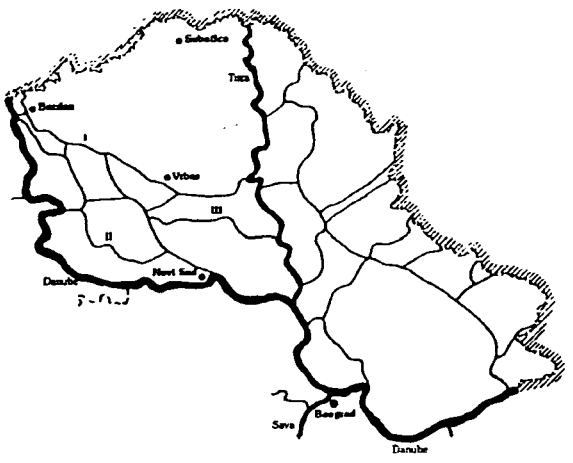

Fig. 1. The Basic channel network of Hydrosystem Danube - Tisza - Danube. Numbers are marking investigated channels: I - Vrbas - Bezdan; II - Backi Petrovac - Karavukovo; III - Jegricka.

Channel Jegrička (Fig. 1/III) used to be natural water flow and recipient for drainage from southern Backa region. By regulatory undertake, mostly done until 1960, Jegrička is today mostly regulated, multipurpose water flow with conductory water regime. Specificity of this channel are hydrotechnical and hydromorphological characteristics, on the basis of artificial and natural specifications of river bed. Jegricka water flow is divided into three gradual basins, with specific water regime. Upper basin (from Despotovo to Zmajevo) is totally regulated, lower basin (near Žabalj) is natural depression transformed into fish pond, and middle basin is partly regulated, and partly consists of natural depression with non-regulated river bed. The total length of Jegrička is 65 km. Water mirror width and depth are different in every basin. Waste waters used to flow in Jegrička from hemp processing plant in Zmajevo, which caused worsening of water quality and destruction of life forms. After closing of this plant (in 1982), aquatic life begun to restore and "normalize", following increase of water quality.

In investigated sections of Hydrosystem DTD, water quality is continuously controlled by physical, chemical and biological analyzes. According to values of most important parameters, waters from all three channels are within limits for II water class. According to results of biological analyzes, these are waters with betha-mesosaprobic features.

Results and discussion

By investigations of macrophyte water vegetation in sections of the Basic channel network of Hydrosystem DTD (channels Vrbas-Bezdan, Bački Petrovac-Karavukovo and Jegrička), different ecological groups of aquatic plants were determined, among which some are to be emphasized because of significant quantitative presence.

From comparative review of floristic structure and covering values of individual plant species (Table 1), it could be seen that there are differences between sections investigated. Channel Vrbas-Bezdan is the richest in floristic sense, and also most interesting. Total of 40 species of aquatic and emerged plants was found.

Among submerged plants which are not rooted, in all channel sections most abundant was *Ceratophyllum demersum* (1- 7678; II - 1559; III - 3075), which occurs in central, deepest parts of channels. Due to dense population, easy multiplication, dispersion, and important organic production, this species represents a serious problem in most of channels of Hydrosystem DTD. From other species in this group of life forms,

Table 1. Covering value of hydrophytes in Hydrosystem Danube-Tisza-Danube sections

Life form		Plant species	Vrbas- Bezdan 200 years I	B. Petrovac-Karavukovo 30 years II	Jegricka 30 years III
SUBMERGED	NON-ROOTED	*Cyeratophyllum demersum* L.	7678	1559	3075
		Ceratophyllum submersum L.	100	353	
		Utricularia vulgaris L.			10
	ROOTED	*Myriophyllum spicatum* L.	8928	885	610
		Potamogeton crispus L.	2535		
		Vallisneria spiralis L.	2200	21 00	
		Ranunculus circinatus Sibth.	1392		
		Najas marina L.	1062		
		Potamogeton perfoliatus L.	982	1 32	
		Zanichellia palustris L.	785		
		Potamogeton pusillus L.	525		
		Myriophyllum verticillatum L.	225		
		Potamogeton lucens L.	5		
		Ranunculus trichophylos Chax.	5		
FLOATING	NON-ROOTED	*Spirodela polyrrhiza* (L.) Schl.	2110	1985	175
		Hydrocharis morsus-ranae L.	1392	915	50
		Lemna rninor L.	50	353	
		Lemna gibba L.		2153	
		Salvinia natans (L.) All.	5250	897	50
		Azolla caroliniana Wild.		1970	
	NON-ROOTED	*Nymphoides flava* Hill.	8125		
		Trapa natans L.	6607	459	50
		Nuphar luteum Sm.	3400		
		Nymphaea alba L.	2335		2155
		Potamogeton fluitans Roth.	78	59	
		Potamogeton gramineus L.	5	353	
		Polygonum amphibium L.	5		
		Stratiotes aloides L.		32	
EMERGED		*Glyceria maxima* (Hartm) Holmbg.	5972	367	
		Phragmites communis Trin.	5275	103	975
		Typha angustifolia L.	1925	367	625
		Sparganium ramosum Huds.	1116		50
		Typha latifolia L.	1100		175
		Iris pseudoacorus L.	475		
		Leersia oryzoides (L.) Sw.	200		
		Rumex hydrolapathum Huds.	175		180
		Butomus umbellatus L.	111		
		Acorus calamus L.	110		
		Heleocharis palustris (L.) R.Br.	100		
		Sium latifolium L.	100		
		Sagittaria sagittifolia L.	100		
		Oenanthe aquatica (L.) Poir.	30		
		Bolboschoenus maritimus (L.) Pal.	28		
		Carex pseudocyperus L.	16		
		Scirpus lacuster L.			1625

Ceratophyllum demersum and carnivorous *Utricularia vulgaris* were present, but with significantly less covering values. Species *Utricularia vulgaris* is present in channel Jegricka only, being differential in comparison to other two investigated sections of channel.

Submerged and rooted macrophytes are more numerous. High quantitative participation is of species *Myriophyllum spicatum* (I - 8928; II - 885; III - 610) and *Vallisneria spiralis* (1- 2200; II - 2100) in first two channels only. Most of other species from this group are differential in comparison to other investigated channels: species from genus *Potamogeton* (*P. crispus, P. lucens, P. pusillus*), *Ranunculus circinatus, Najas marina, Zanichelia palustris* etc.

Floating non rooted hydrophytes are mostly presented by small floating flowering plants, from which *Spirodela polyrrhiza* is most frequent, and with considerable covering value (I - 2110; II - 1985; III - 175). In channel Backi Petrovac - Karavukovo higher participation is of species *Lemna gibba* (II - 2153). Water fern, *Salvinia natans* is abundantly present in channel Vrbas - Bezdan (I - 5250), and *Azolla caroliniana* in channel Bački Petrovac - Karavukovo (II - 1970).

From group of floating rooted plants, by quantitative participation are emphasized *Trapa natans* (I - 6607; II - 459; III - 50) and *Nymphaea alba* (I - 2335; III - 2155). At certain spots, *Nymphoides flava* and *Nuphar luteum* are vastly present, especially in channel Vrbas - Bezdan. These plants, with numerous specimens and large floating leaves, someplace are covering large surfaces of water mirror. It is important to emphasize that water lilies are not present at all in channel Bački Petrovac - Karavukovo, and in channel Jegrička only populations of white water lily (*Nymphaea alba*) are present.

From other floating rooted hydrophytes, *Potamogeton gramineus, Potamogeton fluitans, Polygonum amphibium* and *Stratiotes aloides* are occurring, mostly with insignificant covering value (in channels Vrbas - Bezdan and Bački Petrovac - Karavukovo).

More consideration, from nature protection point of view, deserves *Stratiotes aloides*, being rare and protected species in Vojvodina area. To this category also are belonging *Nymphaea alba, Nuphar luteum* and *Nymphoides flava*.

Among high, emerged macrophytes that narrow coast band consists from, highest participation is of *Phragmites communis* (I - 5275; II - 103; III - 975), *Typha angustifolia* (I - 1925; II - 367; III - 625) and *Glyceria maxima* (I - 5972; II - 367). Dense population of these plants are not allowing numerous development of other species, therefore they are present with lower covering values.

Differences in floristic structure and quantitative presence of certain life forms of aquatic plants in investigated sections of Hydrosystem Danube - Tisza - Danube are resulting from different age of channels (30 to 200 years), different physico-chemical conditions of water environment, purpose functions of channels, level of pollution and application of different protection measures.

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THE EFFECT OF SOME ENVIRONMENTAL FACTORS ON PROTOZOA POPULATIONS OF THE RIVER DANUBE

J.N. Nosek and M.Cs. Bereczky

Nosek, J.N. and Bereczky, M.Cs. (1994): The effect of some environmental factors on Protozoa populations of the River Danube. - Tiscia 28, 29-36.

Abstract. The simultaneous effect of nine environmental factors (water discharge, water temperature, dissolved oxygen content, ammonium content, pH, chemical oxygen demand (by $KMnO_4$), total dissolved solids, Coliform and psychrophyl bacterial counts) were investigated on the population size of 30 planktonic Protozoa species.
Data series of four years with different hydrological regimes were evaluated by correlation and path analyses.
Regarding the direct effects higher than 5%, 57% of the species were influneced by ammonium content, 40% by pH, 33% by dissolved oxygen content, by chemical oxygen demand and by total dissolved solids each, 27% by Coliform, 23% by psychrophylic bacterial count, 17% by water discharge and 7% by water temperature.

Key words: planktonic Protozoa populations, running water, path-analysis, environmental factors, River Danube.

J.N. Nosek, M.Cs. Bereczky, Hungarian Danube Research Station of the Hungarian Academy of Sciences, Institute of Ecology and Botany of the H.A.S. H-2131 Göd, Jávorka S. str. 14., Hungary.

Introduction

One of the classic and even today most important fields in ecology is the investigation of the effects of various biotic and abiotic environmental factors on the living organisms.

For the classic and evergreen nature of this topic, even a concise and selective survey of the references is impossibile. The majority of the studies, however deals with the effect of one, or a few factors. Papers dealing with the joint effects of several factors there are in much smaller number (e.g. Nosek and Bereczky, 1981; Pratt et al., 1987; Reed, 1978; Samuels et al., 1979; Say and Whitton, 1983; Stewart et al., 1986; Wehr and Whitton, 1983; etc.)

There are basically two possibilities for the investigation of the effects of various environmental factors: laboratory experiments and/or field studies. Under laboratory conditions the range of a factor can be adjusted, and the experiment can be reproduced several times. The factors however are not independent from each other, so the effects of their combinations may not be neglected. The adjusting of the factors and their combinations can be solved relatively simply only for a few ones, and the interpretation of the results may be difficult for natural conditions.

In the case of field studies the ranges of each factor and their combinations are determined by nature. The effect of a single factor itself is hardly to be determined (apart from very extreme biotopes). The responses of living organisms reflect the effect of all relevant factors. There are difficulties in the separation of the effects and the determination of their relative importance. The use of the path analysis may, however, overcome these difficulties (Anders, 1986; Lee, 1955; Le Roy, 1956).

This paper describes the complex effect of certain environmental factors on the size of some free living Protozoa populations of River Danube.

Methods

The sampling site is in the main channel of the Danube at Göd, about twenty kilometers above Budapest, at river km. mark 1669. The Danube is here of midland character, with a mean annual water discharge of 2200 m^3s^{-1}. The substrate type is river ballast.

Samples have been taken for more than two decades from this site with weekly frequency, filtering 100 l water through a plankton net of 10 µm mesh size at each occasion. Samples have been analysed partly living and partly fixed by the Lugol method modified by Wilbert (1974) as well as by Bereczky's staining method (Bereczky, 1985).

As in running waters the water discharge is regarded to be the most important abiotic environmental factor, for detailed analysis from the long-term data series data of four years (1981, 1985, 1986 and 1987) were selected so, that the range of water discharge values be the widest possibile. The total number of samples analysed was 140. Nine environmental factors were selected to reflect the natural conditions and the anthropogenic effects, too. The factors and their extreme values are listed in Table I.

Dissolved oxygen content was determined by Winkler's method, the ammonium content by the Nessler's method and the chemical oxygen demand by acid potassium permanganate ($KMnO_4$). Total dissolved solids means the evaporation residue of the filtered water. Bacterial counts were determined after incubation at 20 °C and 37 °C by counting the colonies developed.

Chemical data originate from the chemical laboratory of the Danube Research Station. The bacteriological analyses were carried out in the Institute for Public Health and Epidemiology of the City of Budapest.

Of the more than 500 Protozoa species occuring in the plankton of the Danube, species having relative frequency of 10% or more were included in the study (Table 2.).

The effect of the factors studied was evaluated by path analysis. The path analysis takes the factors simultaneously into consideration. It is also possibile to separate the effects of the single factors, to determine their relative importance, to make distinction between the direct and indirect effects as well as to assess the sum of effects of other factors not investigated (this is the so called error path).

To make the results comparable, species were investigated one by one, using the same path diagram (Fig. 1). The nine environmental parameters represent the independent variables and the number of individuals (the population size) of the given species the dependent one. The correlation between variables was estimated by Bravais correlation coefficient. Correlation between two independent variables was accepted in the diagram only if the sign of the correlation coefficient computed for the single years each and for the pooled data was the same, and its value was higher than 0.2 for the pooled data.

A bidirectional connection was accepted if a mutual influence could be supposed between two variables. This fact is represented in the diagram by dotted lines, and the degree of the correlation was estimated by the correlation coefficient. If only a "one way" effect (unidirectional connection) could be accepted, an arrow with one head, pointing to the direction of the effect was set in the diagram and the degree of correlation was estimated by the value of an internal path coefficient. E.g. in the case of water discharge - total dissolved solids, changes in water discharge may affect the amount of total dissolved solids, but a vice-versa effect is unimaginable. From each independent variable a direct path was ordered to the dependent one. In the diagram the thick, short arrows represent these direct effects of the separate independent variables. (To avoid the confusion they have not been drawn to the Y variable.) The indirect effect of one factor

Table I. Values of the environmental parameters

parameter	code	minimum	mean values	maximum
ammonium content (mg l^{-1})	NH	0.00	0.47	2.68
chemical oxigen content (mg l^{-1})	OD	5.00	7.20	17.30
dissolved oxigen demand (mg l^{-1})	DO	6.59	10.36	20.00
number of Coli-form bacteria (ind ml^{-1})	CB	0.00	222.40	931.00
number of psychrophil bacteria (10 ind ml^{-1})	PB	10.00	6.05	21.00
pH	PH	7.24	8.15	9.68
total dissolved solids (mg l^{-1})	TS	230.00	322.40	466.00
water discharge (m^3 sec^{-1})	WD	986.00	2375.00	6100.00
water temperature (°C)	WT	0.40	12.72	22.00

Table 2. Relative frequency values and indicator character of the species

species	code	relative frequency	indicator character
Carchesium polypinum (Linnaeus,1758).	CAPO	24.3	a
Codonella cratera (Leidy,1877)	COCR	49.3	ob
Coleps hirtus (O.F.Mueller,1786)	COHI	66.4	ba
Coleps hirtus var. *lacustris* (Faure-Fremiet,1924)	COLA	22.9	*
Colpidium campylum (Stokes,1886)	CPCA	21.4	p
Colpidium colpoda (Losana,1829)	CPCO	16.4	p
Epistylis plicatilis (Ehrenberg,1831)	EPPL	15.7	a
Epistylis pyriformis Perty	EPPY	33.6	*
Glaucoma scintillans Ehrenberg,1830	GLSC	22.9	p
Paramecium caudatum Ehrenberg,1833	PACA	39.3	a
Paramecium putrinum Claparede & Lachmann,1859	PAPU	27.9	p
Phascolodon vorticella Stein,1859	PHVO	80.0	b
Prorodon teres Ehrenberg,1833	PRTE	23.6	a
Pseudovorticella margaritata (Fromentel,1876)	PVMA	65.7	b
Staurophrya elegans Zacharias,1893	SPEL	50.7	b
Stentor polymorphus (O.F.Mueller,1773)	STPO	55.0	b
Stokesia vernalis Wenrich,1929	SKVE	45.0	b
Strobilidium caudatum (Fromentel,1876)	SRCA	7.9	ob
Strombidium viride Stein,1867	SBVI	21.4	b
Tintinnidium fluviatile (Stein,1863)	TIFL	75.0	ob
Trithigmostoma cucullulus (O.F.Mueller,1786)	TRCU	27.1	a
Urotricha farcta Claparede & Lachmann,1859	URFA	32.9	a
Vorticella campanula Ehrenberg,1831	VOCA	70.0	b
Vorticella convallaria (Linnaeus,1758)	VOCO	37.1	a
Vorticella incisa Stiller	VOIN	52.9	*
Vorticella microstoma Ehrenberg,1830	VOMI	37.9	p
Vorticella nebulifera O.F.Muller,1773	VONE	79.3	*
Vorticella similis Stokes,1887	VOSI	80.0	*
Zoothamnium minimum Stiller	ZOMI	30.7	*
Zoothamnium varians Stiller	ZOVA	44.3	*

(ob - oligo-betameso-, b - betameso-, ba - beta-alfameso-, a - alfa-, p - polysaprob indicator species,* - species without indicator character)

means the effect of the factor caused by the modification of one or more another factor. E.g. chemical oxygen demand may affect the population size of a species direct and by modifying the ammonium content, or the dissolved oxygen content, etc., too (cf. Fig. 1).

Results

The environmental factors investigated were generally independent from each other, a moderate ($0.4 < r < 0.7$) or strong ($0.7 < r < 0.9$) correlation could be established only in a few cases (Table 3). The correlation between the dissolved oxygen content and pH was already registered in the main channel (Nosek and Bereczky, 1981), but its value was then much lower.

Between the number of individuals of the species and the separate environmental factors moderate positive and/or negative correlation was found only in the case of eight species (*Epistylis plicatilis*-water temperature, r=0.427*; *Epistylis plicatilis*-ammonium content, r=0.571**; *Epistylis plicatilis*-pH, r=0.452*; *Urotricha farcta*-ammonium content, r=-0.632***; *Urotricha farcta*-chemical oxygen demand, r=0.521***; *Glaucoma scintillans*-water temperature, r=0.462**; *Parame-*

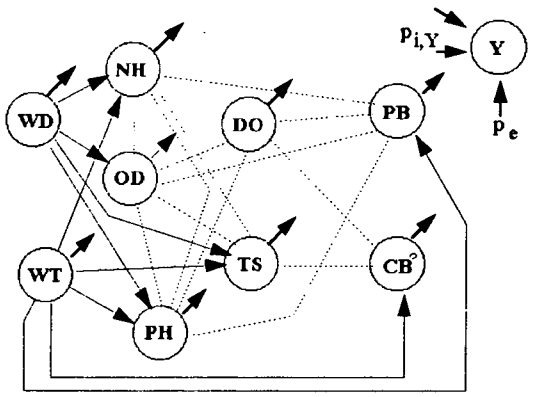

Fig. 1. The path diagram applied to the species. Thin solid lines represent the inner paths, short thick solid lines the direck paths to the dependent variable and dotted lines the bidirectional connections. p_e is the error path.

cium putrinum-water temperature, r=-0.434**; *Strobilidium caudatum*-water discharge, r=0.636*; *Vorticella microstoma*-ammonium content, r=0.659***; *Vorticella microstoma*-number of psychrophil bacteria, r=0.609***; *Vorticella similis*-chemical oxygen demand, r=0.678***; *Zoothamnium minimum*-ammonium content, r=0.647***; *Zoothamnium varians*-total dissolved solids, r=0.491***, where *=p<0.05, **=p<0.01 and ***=p<0.001).

Table 3. The values of the correlation coefficients between the environmental factors

	WT	NH	DO	OD	TS	PH	PB	CB
WD	.125	.290	-.092	-.239	-.506	-.257	.066	-.100
WT		-.415	.014	.064	-.610	.378	-.223	-.282
NH			.039	-.423	-.174	-.500	.135	-.068
DO				.315	.080	.434	-.190	-.159
OD					.174	.205	-.140	-.064
TS						.016	.003	.239
PH							-.302	-.098
PB								.315

[critical values for correlation coefficients (n=140): P0.05 = 0.167, p0.01 = 0.217]

The numerical results of the path analyses are summarized in Tables 4., 5., 6. and 7. (Environmental factors and species are presented by their codes in the tables). The negative sign of a direct, or indirect path coefficient means, that the factor influences the variance of the dependent variable (the population size of species) inversely, that is by increasing value of the factor the population size decreases. The value of R^2 (multiple determination coefficient) shows the proportion of the variance of the dependent variable attributed to the independent variables (all direct and indirect effects). Since p_e^2 equals $1-R^2$, the last column in Table 5. reflects the effect of all unknown factors.

Most of the environmental factors (8) produced a direct effect on *Urotricha farcta*. None of them affected directly the species *Vorticella campanula* and *Tintinnidium fluviatile*. Five species were affected by only one factor (*Coleps hirtus, Colpidium campylum, Epistylis pyriformis, Vorticella margaritata* and *Vorticella nebulifera*). Two factors were effective on seven species (*Coleps hirtus var. lacustris, Paramecium caudatum, Phascolodon vorticella, Prorodon teres, Strombidium viride, Staurophrya elegans* and *Vorticella incisa*). The other species were affected by three or four factors.

Among the 29 species (the path analysis failed in the case of *Vorticella microstoma*), considering direct effects as high as and higher than 5% (Table 6.), water temperature had an effect on two species, water discharge on five species, psychrophylic bacterial count on seven species, Coliform bacterial count on eight species, dissolved oxygen content, chemical oxigen demand and total dissolved solids on ten species, pH on twelve species and ammonium content on seventeen species.

Table 5. contains the sum of indirect effects, too. Most of the indirect effects were also small, of them generally those combinations reached higher values, where the corresponding direct effects were also greater. Regarding the two-step indirect effects ($x_i \rightarrow x_j \rightarrow Y$, $i \neq j$) greater than 5%, in the majority of them one member of the combination were ammonium content, or total dissolved solids, or chemical oxygen demand or pH. Species in general were negatively affected by the indirect effects. Table 7. contains the number of species affected by two-step indirect effects greater than 5%. (Three-step indirect effects - as e.g. the WT→PH→DO→Y, or WD→OD→TS→Y path - were all below 0.01%).

Discussion

The effect of environmental factor on the organisms may be investigated and/or evaluated by different manner. One of the possibilities is the investigation of the ecological valence, revealing whether the range of occurence or the frequency distribution (whithin this range) of a species along a single factor. Such investigation may be carried out under laboratory conditions (e.g. Bick, 1968) or based on field observations (e.g. Bereczky and Nosek, 1993). Another possibility is the application of path analysis, demostrated in this paper.

Although the aim of these approaches is the same, their results cannot be compared directly, or explained mutual, becuse of the differences in their theoretical foundations. In the case of an ecological valence study the question is to establish the ecological demand of a species that is the extreme values of the factor - lower (t_l) and upper (t_u) - are to be found whithin those the species occurs (cf. Fig. 2).

Table 4. Percentage values of the direct path coefficients ($p^{Z}i,Y$)

species	parameters								
	WD	WT	NH	DO	OD	TS	PH	PB	CB
CAPO	(-)5.34	(-)0.24	23.17	(-)9.27	3.85	5.79	7.86	(-)0.66	4.36
COCR	(-)0.62	0.02	(-)8.67	5.54	(-)4.05	(-)4.18	0.92	8.22	1.26
COHI	(-)2.02	(-)0.08	(-)4.46	(-)0.03	(-)2.56	14.23	(-)0.26	(-)4.80	(-)1.46
COLA	.19	(-)0.43	(-)10.93	8.26	(-)3.08	2.36	(-)0.42	(-)3.28	(-)0.01
CPCA	1.56	(-)0.07	1.73	(-)0.01	(-)3.47	17.17	1.24	3.49	(-)0.05
CPCO	4.20	0.02	14.50	0.76	(-)9.18	13.10	24.51	0.27	(-)0.26
EPPL	0.02	0.10	(-)0.10	(-)51.72	15.15	(-)0.17	40.09	(-)1.27	(-)14.39
EPPY	(-)2.10	(-)0.42	(-)0.06	11.60	(-)0.58	(-)0.49	0.01	(-)1.98	0.06
GLSC	0.06	(-)0.13	22.45	(-)4.73	8.06	7.35	2.88	1.61	16.25
PACA	(-) 10.50	0.32	(-) 0.24	(-) 1.47	(-) 2.78	3.32	1.17	(-) 4.24	(-) 13.56
PAPU	(-)0.87	(-)4.58	(-)9.71	0.99	(-)12.02	14.17	(-)19.55	(-)3.91	(-)1.51
PHVO	4.86	(-)0.90	(-)15.96	7.60	(-)3.64	0.73	0.52	(-)0.01	(-)3.18
PRTE	0.01	(-)2.46	(-)5.18	(-)0.61	5.67	0.66	(-)2.24	0.69	0.42
PVMA	(-)4.25	(-)0.19	(-)1.25	(-)0.01	(-)0.69	0.88	(-)1.98	(-)1.01	8.76
SBVI	4.32	0.74	9.49	0.25	(-)2.11	(-)0.96	(-)0.88	(-)8.78	(-)2.36
SKVE	0.93	(-)0.01	0.24	0.40	(-)0.01	1.74	9.63	9.27	(-)9.11
SPEL	0.06	(-)5.78	(-)10.41	3.25	(-)0.49	(-)0.12	(-)0.33	0.87	(-)0.01
SRCA	37.78	(-)0.22	(-)7.88	11.38	(-)0.61	(-)0.02	(-)26.38	(-)0.83	0.75
STPO	(-)5.83	(-)0.92	(-)1.66	0.41	(-)0.14	2.82	(-)11.31	(-)1.44	11.90
TIFL	0.67	0.19	(-) 0.24	0.98	(-) 2.40	0.01	(-) 1.51	(-) 3.63	(-) 0.10
TRCU	(-)3.19	0.18	8.08	(-)1.44	(-)0.96	15.19	12.10	7.08	(-)0.74
URFA	(-)0.17	(-)5.59	(-)6.01	(-)10.62	17.83	13.07	13.62	8.59	8.34
VOCA	(-) 4.13	(-) 3.88	(-) 0.83	(-) 0.01	(-) 0.63	1.77	(-) 0.20	0.06	2.18
VOCO	(-)6.73	(-)2.45	(-)5.16	0.05	(-)6.89	4.23	(-)13.37	0.02	0.87
VOIN	0.01	(-)1.06	(-)3.08	(-)0.35	8.34	(-)2.59	0.24	25.01	(-)4.58
VOMI	(-)0.13	1.10	217.83	(-)33.30	74.18	22.30	97.23	82.54	(-)36.21
VONE	(-)1.80	0.20	1.35	(-)0.02	(-)0.98	5.78	(-)0.11	1.69	(-)0.01
VOSI	0.79	(-)1.89	(-)16.26	13.88	(-)5.62	2.42	(-)0.40	(-)0.04	(-)0.20
ZOMI	(-)0.21	(-)2.67	(-)75.01	1.55	(-)5.35	12.29	(-)66.93	(-)6.61	1.57
ZOVA	(-)0.78	(-)4.87	(-)36.17	5.76	(-)3.57	4.53	(-)37.93	(-)0.63	9.27
IND76		(-) 4.90		(-) 3.50	(-) 0.30				
IND87	(-)0.07	(-)0.58	(-)2.67	2.28	(-)3.83	5.58	(-)0.01	.09	(-)0.01

(Parameters and species corresponding to the codes are listen in Tables 1 and 2. IND76 and IND87 represent the results of the analyses carried out on the total number of individuals of the previous and present study. Negative sign in parenthesis indicates a negative effect of the factor in question.)

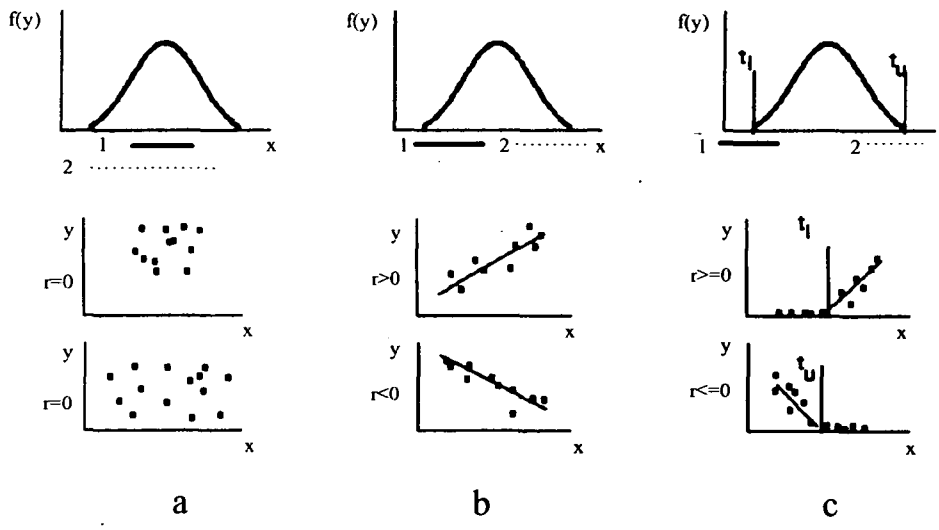

Fig. 2. The relationship between ecological valence and path analysis. (Explanation see in the text.)

The path analysis relies on the behaviour of the variances, that is on the relation between the variances of environmental factors and the variance of the population size of a species. The question is to what extent the size of the population is influenced by the different factors.

The analysis of ecological valences is a univariate method, the factors are considered one by one, independent from each other; even if they are numerous. Path analysis whereas is essentially a multivariate method, revealing the relative importance not only the factors incorporated in the system, but also the total significance of the factors considered (the error path).

Regarding only one factor the relation of these approaches is the following.

If the range of the factor values overlaps with the middle part of the occurence interval of the species, or involves the total interval, no effect can be detected, because factor values both increasing and decreasing the population size are present. The population size appers to be independent of the changes of the factor. The value of the path coefficient will be very low or zero (Fig. 2a).

If the range of the factor coincides only with the lower or upper peius area (suboptimal range) of the species, negative or positive effect can be established (Fig. 2b). The path coefficient will be negative or positive and of different, but not negligable value.

Finally, if the range of the factor is about or exceeds the lower or upper pessimum value of the population, species will be absent, or present only in small and fluctuating degree (Fig. 2c). The value of the path coefficient will be very low or zero (as in case 2a), nevertheless there is an effect, since below (or beyond) a given value (the treshold value) of the factor the species does not occur. This effect is, however, a treshold effect. With other words the treshold effect is a digital sign, while the effect reflected in the path coefficient is an analog sign.

The rank order of the factors, their relative importance, the degree of their effects may be detailed for species to species, the separate species may be compared to one another, but these conclusions are involved in the tables (Tables 4. and 5.), so a textual repetitions seems to be redundant. Therefore instead of this enumeration, we try to draw some generalized conclusions.

Dividing all species into two groups, of which the one (A) contains the oligosaprobic, oligo-beta mesosaprobic and beta mesosaprobic species, indicating a better water quality, and the other (B) contains the beta-alpha mesosaprobic, the alpha mesosaprobic and polysaprobic ones, indicating a worse water quality, we can establish the followings on the basis of direct path coefficients higher than 1%.

Table 5. Percentage values of the direct total, indirect total, R^2 and error path coefficients

species	direct % total	indirect % total	R^2 %	error %
CAPO	60.58	-22.38	38.21	61.79
COCR	33.53	-9.26	24.27	75.73
COHI	29.94	2.51	32.46	67.54
COLA	29.01	-10.77	18.23	81.77
CPCA	28.81	-6.81	22.01	77.99
CPCO	66.84	-29.37	37.48	62.52
EPPL	123.06	-44.94	78.13	21.87
EPPY	17.33	-1.54	15.79	84.21
GLSC	63.55	-12.26	51.30	48.70
PACA	37.64	.99	38.63	61.37
PAPU	67.35	-16.94	50.41	49.59
PHVO	37.43	-14.15	23.28	76.72
PRTE	18.01	-3.93	14.08	85.92
PVMA	19.06	.96	20.03	79.94
SBVI	29.91	14.56	44.48	55.52
SKVE	31.36	-14.81	16.56	83.44
SPEL	21.35	-12.71	8.65	91.35
SRCA	85.89	-30.98	54.91	45.09
STPO	36.48	.62	37.10	62.90
TIFL	9.78	-2.85	6.92	93.08
TRCU	49.01	-19.58	29.43	70.57
URFA	83.90	-7.87	76.03	23.97
VOCA	13.73	8.31	22.05	77.95
VOCO	39.80	-1.03	38.78	61.22
VOIN	45.30	-13.91	31.39	68.61
VOMI	564.85	-398.39	166.47	-
VONE	11.96	.16	11.81	88.19
VOSI	41.54	-21.05	20.49	79.51
ZOMI	172.22	-83.43	88.79	11.21
ZOVA	103.55	-45.98	57.58	42.42
IND76	8.70	2.30	10.90	89.10
IND87	15.12	-3.28	11.85	88.14

(Species corresponding to the codes are listed in Table 2. IND76 and IND87 represent the results of the analyses carried out on the total number of individuals of the previous and present study.)

Ammonium content has a negative effect on all species of group A. Dissolved oxygen content influences positively the population size of the species in group A and negatively the majority of the species in group B. Chemical oxygen demand and the population size of species in group A are inversely related. Total dissolved solids affect positively the number of individuals of all species in group B.

In the case of most species the change in the size of their population were not or hardly determined by the factors investigated (cf. error path values). That is the important factors are not abiotic (physical and chemical), but biotic ones, such as competition, predation, human impacts, etc.

Among the factors studied, water temperature

and water discharge affected the fewest of species. In running water in continental climate this statement might seem a paradox, since seasonal fluctuations in temperature and the flow would be the most important abiotic factors. We should keep in mind, however, that the species investigated are the dominant ones of the Danube. Species with a wide range of temperature-tolerance are present during fast the whole year - if other conditions are suitable -, and species with a narrower tolarance-range are present during some seasons. In the period of their occurence, however the effect of temperature cannot be important, since as dominant species, they must tolerate the changes in temperature.

Investigating the effect of flow, a very important question is the body size of the organisms. The unicellulars are very small compared to the size of loops produced by the turbulent flow occuring in running waters. Therefore these loops cannot cling to these organisms and damage them mechanically. They pass with the water body, performing revolving motion along the turbulent flows. The effect of water discharge in the case of some species can be explained first of all by the direct mechanical effect of the suspend inorganic particles (e.g. *Carchesium polypinum*), or with the drift above a certain water level from the side arms.

Table 6. Direct effects greater than 5%

	parameters											
species	WD	WT	NH	DO	OD	TS	PH	PB	CB	effective parameters		
										-	+	Σ
CAPO	-		+	-		+	+			2	3	5
COCR			-	+				+		1	2	3
COHI						+				-	1	1
COLA			-	+						1	1	2
CPCA						+				-	1	1
CPCO			+		-	+	+			1	3	4
EPPL				-	+		+		-	2	2	4
EPPY				+						-	1	1
GLSC			+		+	+			+	-	4	4
PACA	-								+	1	1	2
PAPU			-		-	+	-			3	1	4
PHVO			-	+						1	1	2
PRTE			-		+					1	1	2
PVMA									-	-	1	1
SBVI			+					-		1	1	2
SKVE							+	+		1	2	3
SPEL		-	-							2	-	2
SRCA	+		-	+			-			2	2	4
STPO	-						-		+	2	1	3
TIFL												
TRCU			+			+	+	+		-	4	4
URFA		-	-	-	+	+	+	+	-	4	4	8
VOCA												
VOCO	-		-		-		-			4	-	4
VOIN					+			+		-	2	2
VONE						+				-	1	1
VOSI			-	+	-					2	1	3
ZOMI			-		-	+	-	-		4	1	5
ZOVA			-	+			-		+	2	2	4
+	1	-	5	7	5	10	6	5	5		44	
-	4	2	12	3	5	-	6	2	3	37		
Σ affected species	5	2	17	10	10	10	12	7	8			81

(Parameters and species corresponding to the codes are listen in Tables 1 and 2. Negative sign indicates a negative, positive sign a positive effect of the factor in question.)

Table 7. Number of species affected by indirect effects greater than 5%

parameter	WD	WT	NH	DO	OD	TS	PH	PB	CB
WD	⊠					5	1		
WT		⊠				4	4		
NH	3	5	⊠		2	1	1	2	
DO				⊠			1		
OD			10	4	⊠	2	5		
TS	2	1	1			⊠	1		
PH	1	1	10	7	1		⊠		
PB					1		6	⊠	
CB				2		2		5	⊠

(Parameters corresponding to the codes are listen in Table 1. Upper right semimatrix contains the number of positively affected species, lower left one contains the number of negatively affected species. Selecting the number of positively affected species = row by column, negatively affected species = column by row. First link of the path is the initial factor, second is the modified. E.g. effect of water discharge via total dissolved solids: positively affected species - intercept of WD row and TS column = 5, negatively affected species - intercept of WD column and TS row = 2.)

Regarding the other factors, it cannot be said, however, that the ranges of their fluctuations correspond to the natural conditions devoid of anthropogenic effects. The human effects, especially the various pollutions have decreased (e.g. dissolved oxygen content) or increased (e.g. ammonium content, chemical oxigen demand, pH) the range of the factors. These changes also extended over the lower or upper suboptimal range of the dominant species adapted to the former 'natural' conditions, and cause appreciable changes in the population size.

In our former study (Nosek and Bereczky, 1981) the effects of some physical and chemical factors were investigated on the total number of planktonic Protozoa species. As the species investigated in this study are the dominant ones of the plankton, forming at least 90% of the total individual number of all species, so the results could be compared.

In the first study water temperature showed the greatest effect, dissolved oxygen content, chemical oxygen demand and pH played a more subordinated role (4.9%, 3.5%, 0.3% and less than 0.1% respectively). In the present situation the relative importance of chemical oxygen demand and dissolved oxygen content is greater than that of the water temperature (OD > DO > WT > PH).

The values of the error path is the same in both study. This indicates, that the total effect of the abiotic factors did not increase, but their relative importance altered.

This rearrangement in the relative importance and the effect of ammonium content, pH and total dissolved solids on a considerable number of the dominant species suggests that a gradual change has been started in the Danube compared its earlier state and this will involve the rearrangement of the species composition of the protozoan fauna.

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TISCIA 28, 37-40

ECOLOGICAL ASSESSMENT OF WATER QUALITY OF THE TISZA BY PHYSICO - CHEMICAL AND BIOLOGICAL PARAMETERS

N. Djukić, S. Maletin, V. Pujin, A. Ivanc, K. Kojčić and B. Miljanović

Djukić, N., Maletin, S., Pujin, V., Ivanc, A., Kojčić, K. and Miljanović, B. (1994): Ecological assessment of water quality of the Tisza by physico-chemical and biological parameters. - Tiscia 28, 37-40.

Abstract. Investigations during the period 1990-1992 showed disturbance of oxygen regime with evident minimum in the summer to occur in the River Tisza concurrently with a relatively high content of nutrients, mineral nitrogen particularly. Zoocenological analysis also pointed to increase in organic load. In plankton samples and bottom fauna and fish, the species being characteristic of eutrophic environment dominated. Therefore, a section of the River Tisza investigated is characterized by a rapid process of eutrophication.

Keywords: oxygen regime, nutrients, zooplankton, bottom fauna, fish, eutrophication.

N. Djukić, S. Maletin, V. Pujin, A. Ivanc, B. Miljanović, University of Novi Sad, Faculty of Sciences, Institute of Biology, 21000 Novi Sad, Yugoslavia, K. Kojčić, Republic Weather Bureau, Hydrological Station, 21000 Novi Sad, Yugoslavia

Introduction

A long-term investigation of water quality of lower River Tisza pointed out variations of values of physico-chemical and hydrobiological parameters, in particular after the dam was built, in the vicinity of Novi Becej, and stream reservoir formed (Djukić and Stanojević, 1981, 1983; Djukić and Kilibarda, 1985; Pujin, 1985, 1989, 1992; Pujin et al., 1984, 1990; Kojčić et al., 1989). Consequently, the whole body of water of the Tisza in this section, in particular in the period of its low level is slow down. In past few years, oxygen regime was found to be unbalanced evidently as well as the concentration of some nutrients. Therefore, the aim of this paper was to evaluate water quality of the lower River Tisza and to suggest certain protection measures on the basis of most recent data obtained.

Methods

In the period 1990-1992, the samples for studies of physico-chemical parameters of water and hydrobionts were collected. The analysis included oxygen regime, nutrients concentration, as well as composition and dynamics of plankton and bottom fauna communities by using standard American methods. The ichthyofauna data are based upon the results of economic and sport catch in the form of annual values.

Results and discussion

Analysis of oxygen balance, organic load, and nutrient content pointed to the two characteristic periods as dependent on the hydrological and climatic conditions. Summer and early autumn low level of water, sedimentation and changes of oxygen regime due to stream slow down were observed. A considerable organic load and an increased content of nutrients were the basic characteristics of the River Tisza at all the profiles under investigation. The effects of the reduction of organic load along the stream owing to the deposition of organic matter with the suspended materials and nitrification were not so evident due to influence and the arrangement of pollutants. In the period 1984 - 1986, an evident increase in all the mineral forms of nitrogen, in particular ammonia, was recorded (Kojčić et al., 1989), while the period of stagnation followed after.

Nitrate form (7.62±4.11 mg/l,) making up 60-80% of total nitrogen predominated. Ammonia

Table 1 Qualitative composition of zooplankton of lower River Tisza

Species	1990	1991	1992
Protozoa			
Amoeba vulgaris EHR.	+		
Aspidisca costata (DUJ.) CL.L.	+	+	+
Carchesium polypinum L.	+	+	+
Trithigmostoma cucullulus (O.F.M.)	+	+	+
Chilodonella uncinata EHR	+		
Colpidium colpoda (EHR.) STEIN	+	+	+
Didinium nasutum O.F.M.	+		
Epistylis plicatilis EHR.	+	+	+
Paramecium aurelia complex	+	+	+
P.caudatum EHR.	+	+	+
P.putrinum STOCKES	+	+	+
Stylonychia mytilus EHR.	+		
Tintinnopsis lacustris complex	+	+	+
Tokophrya quadripartita Cl.L.	+	+	
Vorticella campanula EHR.	+	+	+
microstoma EHR.	+	+	+
Rotatoria			
Anuraeopsis fissa (GOSSE)	+	+	+
Asplanchna brightwelli (GOSSE)	+	+	+
A.girodi DE GUERNE	+		
A.priodonta GOSSE	+	+	+
Brachionus angularis GOSSE	+	+	+
B.budapestinensis DADAY	+	+	+
B.calyciflorus PALLAS	+	+	+
B.diversicornix DADAY	+	+	+
B.leydigi COHN	+		
B.quadridentatus HERMANN	+		
B.urceolaris (O.F.M.)	+		
B.urceolaris var. rubens EHR	+	+	+
Cephalodella catellina (MÜLL.)		+	
C.gracilis EHR.		+	
Colurella dicentra GOSSE	+	+	
Epiphanes senta (MÜLL)		+	
Euchlanis dilatata (EHR.)			+
Filinia longiseta (EHR.)	+	+	+
Hexarthra mira (HUDSON)			+
Keratella cochlearis (GOSSE)	+	+	+
K.cochlearis var. *tecta* (LAUTER.)	+	+	+
K.quadrata (O.F.M.)	+	+	+
K.valga f. *monospina* (KLAUS.)	+	+	+
Lecane bulla (GOSSE)	+		
L.luna MÜLLER	+	+	+
L.lunaris (EHR.)	+		
Liliferotrocha subtilis RODEW.	+	+	+
Mytilina mucronata (EHR.)		+	
Notholca squamula (O.F.M.)	+	+	+
Polyarthra dolichoptera IDELS.		+	+
P.vulgaris CARLLIN	+	+	+
Pompholyx complanata GOSSE	+	+	+
Rotaria neptunia EHR.	+	+	+
R.neptunoides HARRIG	+	+	+
R.rotatoria (PALLAS)	+	+	+
Synchaeta oblonga EHR.	+	+	+
S.pectinata EHR.	+	+	+
Trichocerca dixon-nuttalli JENN.		+	
T.rattus (MÜLLER)	+	+	+
Cladocera			
Alona quadrangularis (O.F.M.)		+	
Bosmina longirostris (O.F.M.)	+	+	+
Ceriodaphnia quadrangula (O.F.M.)		+	
Chydorus sphaericus KURZ	+	+	+
Daphnia longispina O.F.M.		+	
D.magna STRAUSS		+	
Diaphanosoma brachyurum LIEVIN	+		
Moina micrura (KURZ) SRÁMEK-HUSEK	+	+	+
M.rectirostris (LEYDIG)	+	+	+
Scapholeberis kingi SARS		+	
Copepoda			
Acanthocyclops robustus SARS	+	+	+
A.vernalis FISCHER	+	+	+
Cyclops vicinus (ULJANIN)	+	+	+
Eucyclops serrulatus FISCHER	+	+	+
Mesocyclops leucarti CLAUS	+	+	+
Thermocyclops crassus (FISCHER)	+	+	+

concentration (0.99±0.85 mg/l) pointed to a periodically high pollution of the Tisza and during summer it made up 2-6% total nitrogen, whereas in winter even 30%. Nitrite content (0.24±0.27 mg/l) did not exceed 10% total nitrogen.

Phosphate amount (PO_4 - 0.38±0.21 mg/l; TP - 0.22±0.12 mg/l) was found to be significant at the section under consideration. Ratio of nitrogen to phosphorus pointed out the limiting role of phosphorus in eutrophication.

The changes in the oxygen regime (dissolved oxygen - 7.49±2.95 mg/l; oxygen saturation - 75.2±28.58%) with decrease in content of dissolved oxygen were most frequently due to the stream slow down. Relatively small concentrations and saturation (rarely over 80%) showed seasonal variations. Summer and early-autumn minimum were expressively evident. At the end of August of 1992 fish killing at the upstream section nearby Novi Knezevac as a result of oxygen deficiency was recorded. Supersaturation phenomenon is not a characteristic of the Tisza and it is recorded during short intervals, namely most frequently at the end of July and at the beginning of August as the result of phytoplankton activity.

During winter and in summer chlorophyll content was low, namely below 10 mg/m^3. At the end of May, however, at water temperature of 20 °C, an increase in its concentration was recorded. Characteristic maximum values were observed in the middle of June and at the end of July-beginning of August. At luxuriant growth of plankton algae, evident fluctuations in diurnal-nocturnal oxygen cycle were observed.

During three-year investigations the phytoplankton community remained at small species number. In spring and autumn Bacillariophyta in particular the species of the genus *Stephanodiscus, Navicula, Nitzschia, Asterionella, Melosira,* and *Synedra* predominated. In summer, however, number of green algae, in particular species of genus *Pediastrum* and *Scenedesmus* increased. Cyanobacteria and Pyrrhophyta occurred occasionally and were less abundant as well as Euglenophyta.

In relation to qualitative composition, number of zooplankton species was decreased when compared to previous results. In the Rotatoria group the species of the genus *Brachionus* and *Keratella* dominated while Ciliata in Protozoa namely the

species being the characteristic of water rich in organic matter (Table 1).

Quantitatively, water of the Tisza was evidently poor in zooplankton and therefore in 1992 only Protozoa dominated (Table 2).

Table 2 Quantitative composition of zooplankton (ind/ dm^3) of lower River Tisza (mean values)

Groups	1990				1991				1992			
	W	S	S	A	W	S	S	A	W	S	S	A
Protozoa	12	8	32	16	21	18	40	20	60	20	30	40
Rotatoria	3	17	74	20	6	40	115	15	5	23	60	15
Cladocera	2	8	3	5	5	2	3	5	3			
Copepoda	3	25	16	2	32	12	5	5	10	22		
Total	15	30	139	55	29	95	172	42	65	51	105	80

The Oligochaeta species dominated in bottom fauna of littoral zone of the river. The specific physico-chemical conditions of the river reduced species number in 1992. Qualitatively, only six species of the four genera and the family Tubificidae - *Limnodrilus hoffmeisteri, L. claparedeanus, L. udekemianus, Branchiura sowerbyi, Potamothrix hammoniensis* and *Psamoryctides barbatus* were found. The species of the genus *Limnodrilus* being a characteristic of still and eutrophic waters evidently dominated. This is in close connection with oxygen reduction and increase in nutrients.

The quantitative analysis of bottom fauna showed variations of numbers of the Oligochaeata individuals in two decades with an evident increase in 1991 when average annual number was 1,435 ind/m^2 (Djukic and Kilibarda, 1985; Djukic et al. 1993). In 1992, however, mean annual number of Oligochaeta decreased significantly and it was even six times as low as numbers in previous year (227 ind/m^2). Drastic reduction of individual and species numbers respectively of Oligochaeta was probably due to the influence of unfavorable physico-chemical and hydrobiological parameters upon sediment concurrently affecting the disturbance of the biological balance.

Investigation of fish community has been aimed to different habitats and involves species being the indicators of water quality (with the exception of *Acipenser ruthenus*). Trend of total catch at fishing sectors of the Tisza I (Hungarian - Yugoslav border - dike nearby Novi Becej) and the Tisza II (dike nearby Novi Becej - river mouth) was analyzed. The share of characteristic species inhabiting river bed (*A. ruthenus*), littoral zone (*Stizostedion lucioperca*), and flood zone (*Esox lucius*) were also studied. Particular attention was paid to the participation of *Carassius auratus* which in total catch of noncommercial species ("other fish species") had individual share over 20% while its dominance was 60-70%.

Total catch at Yugoslav section of the river stream was mostly constant in the period under consideration with values ranging from 100 to 111 t per year (Table 3).

Table 3 Fish catch analysis of lower River Tisza in kg (whole section)

Year	Total catch	*A. ruthenus*	*S. lucioperca*	*E. lucius*	Other fish
1990	100427	7811	7115	1994	83507
1991	111628	2167	3032	1967	104462
1992	108909	1828	1546	504	105031
Total	320964	11806	11692	4465	293000

When the part of individual species in total catch was analyzed, however, drastic decrease in *A. ruthenus* as well as the indicator species *S. lucioperca* (S = 1.50) and *E. lucius* (S = 1.75) was recorded. At the same time, the participation of *C. auratus* (S = 2.50) was unchanged and remained at a remarkable level tending to increase slowly.

Table 4. Fish catch analysis of Tisza I sector (in kg)

Year	Total catch	*A. ruthenus*	*S. lucioperca*	*E. lucius*	Other fish
1990	56713	3813	3863	790	48247
1991	65315	387	796	103	64029
1992	67772	739	614	178	66242
Total	189801	4939	5273	1071	178518

Additional analysis of catch by sectors showed certain differences between the fishing areas. Total catch in the Tisza I maintained similar annual values, but in the amounts of caught *A. ruthenus, S. lucioperca* and *E. lucius* (Table 4) were evidently reduced. Trend of reduction of catch of the investigated species in the Tisza II sector was somewhat less expressed in the first two years, whereas it was evident in *S. lucioperca* and *E. lucius* in 1992 (Table 5). The catch of *C. auratus* expressed by sectors analyzed, remained the same (unchanged), in particular in the downstream sector.

Table 5. Fish catch analysis of Tisza II sector (in kg)

Year	Total catch	*A. ruthenus*	*S. lucioperca*	*E. lucius*	Other fish
1990	43714	3998	3252	1204	35260
1991	46313	1780	2236	1864	40433
1992	66242	1089	932	326	38789
Total	131163	6867	6420	3394	114482

A significantly smaller catch, in particular when fishes of prey were analyzed, than that at beginning

of previous decade may be noted at the same area (Budakov et al., 1985). Trend of reduction in numbers of these fish species continued in past decade (Maletin et al., 1990) and in the period under consideration the catch of *S. lucioperca* and *E. lucius* reached the lowest values.

The ichthyological results obtained show that the water quality of lower River Tisza was getting worse during the last two decades. The finding is in agreement with the data on a slower growth rate of *Blicca bjoerkna* (Budakov and Maletin, 1981), and *S. lucioperca* when compared with that reported from other rivers or water bodies in this part of the Pannonian basin (Maletin and Budakov, 1984) as well as central part of the Tisza (Harka, 1992).

The changes reported for the hydrobiont communities under consideration are a signal for a need of more detailed investigations, in particular sediments, and for a positive action in controlling and protecting this section of the River Tisza.

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TISCIA 28, 41-45

MELIORATIVE EFFECT OF GRASS CARP (*CTENOPHARYNGODON IDELLA*) IN CONTROLLING AQUATIC MACROPHYTES IN THE TISZA VALLEY

S. Maletin, N. Djukić, S. Stojanović, A. Ivanc, M. Žderić, A. Matić, B. Andrić, Lj. Radak and B. Miljanović

*Maletin, S., Djukić, N., Stojanović, S., Ivanc, A., Žderić, M., Matić, A., Andrić, B., Radak, Lj. and Miljanović, B. (1994): Meliorative effect of grass carp (**Ctenopharyngodon idella**) in controlling aquatic macrophytes in the Tisza valley. - Tiscia 28, 41-45.*

Abstract. Effect of biomanipulation with grass carp monoculture was studied to suppress macrophytes overgrowth under controlled conditions during vegetation period of 1993. The experiment was performed in two separate basins of 0.15 ha each. A hundred specimens of 3-5 years of age and approximately 4 kg individual body weight on the average were stocked in each basin. A favourable meliorative effect coinciding with a significant increase in ichthyomass and satisfactory condition and general physiological status of fish was obtained when abundance and coverage of aquatic (*Polygonum amphibium* and *Spirodela polyrrhyza*) and semiaquatic vegetation (*Phragmites australis, Typha latifolia* and *T. angustifolia*) varied and supplementary feeding with fresh biomass of *Ceratophyllum demersum* (95%) and *Potamogeton pusillus* (5%) was regularly supplied. Also, selection in nourishment taking into consideration the presence of stands of various phytocenoses was evident.

Keywords: herbivorous fish, aquatic weeds, biomanipulation, food selection.

S. Maletin, N. Djukić, S. Stojanović, A. Ivanc, M. Žderić, Lj. Radak, B. Miljanović, University of Novi Sad, Faculty of Sciences, Institute of Biology, 21000 Novi Sad, Yugoslavia, A. Matić, Fishpond "Bečej", 21220 Becej, Yugoslavia, B. Andrić, Tempus Center, University of Novi Sad, 21000 Novi Sad, Yugoslavia

Introduction

The control of macrophyte overabundance by biomanipulation with grass carp in an extended part of its distribution area has shown great meliorative potential of this exotic herbivorous fish. In many situations, the grass carp offers a very attractive alternative weed control in comparison to mechanical removal, herbicide application or water level manipulation. Also, the control of overgrowth of aquatic vegetation by grass carp introducing is less expensive and lasts considerably longer than other methods (Rotman, 1977; van Zoon, 1979). In that way, detrimental effects of an excessive primary production on navigation, drainage, recreation, and other purposes of water bodies may be efficiently made less (Opuszynski, 1972, 1979; van Zoon, 1974, 1977). Due to a favourable stock of grass carp, beside other facts mentioned above, an outcome is also the conversion of nonutilized portion of macrophyte production into highly edible proteins (van Zoon, 1977, 1982).

Efficiency of biomanipulation by fish community in process of suppression the development of primary and partly of secondary production has been discussed recently. Mestrov et al. (1972) reviewed that not only phytophagous fish can wholly solve the problem of lake sanation, but, also mechanical elimination of sediment is necessary. In the past decade there was a great number of papers dealing with this hypothesis and positive and negative arguments on the possibilities of biomanipulation in regulation of water, namely, most frequent lake ecosystems (Carpenter et al., 1985; Zalewski et al., 1990; Brönmark and Weisner, 1992; De Melo et al., 1992; Carpenter and Kitchell,

1992). In this paper therefore the results on the efficiency of meliorative role of grass carp in controlling aquatic weeds are presented from the valley of lower part of river Tisza.

Methods

The experiment was performed in two separate basins of a 0.15 ha each to evaluate the efficiency of the meliorative effect of grass carp upon the control of number, coverage and diversity of aquatic vegetation. The stock included 100 specimens for each of average individual weight of 4 kg and of 3-5 years of age.

Phytocenological investigations of the aquatic macrophytes were performed by the method of Braun-Blanquet. Plant names were presented according to Flora Srbije (Josifovic, 1970-1986), while only certain cases after Soó (1964-1985).

Also, length and body weight growth, intensity and preference in relation to diet, as well as condition status according to the fattening coefficient.

General physiological status of fish was estimated on the basis of the hematological status. Number of erythrocytes and leukocytes were counted in haemocytometer, according to Kekic and Ivanc (1982). Hemoglobin concentration was estimated using haemoglobincyanide method, and hematocrit was determined by micromethod. From those values mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were calculated. Differential blood count was determined on blood smears stained by Pappenheim method (Heckner, 1975).

In addition to the biological investigations, also abiotic factors, such as temperature, pH and oxygen regime were measured.

Results and discussion

On June 3 at the beginning of the experiment, the experimental units A and B were overgrown with macrophyte to various extent. Dominants of the basin A were *Typha latifolia* and *Polygonum lapatifolium*, while *Phragmites australis, Typha latifolia, Typha angustifolia* and *Polygonum amphibium* of the basin B. Also, *Spirodela polyrrhyza* was observed in either unit. Total covering in the basin A was 30-40 %, and in basin B 80 %, respectively.

In such conditions, grass carp specimens of total ichthyomass of 400 kg were stocked. In June, total coverage was reduced by approximately 10 %. At the same time, varying overgrowth of macrophytes affected variation of growth rate of total fish weight (Tab. 1).

Table 1. Body weight and length growth and coefficients of fattening.

Date	m	l	Q_F	Q_C
Basin A				
3.6.	400	612	1.74	1.57
18.6.	433	617	1.84	1.66
1.7.	430	624	1.77	1.61
16.7.	486	637	1.88	1.67
3.8.	469	638	1.80	1.64
18.8.	452	657	1.59	1.29
16.9.	446	657	1.57	1.41
Basin B				
3.6.	400	611	1.75	1.59
18.6.	509	641	1.93	1.74
1.7.	550	663	1.89	1.71
16.7.	690	663	2.36	2.01
3.8.	650	682	2.05	1.73
18.8.	620	687	1.91	1.76
16.9.	581	704	1.66	1.50

m = total fish biomass (kg); l = individual standard length (mm); coefficients of fattenig: Q_F = Fulton index; Q_C = Clark index.

After first two weeks total weight of stocked fish in the basins A and B were 433 and 509 kg, respectively. Such a variation was primarily due to larger resource in the basin B. The fattening coefficient in this period was found to increase in both fish groups pointing to optimum diet in the first third of the experiment.

In the following months, after a period of adaptation, grass carp diet was even more intensive affecting total ichthyomass. After four weeks, this difference amounted to 120 kg. In both basins, a drastic reduction in overgrowth was observed, namely in July only the macrophyte *Polygonum lapatifolium* was recorded in the basin A while total coverage in basin B was 40-50 % where *Phragmites australis* and species of the genus *Typha* dominated. Therefore, in July 1, fresh plant material consisting of *Ceratophyllum demersum* (95 %) and *Potamogeton pusillus* (5 %) was added in three equal portions (total of 10 kg) per experimental unit. In the next days, offered quantity of added fresh biomass of aquatic plants became greater and varied in relation to its consumption (Tab. 2). In July, grass carp in the basin A and basin B consumed 955 and 435 kg additional biomass of plant food, respectively. Such a difference was due to different supply of original components. In that period total ichthyomass again increased up to 486 (basin A) and 690 (basin B). Also, an increase was recorded in fattening, in particular in specimens from the area B. These coefficients reached the

maximum in the middle of July, in both fish groups.

Table 2. Daily dynamics of consumption of additional fresh microphytes biomass (kg).

	July		August	
Day	A	B	A	B
1	-	-	55	30
2	-	-	55	-
3	10	10	55	35
4	-	-	55	35
5	-	-	55	-
6	-	-	55	-
7	-	-	58	30
8	-	-	55	-
9	20	-	50	20
10	25		55	-
11	-	-	55	-
12	15	15	-	30
13	20	20	55	-
14	50	-	50	20
15	-	-	60	-
16	30	30	55	15
17	40	40	45	-
18	-	-	45	30
19	30	30	45	-
20	30	30	45	-
21	30	50		
22	50	50		
23	110	30		
24	150	-		
25	110	30		
26	60	50		
27	60	-		
28	-	50		
29	60	-		
30	55	-		
Totoal	955	435	903	215

Similar situation was observed in August, namely the presence of *Polygonum lapatifolium* was recorded in basin A while addition of a portion containing *Ceratophyllum* and *Potamogeton* together with daily control continued up to 20 August. Total coverage in basin B was reduced to 35 % where species observed in July dominated. Total plant weight of macrophytes was reduced to app. 10 % in basin B until the end of experiment. The mass was composed of *Phragmites australis* and dried *Typha latifolia* and *T. angustifolia* specimens. Also in this case, greater consumption was recorded in basin A (903 kg) than in basin B (215 kg). Total amount of available food, in particular that originated from the experimental units, however, was reduced considerably resulting in ichthyomass decrease. Therefore, in the middle of August, total fish mass was 452 kg and 620 kg in basins A and B, respectively. Biomass decrease reflected also in reduced values of fattening coefficient approaching the initial status.

At the end of the experiment on 16 September when the addition of fresh mass of aquatic plants was stopped and when poverty of vegetation was evident, again decrease in total ichthyomass to 446 kg (basin A) and 581 kg (basin B) were recorded due to starvation.

In the study of meliorative effect of grass carp upon the control of excessive growth of macrophyte vegetation, particular attention has been paid to the preference to individual plant species. Permanent presence of *Polygonum* species was recorded characterized by stable numbers and coverage during entire experiment. The analysis of the intestinal content of grass carp showed certain selectivity in diet under the given conditions. Analyzed specimens were found to consume additional fresh plants (*Ceratophyllum* and *Potamogeton*) only when all the original vegetation available, primarily *Typha* species, were consumed.

General physiological condition of fish was followed on the basis of hematological status fortnightly during the entire experiment. The results obtained show that the number of erythrocytes, hemoglobin concentration, hematocrit, MCV, MCH, MCHC, leukocyte count and differential blood count of grass carp ranged within expected values (Ivanova, 1983) in both experimental areas (Tab. 3 and 4). Decreased values of erythrocyte count recorded in basin A at the end of the experiment, however, were primarily the result of meager diet in that period. Fluctuation in the number of leukocytes which resulted in high standard deviation should be explained by a normal seasonal changes noted also in other fish species (Ivanc et al., 1985).

Table 3. Erythrogram of grass carp under different nutritional conditions (mean and standard deviation).

	Basin A	Basin B
No. of individuals	17	17
RBC count	2.063E+12 2.806E+11	2.183E+12 4.413E+12
Hemoglobin concentration (g/l)	79.94 7.74	81.90 16.50
Hct. (l/l)	0.403 0.061	0.414 0.100
MCV (fl)	196.89 31.79	189.37 28.31
MCH (pg/l)	39.09 3.44	37.58 3.14
MCHC (gHb/l Erc)	202.01 26.20	200.26 12.55

The basic physico-chemical parameters ranged within expected values (e.g. water temperature 19-24 °C and pH 7.40-9.03; Tab. 5). Oxygen regime values were in most cases satisfactory except in

certain periods when deviations were recorded. For example, extremely high oxygen concentration and saturation were recorded at the beginning of the experiment while decrease in these parameters and therefore their optimum values may be in great part attributed to the meliorative role of grass carp. Only periodically, greater decrease in oxygen amount, as well as in saturation during September (basin A) and in June (basin B) were noted.

Table 4. Differential blood count of grass carp under different nutritional conditions (mean and standard deviation).

	Basin A	Basin B
No. of individuals	17	17
WBC count	2.791E+10 1.295E+10	3.103E+10 1.171E+09
IBN	0.011 0.014	0.024 0.024
Neutrophils		
Nonsegmented	0.245 0.201	0.206 0.125
Segmented	0.018 0.017	0.024 0.022
Pseudoeosinophil	0.384 0.192	0.452 0.166
Lymphocytes	0.315 0.193	0.256 0.148
Monocytes	0.027 0.034	0.038 0.044

On the basis of results obtained, the meliorative abilities of grass carp under high stock density may be evaluated very satisfactory. At optimum temperature, oxygen regime and pH values, grass carp consumed very intensively the present macrophyte while its deficit effected the consumption at additional portion of fresh plant mass showing some selectivity to certain species of aquatic vegetation. Similar results on the control of aquatic plants were reviewed by Gajdusek and Lusk (1982) in Czechoslovak waters, Riemens (1982) in Holland, Mugridge et al. (1982) in South England channels, and Gharably et al. (1982) in irrigation and drainage channels in Egypt. Promising effects of biomanipulation with fish are also emphasized by Gophen (1990) who speaks about a significant role of grass carp in nutrient transfer (mostly P) from the sediment through macrophyte. Unfavourable climatic conditions, primarily low temperature, low stock density, poor water quality during overwintering have been cited as main limiting factors (Müller, 1982).

The physico-chemical parameters have shown to be satisfactory in biomanipulation by grass carp to control macrophyte aquatic vegetation. Extremely dense stock and relatively old experimental specimens affected high consumption of present and added amounts of food and also a slower growth pointing to application of some other combination of stock in planning the directions in the control of the aquatic vegetation. Present results show undoubtedly that this biomanipulation should be introduced in the control mentioned taking into account its positive and negative aspects.

Table 5. Physico-chemical parameters of water.

Date	t (°C)	pH	O_2	Sat. (%)
Basin A				
3.6.	24	8.20	18.6	218
18.6.	21	7.50	6.1	68
1.7.	21	9.03	10.2	114
16.7.	21	7.70	9.7	108
3.8.	24	8.42	11.2	132
18.8.	24	8.42	11.5	135
16.9.	20	7.83	3.6	39
Basin B				
3.6.	24	8.10	19.2	225
18.6.	22	7.60	3.5	40
1.7.	21	8.37	9.0	100
16.7.	21	7.40	6.5	72
3.8.	24	8.16	8.6	101
18.8.	24	7.85	9.5	117
16.9.	19	8.44	7.8	83

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TISCIA 28, 47-51

COMPARATIVE INVESTIGATION BETWEEN PHYTOPLANKTON AND THE INTESTINAL CONTENTS OF CARP

Lj. Budakov, D. Branković and S. Gajin

Budakov, Lj., Branković, D. and Gajin, S. (1994): Comparative investigation between phytoplankton and the intestinal contents of carp. - Tiscia 28, 47-51.

Abstract. Algological and ichthyological examinations were performed during the period from September 1990 to May 1993 in the Old Begej (Stari Begej) nature reserve.
Main aim of this paper is to recognize the phytoplankton in the water and in the intestinal content of carp.
Age of the examined carp individuals was between 2^+ and 6^+. Average body length waried betwen 144.30 and 3887.55 mm, and body weight between 1203.50 and 1691.56 g. All available food promoted good growth of carp.
232 species, varieties and forms of algae were recorded in the samples from Old Begej, and Chlorophyta was a dominant group of algae. In the intestinal content of carps 160 taxa of algae were recorded but dominant groups were Bacillariophyta and Chlorophyta.
On the basis of saprobity index after Pantle and Buck and quantity of carp, the water of Old Begej can be ranked as β-mesosaprobic one.

Keywords: bioindicators, carp, intestinal content, phytoplankton, saprobity.

Lj. Budakov, D. Branković, Institute for Nature Protection of Serbia, Department in Novi Sad, Tvrdjava 3, 21000 Novi Sad, Yugoslavia, S. Gajin, Institute of Biology, University of Novi Sad, 21000 Novi Sad, Yugoslavia.

Introduction

During a manyfold examination of flora, vegetation and fauna of the Regional Park Old Begej (Stari Begej), performed by Institute for Nature Protection of Serbia, Department in Novi Sad, ichthyological and algological examinations played an important role. The Old Begej nature reserve is situated in low stream of the rivers Begej and Tisza. It is populated by 24 fish species (Budakov, 1989).

In the former examinations, attention was paid to the fish species of special protection demand and listed in the Red Book od Serbia, such as pike and pike-perch (Budakov, 1992) and weatherfish which is a natural rarity in the waters of Serbia (Budakov, 1993). Characteristics of growth of roach, significantly frequent in this biotop, were examined (Budakov, 1989a), as well.

Recently, our examinations have been directed towards carp, examined by a lot of local and foreign authors. Although carp is traditionally the most important fish of our waters, it is on the list of Red Book of Serbia, because its survival is endangered.

Complex examinations of growth rate and feeding of carp pointed out that the phytoplankton participated in the diet of carp only in the first years of its life (Janković, 1983).

Main aim of this paper was to recognize the phytoplankton community in the water of Old Begej, presence of algae in the intestinal content of carp, as well as presence of algae in the intestinal content of carp individuals of different age.

Material and methods

Examinations of carp were performed on the basis of samples caught during the period from September 1990 to May 1993 in the Old Begej (Stari Begej) nature reserve. Altogether 73 individuals were analysed. Age, longitudinal growth, growth of weight and growth rate were

calculated according to Ćugunova (1959).

Samples were taken from different intestinal regions of each individuals for the analysis of intestinal content, and relative abundance (percentage participation) of different phytoplankton species were measured.

Samples were taken simultaneously with carp catching for qualitative and quantitative analysis of the phytoplankton community and of saprobiological characteristics of the water of Old Begej. Standard limnological methods were used (Hribar, 1978). Saprobity index was calculated after Pantle and Buck (1955) on the basis of phytoplankton indicator species.

Results

232 species, varieties and forms of Cyanobacteria (19), Pyrrophyta (10), Xantophyta (3), Chrysophyta (4), Bacillariophyta (46), Euglenophyta (38) and Chlorophyta (112) were recorded in the samples from Old Begej. Overal density of the phytoplankton community was changeable, and varied from 18.5x103 ind/cm^3 to 53.3x103 ind/cm^3.

Relative abundance of different algal groups in the water of Old Begej is given in Fig. 1. Chlorophyta was the most abundant algal group throughout the whole examination period. Their relative abundance varied from 49.3 to 56.6 %. Relative abundance of Euglenophyta varied from 15.0 to 21.0 %, and that of Bacillariophyta varied from 9.3 to 18.8 %. Cyanobacteria and Pyrrophyta were less important members of the phytoplankton community, being present with 4.9 to 9.3 and 3.3 to 10.0 %, respectively. The representatives of Xantophyta and Chrysophyta were present constantly, but their relative abundance was low.

Table 1. Relative abundance of different groups of algae in the intestinal content of different age groups of carp.

	3+	4+	5+	6+
Cyanobacteria	5.9	5.0		
Pyrrophyta	4.4	1.2	2.9	4.9
Xantophyta	0.7	1.2	2.9	
Bacillariophyta	40.5	35.1	40.6	47.1
Euglenophyta	11.0	12.4	8.6	11.7
Chlorophyta	37.5	45.1	45.0	36.3

The phytopankton in carp feeding was examined in the total sample of carp. 68 of 73 individuals had intestinal content. 160 species, varieties and forms of Cyanobacteria (11), Pyrrophyta (6), Xantophyta (1), Chrysophyta (4),

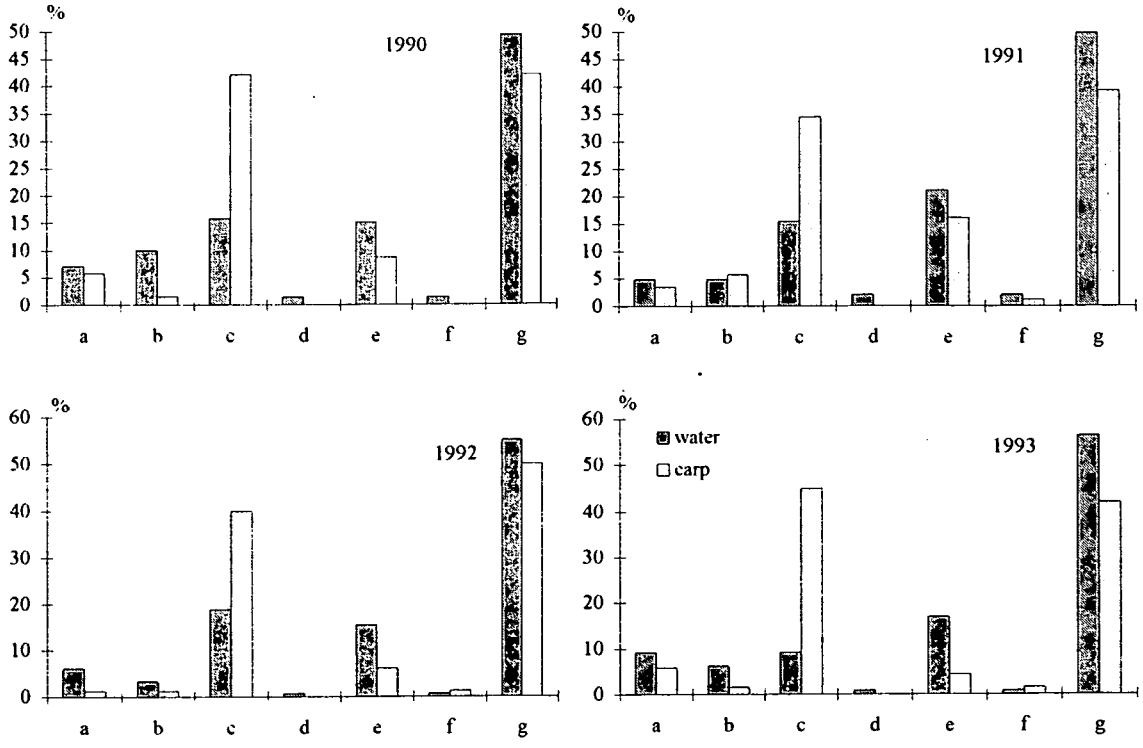

Fig. 1. Relative abundance of the phytoplankton in the water and in the intestinal content of carp

Bacillariophyta (63), Euglenophyta (18) and Chlorophyta (61) were recorded in the intestinal content. Fig. 1. shows relative abundance of different groups of algae, and Table 1. presents the distribution of relative abundance of algal groups among age groups.

Regarding relative abundance, Bacillariophyta and Chlorophyta represented dominant algal groups. Relative abundance of Cholorphyta varied from 34.5 to 44.9 %, while that of Chlorophyta ranged from 39.1 to 50.0 %.

Algae from Euglenophyta and Cyanobacteria groups are less important in carp feeding. Their relative abundance in the intestinal content of carp varied from 4.3 to 16.0 %, and from 1.3 to 5.8 %, respectively. Representatives of Xantophhyta were recorded sporadically, while those of Chrysophyta were not recorded in the intestinal content of carp.

Data related to the growth rate of carp are contribution to the knowledge of its ecology as well as a base for proposal of measures which would resulted in higher growth rate. In the examined sample, individuals of carp belonged to the age classes from 2^+ to 6^+ but individuals of ages from 3^+ to 5^+ were the dominant. Mean values of body length (without anal fin) ranged from 345.5 to 415.0 mm. According to calculated values the longitudinal growth (Fig. 2.) after the second year (114.3 mm) was duplicated, showing intensive increase in the first years of life. From the age 3^+ to the age 6^+, the longitudinal growth slightly increased (305.24 to 387.55 mm) but the weakest longitudinal growth occurred in the age groups 4^+ and 5^+.

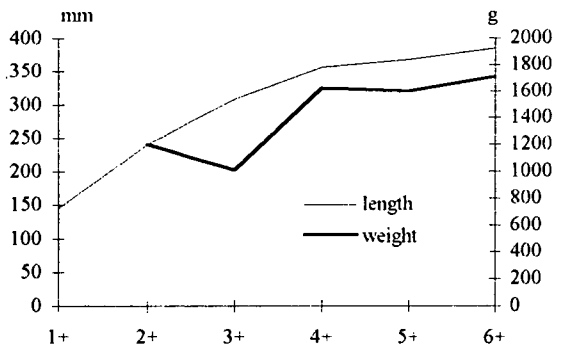

Fig. 2. Longitudinal and weight growth of *Cyprinus carpio* L. in Old Begej.

Annual longitudinal growth was wery intesive in the first year of life, then slightly decreased up to the age 5^+ (7.55 mm) but prominent increase (21.75 mm) was noticed then.

Body weight of examined carps ranged from 1203.30 to 1691.56 g. The growth of weight slightly increased regarding the age. Drastic decrease of weight growth happened after the age 2^+ (-195.95.g) but after the age 3^+ the weight growth increased (604.75 g) and had approximately similar values up to the age 6^+.

On the basis of physico-chemical parameters as well as on the basis of limnological examinations, which included the phytoplankton community and carp, saprobity of the Old Begej waters was determined. Indicator species of algae of the highest polluted waters, α-mesosaprob, β-mesosaprob and oligosaprob degree were recorded, but indicators of β-mesosaprob degree were dominant. Saprobnity index after Pantle and Buck (1955) varied from 2.1 to 2.4 pointing out to β-mesosaprob waters.

Discussion

Growth rate of the fish depends on several factors. First of all it depends on the food. Growth rate varies depending on conditions in the water biotop and differs from year to year. In eutrophic water biotops, it is generally higher because of sufficient available food. But, higher and higher pollution of the waters has negative influence on the growth rate of fish so the growth rate is not adequate to trophic level.

In the Old Begej waters, 232 species, varieties and forms of algae were recorded during the period of examinations which differs from the former ones (Brankovic, 1993), when 274 taxa of algae were recorded. Saprobity index was generally identical while density of the phytoplankton community was significantly higher compared to the former examinations. Higher density of the phytoplankton community pointed out to more intensive eutrophic processes in the water biotop.

The differences between these and former examinations could be explained by variation of climatic and other conditions in this biotop, by human influence, as well as by different number of samples and time of sampling.

Regarding some rivers in this region, the differences in qualitative composition of the phytoplankton community were noticed.

Examinations of the river Ponjavica (Obušković, 1991) showed that Euglenophyta and Chlorophyta were dominant groups of algae and were followed by Bacillariophyta and Cyanobacteria. Other groups of algae were represented with significantly lower number of taxa.

Obušković (1982) found that in the river Bosut

the representatives of Bacillariophyta were dominant and were followed by the representatives of Chlorophyta, Cyanobacteria and Euglenophyta. Other groups of algae were presented with significantly lower number of taxa.

It can be pointed out, that qualitative composition of the phytoplankton community of this aquatic biotop was almost similar to that in the Lake Ludaš (Seleši, 1981; Branković and Budakov, 1993) which is a protected area, as well. Namely, in the Lake Ludaš Chlorophyta were also a dominant group of algae, with the highest number of taxa. Bacillariophyta ranked the second place and were followed by Euglenophyta, Cyanobacteria and Pyrrophyta. Xanthophyta and Chrysophyta were present with only one taxa, respectively.

There were very significant differences between total number of taxa and number of taxa of different groups of algae in the water of Old Begej and in the intestinal content of carp. Relative abundance of Bacillariophyta was always higher in the intestinal contents while those of Chlorophyta and Euglenophyta were higher in the water (Fig. 1).

Some species, e.g. Chrysophyta were recorded sporadically in the waters but they were not found in the intestinal content of carp.

Relative abundance of Cyanobacteria, Pyrrophyta and Xantophyta were similar in the water and in the intestinal content.

There were significant differences between relative abundance of Chlorophyta, Euglenophyta and Bacillariophyta in the waters and in the intestinal content. The differences can be explained with characteristics of carp feeding and of different groups of algae. Because most of the species from the division Bacillariophyta are epiphytes, carp took in higher number of these algae with the detritus. These algae have characteristic silicate shells that made possible their determination for longer period. From the division Chlorophyta, the most abundant species were in the intestinal content of carp from the genus *Scenedesmus* what can be explained with their abundance in the water with their cell wall characteristics: the cell wall of these species contains sporopollenin which is enzyme-resistant.

Recently, examinations of growth rate and feeding of fish were very actual in the protected areas, e.g. Lake Palič and Lake Ludaš, the Old Begej and the Obedska bara swamp (Pujin and Budakov, 1979; Budakov, 1980, 1989, 1992; Maletin and Budakov, 1983; Budakov and Lecic, 1992).

From Old Begej, attention was paid to the growth rate and feeding of pike and pike-perch which species are listed in the Red Data Book of Serbia (Budakov, 1992) as well as to some allochtonous species (Maletin, 1988).

Literature data on feeding of Cyprinidae species are rather limited from this region. Complex examinations of growth rate and feeding of carp were carried out on the samples from the River Danube (Ristić, 1971), from the Lake Skadar (Drecun and Ristić, 1972) and on carp from several fishponds in Vojvodina (Pujin, 1967).

Carp inhabits slow-running and still waters and in certain period of year can be found on flooded areas. Carp is benthophagous (Drecun and Ristić, 1972) but Nikitina (1981) classified it as polyphagous species.

In the first years of its life, carp eats the phytoplankton, zooplankton and benthos but in older ages it usually consumes larger organisms of benthos such as larvae of Chironomida, Oligochaeta and others as well as ripe fruits. Older carps turn to predation and catch young individuals of other fish species.

Results of our examinations pointed out that algae are important in wide range of carp feeding. At all ages of carp, up to age class 6^{+}, different groups of algae were recorded dissimilar from literature data. Kostomarov (1961) stated that carp was selective in feeding, it showed an age dependent selection though there vere several species in the natural food source. We can not accept this statement on selectivity, because we recorded approximately the same proportions of different algal groups in all investigated age classes.

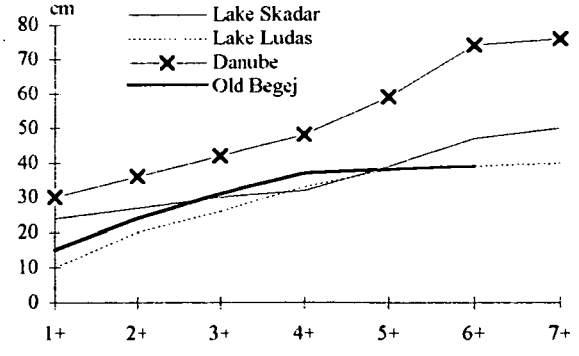

Fig. 3. Longitudinal growth of *Cyprinus carpio* L. in some aquatic habitats.

The growth rate of carp is good under optimal circumstances. The order of studied aquatic habitats on the basis of growth rate of carp is the following: Lake Ludaš < Stari Begej < River Danube < Lake Skadar. It was higher in Old Begej only compared

to Lake Ludaš (Pujin and Budakov, 1979). Lake Ludaš was characterized by intesive development of phytoplankton and by large variation in oxygene regime. A similar phenomenon was noticed in fishponds when, in the period of high temperature and intensive growth of phytoplankton, oxygen content of the water varied causing weaker growth of carp even though the food supply was not limiting (Pujin, 1967).

Oxygen content in Old Begej was very low in the first year of our examination. From May to October 1991 its values ranged from 6.46 to 11.22 mg/dm^3.

High density of phytoplankton community, favourable temperature regim and improvment of oxygen regime did not cause higher growth rate because of probable competition for food with other fish species.

In the protected area of Old Begej there are a lot of allochtonous species beside autochtonous ones, e.g. *Carassius auratus gibelio, Hypophthalmichthys molitrix* and *Aristichthys nobilis*. These allochthonous species adapted easily to the feeding conditions in the extended area, and because they are aggressive compete out autochthonous species (*Carassius carassius, Tinca tinca, Abramis brama, Rutilus rutilus, Cyprinus carpio*).

Aim of this study is the implementation of protection of autochthonous and all endangered species. These investigations are also important for protection of ichthyogenetic fund in our waters.

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TISCIA 28, 53-56

ECOPHYSIOLOGICAL INTERPRETATION OF HEMATOLOGY OF DIFFERENT PERCIDAE SPECIES IN THE RIVER TISZA

A. Ivanc, S. Maletin, N. Djukić and B. Miljanović

Ivanc, A., Maletin, S., Djukić, N. and Miljanović B. (1994): Ecophysiological interpretation of hematology of different Percidae species in the river Tisza. - Tiscia 28, 53-56.

Abstract. Hematological analyses of pikeperch (*Stizostedion lucioperca*) and perch (*Perca fluviatilis*) originated from the River Tisza nearby Novi Becej were performed.
The fish were caught by electrofishing, recovered during 24 hours, and finally heart puncturing was undertaken for blood collection. Number of erythrocytes, erythroblast percentage, haematocrit, hemoglobin concentration, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), number of leukocytes, and differential blood count were determined. Different values for hematological parameters were obtained, in particular hemoglobin concentration, MCHC, and differential blood count. The differences noticed were discussed from the aspect of idioecological specificity of these two Percidae species.

Keywords: erythrocytes, erythroblast, haematocrit, hemoglobin, MCV, MCH, MCHC, leukocytes.

A. Ivanc, S. Maletin, N. Djukić, B. Miljanović, University of Novi Sad, Faculty of Sciences, Institute of Biology, 21000 Novi Sad, Yugoslavia

Introduction

Having fair knowledge of the hematological status of certain fish species is equally useful from the point of view of their physiology and ecology. Hematological state of an organism is defined by the interaction of hereditary and ecological factors. The former determines basic structural and functional features of a species formed during its speciation and adaptation to a given environment. The latter manifests its effects by an immediate influence upon an organism occupying certain habitat. As a response, an organism activates its physiological regulatory mechanisms and/or adaptational mechanisms such as acclimation and acclimatization (Slonim, 1971; Ivanc et al., 1985). Distinction between hereditary and ecological determinants in actual values of certain physiological parameters is essential for a more comprehensive understanding of both physiology and ecology of a species. It could be hardly carry out, however, due to a complex interaction of factors and the fact that actual response on the organismic level is influenced by the state of its internal environment and the faze of its life cycle, such as age, reproductive activity etc. (Speckner et al., 1989). Data on a comparative hematology of freshwater fish are not rare but most frequently such investigations were not carried out in the way enabling the differentiation between hematological adaptation typical of a species and physiological acclimation and/or acclimatization (Hart, 1962).

This paper deals with the hematology of two species of the family Percidae (pikeperch and perch) living in the same habitat under the same basic environmental conditions. To eliminate the environmental influence upon the results of hematological investigations of these two fish species they were analyzed on the same day and therefore the obtained values may be considered as characteristic for species.

Methods

Hematology of two species (*Stizostedion lucioperca* and *Perca fluviatilis*) from the River Tisza was studied. Individuals of both species were caught from the same locality nearby Novi Becej. They were caught by electrofishing and then let to recover for 24 hours in net cages kept in the river.

Blood samples were taken by cardiac puncture, without using anticoagulant. Erythrocyte and leukocyte numbers were counted in Neubaur-chamber following Kekic and Ivanc (1982). Hemoglobin concentration was estimated photometrically by means of hemoglobincyanide method (Blaxhall and Daysley, 1973). Hematocrit was determined by centrifuging blood in heparinized capillary glass tubes at 15000 rpm for 5 minutes. Mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were determined by calculations based on erythrocyte number, hemoglobin concentration and haematocrit. Differential leukocyte count and erythroblast count were made on blood smears stained according to Pappenheim and Graham-Knoll (Romeis, 1968; Heckner, 1975). Significance of differences in mean values of hematological parameters between the two species were established by Student's "t"-test.

Results and discussion

Number of erythrocytes, hemoglobin concentration, haematocrit, MCV, MCH, MCHC, and number of polychromatic and acidophilic erythroblasts are given in Tab. 1. and leukocyte number and proportions of different white blood cells are given in Tab. 2.

Perch had significantly higher values of hemoglobin concentration, MCH and MCHC than pikeperch, while the values of erythrocyte number, haematocrit and MCV were almost identical in these two species. The leukocyte number had similar values in both perch and pikeperch but individual variation of this parameter was higher in perch, as it is evident from broad range and high standard deviation. As to differential leukocyte counts, perch and pikeperch differed significantly. In the blood of pikeperch immature (myelocyte and metamyelocyte) neutrophils and mature pseudo-eosinophilic granulocytes were present while they were not found in the blood of perch. Perch had higher proportions of nonsegmented and segmented neutrophils and lower proportion of lymphocytes.

The differences in hemoglobin concentration, MCH and MCHC of pikeperch and perch found in this study can hardly be attributed to environmental influences because fish of both species inhabited the

Table 1. Comparative hematology of *Stizostedion lucioperca* and *Perca fluviatilis* - Erythrogram (mean, SD, range, significance of differences between means).

Species	No. of ind.		Body weight g	Total body length cm	RBC count x 10^{12}/l	Hemoglobin concentration g/l	Hct. l/l	MCV fl	MCH pg/l	MCHC gHb/l erc	Number of erythroblasts per1000 erythrocytes	
											polych	acidophil.
Stizostedion lucioperca	7	mean	612.3	31.9	1.735	54.09	0.431	250.50	31.51	126.07	21.1	14.6
		SD	435.2	10.4	0.217	3.78	0.041	25.12	3.36	10.17	14.7	5.4
		Range	128.0	26.5	1.513	49.60	0.379	212.27	25.89	113.36	5.0	5.0
			1258.0	52.0	2.200	60.21	0.488	283.72	35.25	147.70	54.0	25.0
Perca fluviatilis	7	mean	73.1	16.9	1.625	82.68	0.435	269.01	51.12	190.68	20.3	16.7
		SD	58.8	3.7	0.105	6.58	0.043	34.75	5.57	8.77	10.2	6.6
		Range	26.0	13.0	1.467	76.48	0.389	228.83	42.89	174.01	4.0	4.0
			212.0	25.0	1.783	94.38	0.487	317.91	59.92	203.44	34.0	24.0
p					>0.200	<0.001	>0.400	>0.200	<0.001	<0.001	<0.001	>0.400

Table 2. Comparative hematology of *Stizostedion lucioperca* and *Perca fluviatilis* - Leucogram (mean, SD, range, significance of differences between means).

Species	No. of ind.		Leukocytes x 10^9/l	Myelocytes	Metamyelocytes	Neutrophils Nonseg	Seg.	Pseudo-eosinophils	Lymphocytes	Monocytes
Stizostedion lucioperca	7	mean	20.140	0.013	0.019	0.444		0.004	0.429	0.090
		SD	5.276	0.016	0.023	0.124		0.007	0.161	0.065
		Range	13.000	0.000	0.000	0.240		0.000	0.240	0.020
			27.000	0.040	0.060	0.580		0.020	0.660	0.190
Perca fluviatilis	7	mean	25.000			0.813	0.007		0.177	0.004
		SD	10.001			0.063	0.014		0.072	0.007
		Range	9.000			0.690	0.000		0.050	0.000
			43.000			0.910	0.040		0.310	0.020
p			>0.200	>0.050	>0.050	<0.001	>0.200	>0.100	<0.001	<0.010

same microhabitat. Handling of fish, technical and analytical methods were identical and were performed at the same period of day, so that effects of that kind were also similar.

Therefore, the differences observed are due to certain other factors, possibly to perch speciation within which this species was adapted also to waters with lower oxygen concentration (Muus and Dahlström, 1978), at least in certain periods of a year. Within this process, in perch blood a transport system providing satisfactory oxygen supply of tissues, even when its concentration in the environment is low, was developed. This may account for its being widespread in almost all inland waters (Müller, 1987). The fact that in the same microhabitat and at the same physico-chemical features of water perch has evidently different hematological parameters than pikeperch, shows that here indeed operate the physiological adaptation and hereditary characteristics of the species. Similar differences in hematological parameters were reported by Halsband et al. (1981) in two species of the family Cyprinidae (*Carassius auratus* and *Cyprinus carpio*) of which the former better endures unfavourable conditions of environment. Hematological characteristics of such type were also found in other fish species and usually they were explained by differences in habitat quality and activity level. Therefore, in active species considerably higher values of erythrocyte parameter were reported. This phenomenon is explained by a higher metabolic rate, and greater tissue requirements for more efficient oxygen supply. Thus, Romestand et al. (1983) in their study of hematology of a number of sea and freshwater fish observed that the number of erythrocytes is higher in sea fish while they have smaller volume (MCV) and smaller amount of hemoglobin (MCH). The authors stated that an adaptive character was established since at the same total volume (hematocrit) a great number of small erythrocytes is characterized by a greater total surface than a small number of large erythrocytes. This improves gas exchange and breathing in sea water in which oxygen dissolubility is lover. Rambhaskar and Srinivasa Rao (1987) found that more active species of tropical sea fish were characterized by a greater erythrocyte number, higher hemoglobin concentration, and higher MCH and MCHC values, and smaller volume of erythrocytes (MCV) than less active fish species from the same water. They concluded that in fish both the increase of hemoglobin concentration and the decrease in erythrocyte volume appear as adaptive characters but that ratio of these two adaptation aspects differed from one another.

Differences in proportions of leukocytes between pikeperch and perch obtained in our study may be probably attributed to adaptation of these fish species to different ecological niches. In other words, in waters inhabited by perch greater amount of organic matter and facultative pathogenic microorganisms are present. They were showed to be the reason of an increase in proportion of phagocytic leukocytes in other fish species (Alvarez-Pellitero and Pinto, 1987; Siwicki and Studnicka, 1987; Hine and Wain, 1988; Ivanc et al., 1993).

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TISCIA 28, 57-62

A CONTRIBUTION TO THE STUDY OF THE CAUSE AND DISTRIBUTION OF MINAMATA DISEASE IN THE LOWER COURSE OF THE RIVER TISZA (YU)

D. Karabasil and D. Bukurov

Karabasil, D. and Bukurov, D. (1994): A contribution to the study of the cause and distribution of Minamata disease in the lower course of the River Tisza (YU). -Tiscia 28, 57-62.

Abstract. The research was started after a mysterious disease had been observed with a ten-year-old girl in Novi Sad, Yugoslavia. It was manifested by convulsions lasting for several hours. These crises of consciousness repeated cyclically in irregular intervals of approx. 90 days. Diagnosis of the disease was Sindroma-Lenox-Gastaut.
Test on toxic metals shoved enormously increased mercury contents in the little patient's urine. Our further investigations brought us to the irrigation/drainage canal DTD (Danube-Tisza-Danube) a pond called Beljanska Bara and the river basin of the river Tisza. Fish from Beljanska Bara had a considerable quantity of accumulated mercury.
The child was poisoned postnatally in the phase of lactation through her mother, who had used the fish mentioned above regularly in her meals.
The goal of the paper is to prove that Sinrdoma Lenox-Gastaut is in fact postnatal poisoning with methyl-mercury in the phase of lactation.

Keywords: Phenyl-mercuric acetate, methylation, methyl-mercury, lactation, methyl-mercury poisoning, Sindroma Lenox Gastaut, DMPS.

D. Karabasil, Institute for Protection in Technology, Advanced Technical School, 21000 Novi Sad, Yugoslavia, D. Bukurov, Institute for Health Protection, Faculty of Medicine, 21000 Novi Sad, Yugoslavia

Introduction

Poisoning with mercury was known even in the Roman Empire. They believed that the verdict by which a slave was sentenced to a forced labour in mercury mines was in fact a death penalty. Mercury poisoning in the second half of the 20th century was very frequent spreading rapidly among many people like epidemic. One of the biggest and certainly the most notorious epidemic of this kind was observed in Japan, near Minamata Bay. The inhabitants of the bay were struck by a mysterious and serious disease. 121 persons were infected, and in the period from 1953 to 1966, 46 of them died. On the basis of investigations performed it was found out that they were infected with contaminated fish from the bay which was used as their food.

Contamination of fish with mercury reached to 50 mg/kg with some kinds, depending on the way of nutrition, size and other factors.

Mercury went to the bay through a polyvinyl factory Chisso Minamata which released this metal in its waste water. By the process of methylation in fish, mercury was transformed into its most toxic form: methyl-mercury.

The number of victims of this factory was later increased by more than approx. 100 persons who died after 1966, while more than 700 inhabitants of Minamata Bay suffered terrible physical and psychical deformations. The disease was named after this epidemic "minamata-disease".

Preliminary investigations

The investigations started with the case of ten-year-old girl who had first crises of consciousness when she was at the age of three.

The crises started with spasms of fingers usually of the left hand. The spasms were usually followed and replaced by tremor of fingers which

was spread over the arm, from the arm it was expanded into the left side of the body, and finally came over the whole body. These crises of consciousness lasted for several hours before Valium i.v. was given after hospitalization. The crises occurred in irregular intervals of 3, 6 or 12 months, respectively. After comprehensive medical investigations, the final diagnosis was Sindroma Lenox-Gastaut. In the meantime the girl fell into a coma and came out of it after more than 60 days.

That mysterious disease was not observed and medical records were not found either with the girl's parents or ancestors. At the end of 1989, the research was focused on toxicology examinations. The child became the patient of Dr. med. habil. Max Daunderer toxicologist from Munich and she received the following treatment: For secreting of possible heavy metals from the body of the girl Dimaval was used produced by chemical-pharmaceutical factory Hely from Berlin. Active matter is 2,3-dimercapto-1-sodiumpropane sulphonate: (DMPS). This antidote had been synthesized by scientists and they achieved very good results with it in detoxification after poisoning with chloride of mercury. Here it was used mainly for detoxification of cumulated mercury (mostly organic).

Results of toxicological research

Analyses were based on urine samples and urinalysis. Urine I had been taken before antidote was inserted into the organism of the little patient. Urine II was always taken 60 minutes after inserting of antidote, while Urine III was taken 120 minutes after inserting of antidote into the organism.

Samples for the first analysis were taken on 12 February, 1990. The results of this analysis are presented in Table I.

Table 1. Results of urine analysis on 12 February, 1990 before Dimaval treatment.

	Urine I	
	Obtained values	Normal values
Creatinine i.U	2,57 g/dm^3	
Mercury i.U.	15.4 µg/dm^3 6.0 µg/g creat	< 4
Zinc i.U.	958 µg/dm^3 373 µg/g creat	140 - 720 > 140

As it can be seen from Table 1 high values of excreted mercury point to the possible chronical poisoning with this metal.

Urine II and Urine III were taken 60 and 120 minutes, respectively, after inserting of 600 mg of Dimaval perorally.

From Table 2 it is obvious that in Urine III mercury was excreted in the quantity of 417.2 µg/g creat. As chronical poisoning appears already when more than 50 µg of mercury per g creatinine is excreted, it can be concluded that here in this case it is a very serious intoxication.

Table 2. Results of urine analysis on 12 February, 1990 after Dimaval treatment.

	Urine II 60 min. later		Urine III 120 min. later	
Element	Obtained values	Normal values	Obtained values	Normal values
Creatinine i.U.	1.59 g/dm^3	1.00-2.50		
Arsenic i.U.	3 µg/dm^3 2 µg/g creat.			
Lead i.U.	43 µg/dm^3 27 µg/g creat.			
Cadmium i.U.	1.2 µg/dm^3 2.0 µg/g creat.			
Copper i.U.	773 µg/dm^3 486 µg/g creat.	<500	1262 µg/dm^3 789 µg/g creat.	<500
Mercury i.U.	247.5 µg/dm^3 155.7 µg/g creat.	<50	667.5 µg/dm^3 417.2 µg/g creat.	<50

The next analysis of urine was performed on 26. February, 1990. Dimaval was given on 600 mg i.v. The obtained results are presented in Table 3:

Table 3. Results of urine analysis on 26 February, 1990 after Dimaval treatment.

	Urine II 60 min. later	
Element	Obtained values	Normal values
Creatinine i.U.	0.55 g/dm^3	1.00-2.50
Arsenic i.U.	6 µg/dm^3 11 µg/g creat.	
Lead i.U.	46 µg/dm^3 84 µg/g creat.	
Cadmium i.U.	0.3 µg/dm^3 0.5 µg/g creat.	
Copper i.U.	440 µg/dm^3 800 µg/g creat.	<500
Mercury i.U.	100.3 µg/dm^3 182.4 µg/g creat.	

From the above data it can be seen that mercury values excreted in urine were decreased to 182.4 µg/g creatinine. Between the two analyses the patient took one capsule of Dimaval (200 mg) every third day.

Table 4 presents the results obtained after 200 mg Dimaval was taken perorally on 5. March, 1990. Urine was taken 60 minutes after DMPS capsule had been taken.

In Table 5 analysis of urine performed on 2.

April, 1990. after taking Dimaval (200 mg) perorally is given. Urine was taken 60 minutes after taking Dimaval.

Table 4. Results of urine analysis on 5 March, 1990 after Dimaval treatment.

	Urine II 60 min. later	
Element	Obtained values	Normal values
Creatinine i.U.	1.16 g/dm^3	1.00-2.50
Arsenic i.U.	12 μg/dm^3 10 μg/g creat.	
Lead i.U.	39 μg/dm^3 34 μg/g creat.	
Cadmium i.U.	0.6 μg/dm^3 0.5 μg/g creat.	
Copper i.U.	658 μg/dm^3 567 μg/g creat. after DMPS	<500
Mercury i.U.	104.6 μg/dm^3 90.2 μg/g creat.	

Excretion of mercury was decreased, but it was still above the level of chronical poisoning, which is 16 μg/g creatinine, when 3 mg/kg of Dimaval is taken perorally.

Table 5. Results of urine analysis on 2 April, 1990 after Dimaval treatment.

	Urine II	
Element	Obtained values	Normal values
Creatinine i.U.	0.86 g/dm^3	1.00-2.50
Copper i.U.	236 μg/dm^3 274 μg/g creat. after DMPS	<500
Mercury i.U.	21.1 μg/dm^3 24.5 μg/g creat. after DMPS i.v. orally 10 mg/kg 3 mg/kg	<50 <50 <16

120 days after the beginning of the therapy, the urinalysis was performed on 16. July 1990, under the same conditions as the previous one (200 mg Dimaval perorally, urine taken 60 minutes later). At that time the patient took 200 mg of Dimaval weekly. The results of urinalysis to heavy metals are given in Table 6.

Excretion of mercury in urine at the level of chronical poisoning was found on 1. October, 1990. Urine sample was taken 60 min. after taking 200 mg of Dimaval that was a little more than 3 mg/kg of the weight of the patient. The obtained results are presented in Table 6.

The next analysis to heavy metals was performed on 28 January, 1991. Urine sample was taken 60 minutes after taking 200 mg of Dimaval. The results are given in Table 7.

From this Table it is obvious that total excreted mercury is 0.9 μg/g creatinine. It means that detoxification is finished. From the Table 7 it can also be seen that a greater part of excreted mercury is organic (0.7 μg/g creatinine).

Table 6. Results of urine analysis on 16 July, 1990 after Dimaval treatment.

	Urine II		
Element	16 July, 1990	01 Oct., 1990	Normal values
Creatinine i.U.	0.61 g/dm^3	2.14 g/dm^3	1.00-2.50
Lead i.U.	86 μg/dm^3 141 μg/g creat. after DMPS	230 μg/dm^3 107 μg/g creat.	<150
Cadmium i.U.	0.2 μg/dm^3 0.3 μg/g creat. after DMPS	1.1 μg/dm^3 0.5 μg/g creat.	<5
Copper i.U.	705 μg/dm^3 1156 μg/g creat. after DMPS	4200 μg/dm^3 1963 μg/g creat.	<500
Mercury i.U.	11.0 μg/dm^3 18.0 μg/g creat. after DMPS 3 mg/kg	34.3 μg/dm^3 16.0 μg/g creat.	<16
Selenium i.U.	8.3 μg/dm^3 13.6 μg/g creat.		
Tin i.U.	2.0 μg/dm^3 3.3 μg/g creat.		

Table 7. Results of urine analysis on 28 January, 1991 after Dimaval treatment.

	Urine II	
Element	Obtained values	Normal values
Creatinine i.U.	1.47 g/dm^3	1.00-2.50
Copper i.U.	460 μg/dm^3 307 μg/g creat. after DMPS	<500
Mercury i.U.	1.3 μg/dm^3 0.9 μg/g creat. after DMPS i.v. orally 10 mg/kg 3 mg/kg	<50 <50 <16
Organic Mercury i.U.	1. 0 μg/dm^3 0.7 μg/g creat.	

The last toxicological analysis was performed on 1 August, 1991, under the same conditions as the previous ones. The results obtained are presented in Table 8.

Table 8. Toxicological analysis performed on 1 August, 1991.

	Urine II	
Element	Obtained values	Normal values
Creatinine i.U.	0.61 g/dm^3	1.00-2.50
Lead i.U.	53 μg/dm^3 87 μg/g creat. after DMPS	<150
Copper i.U.	1230 μg/dm^3 2016 μg/g creat. after DMPS	<500
Mercury i.U.	3.5 μg/dm^3 5.7 μg/g creat. after DMPS i.v. orally 10 mg/kg 3 mg/kg	<50 <50 <16

It is obvious from the above data, that this little patient suffered from serious poisoning with mercury. As the whole case started to resemble the poisoning in Minamata, Niigato, Alomogord, which

were caused by poisoned fish or some other meat, our analysis was focused on the food the child was nourished for. Our investigations were focused mainly on fish.

In the course of our research, the patient's mother recalled that in the period of lactation, she used to eat a lot of fish.

Toxicological analysis on heavy metals was performed with mother on 12 March, 1990. Dimaval as antidote was given i.v. 600 mg. Analysis of Urine I before taking Dimaval is presented in Table 9.

Table 9. Toxicological analysis of mother's urine on 12 March, 1990, before Dimaval treatment.

	Urine I	
Element	Obtained values	Normal values
Creatinine i.U.	0.43 g/dm^3	1.00-2.50
Zinc i.U.	131 μg/dm^3 305 μg/g creat. after DMPS	150-720 >140

60 minutes after taking Dimaval, the sample of Urine II was taken. The results obtained are given in Table 10.

From Table 10 it is obvious that mercury content in urine of this patient is 397.2 μg/g creatinine, what is approximately the same to the content of mercury found with the child examined (Table 2).

Table 10. Toxicological analysis of mother's urine on 12 March, 1990, after Dimaval treatment.

	Urine II	
Element	Obtained values	Normal values
Creatinine i.U.	0.71 g/dm^3	1.00-2.50
Copper i.U.	1372 μg/dm^3 1932 μg/g creat. after DMPS	<500
Mercury i.U.	282.0 μg/dm^3 397.2 μg/g creat. after DMPS i.v.	<50

It was most likely that fish was the possible source of mercury.

Investigations on the source of mercury

Our analysis started with the very beginning - we examined all details from the child's birth - (the end of June, 1980). In the patient's family fish was regularly in meals (even 4 times a week). The patient's mother especially ate fish in the phase of lactation of the baby, at the end of August, in September, October, November and December. In 1980 the mother ate fish from a pond called Beljanska Bara, situated near the village Turija in the central part of Backa (in Vojvodina). By leafing through a list of the factories in this part of Backa, and analyzing which of them used mercury in their plants, we came by the factory "Agrobacka" from Backa Topola where fungicides on the basis of organic mercury are used for seed processing mainly phenyl-mercuric acetate in "Zorosan" and "Radosan". After moist treating of seed water solutions of phenyl-mercuric acetate flew through waste-water industrial sewage system into the little river Krivaja - which empties into the irrigation/drainage canal DTD near Turija. Beljanska Bara gets water from the canal 500 meters farther. This canal flows into the river Tisza near Becej.

Sampling

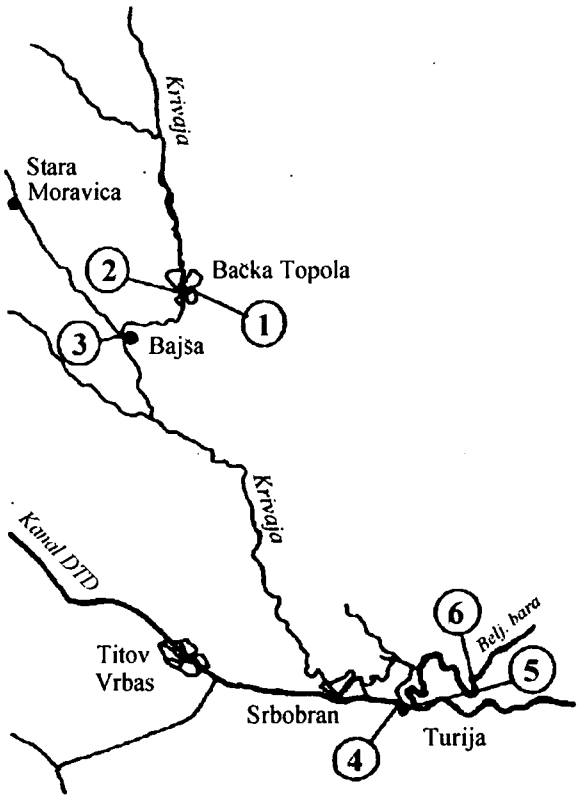

Fig. 1. Sampling places. 1, 2, 3, 4 and 5 - places where water and silt samples were taken, 6 - the place where fish samples were taken.

Samples of river silt were taken from the Krivaja river and sewage system of Backa Topola as shown in Fig. 1. These specimens were taken at the beginning of March, 1990, when all activities regarding treating seed with fungicides were finished a long time ago. The first sample was taken from industrial sewage system of the factory producing seed material; the second at the mouth of

the Krivaja - where the sewage system flows into it, the third one at Bajsa (at the place where branches of the river Krivaja from Backa Topola and Stara Moravica join); the fourth sample was taken at the mouth of the Krivaja into DTD canal, branch Bezdan-Vrbas-Becej; and the last (the fifth) one was taken from Beljanska Bara - (from its mouth) - (Fig 1).

Samples of fish were taken at the beginning of January, 1990 from Beljanska Bara. At the time when the samples were taken, bigger fish individuals unfortunately could not be caught, although they would be much better and more representative for our research. Fish samples were taken from the most distant point of Beljanska Bara in relation to the irrigation/drainage canal DTD-as the source of pollution (from which water is obtained) - Fig. 1. Also these samples were taken when all activities regarding treating seed with fungicides were finished a long time ago.

Results

The results obtained regarding analysis of silt to the total mercury are presented in Table 11. A considerable amount of mercury was found in the last 3 samples of silt, sand with a little share of organic matter prevailed, what was probably one of the reasons for decreased quantity of mercury in these samples.

Table 11. Results of silt examination on total mercury.

Sampling place	Mercury content [mg/kg]
Sewage system of the factory producing seed material	0.56
Place where sewage system empties into the Krivaja, at Backa Topola	0.31
Place where branches of the River Krivaja from Backa Topola and Stara Moravica join - near Bajsa	0.08
At the mouth of the Krivaja into DTD canal	<0.001
At the mouth of Beljanska Bara	<0.001

The results of fish examination are presented in Table 12. As it can be seen from the Table only predatory fish *Perca fluviatilis* L. is at the level of maximum allowed concentration of 0.5 mg/kg mercury. As mercury in fish is mainly in a methyl form of 70 - 90 %, methyl-mercury content is approx. 0.4 mg/kg, what is also at the level of maximum concentration allowed. Results of examining fish to total mercury are given in Table 12.

Lack in mercury with *Abramis sapa* Pallas can explained by the way of its nutrition because it usually takes place in the upper and surface layers of water.

Table 12. Mercury content of fish species.

Fish species	weight [g]	Mercury content [mg/kg]
Perca fluviatilis L.	240	0.44
Carassius carassius L.	62	0.19
Carassius auratus gibelio Bloch	265	0.13
Abramis sapa Pallas	71	<0.001

However, in order to come to valid and exact conclusions of the degree of mercury contamination of this region of central Backa, it is necessary to perform investigations on a greater number of fish samples (according to different kinds of size, age, and number).

Unfortunately, because of the war in Yugoslavia and the sanctions of the international community this research has been stopped. The goal of this paper is to arouse interest of some researchers outside Yugoslavia whose countries are not burdened with the international sanctions to continue this research.

Conclusion

On the basis of the obtained results and data mentioned above, the following conclusions may be drawn:

1. The paper has proved that the little patient and her mother are the victims of mercury poisoning.
2. At the same time, it is obvious that fish with mercury content of 0.5 mg/kg must not be used for nutrition in the phase of lactation, although it is allowed in the majority of European countries.
3. Sindroma Gastaut-Lenox is in fact postnatal poisoning with methyl-mercury in the phase of lactation.

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TISCIA 28, 63-65

DIVORD 1.60. DIVERSITY ORDERING: FINITE AND INFINITE SAMPLES

B. Tóthmérész

Tóthmérész, B. (1994): DivOrd 1.60. Diversity Ordering: Finite and Infinite Samples. - Tiscia 28, 63-65.

Abstract. Changes in the 1.60 release of DivOrd program are discussed. The main improvement is that it is possible now, to choose between the finite and infinite sample versions of rarefaction diversities. The arrangement of the menu system also has changed a little.

Keywords: diversity index families, diversity ordering, rarefaction diversity

B. Tóthmérész, Ecological Institute, Kossuth L. University, H-4010 Debrecen, POBox 71, Hungary

Introduction

Different diversity indices may rank inconsistently a given pair of communities (Hurlbert, 1971). This is related to the different sensitivities of diversity indices. A solution is to use parametric families of diversity indices instead of a numerical-valued diversity index. An important property of the family of diversity indices is their variable sensitivity to rare and abundant species. This means that communities can be compared for different "dominance levels" as a scale parameter changes. The family may be portrayed graphically by plotting diversities D_α against the scale parameter α; this curve is the diversity profile of the community (Patil and Taillie,1979, 1982). In fact, α serves as a scale parameter; members of the D_α family have varying sensitivities to the rare and abundant species as α changes.

Using diversity profiles the diversity ordering of communities is defined in the following way: Community A is more diverse than community B when the diversity profile of A is above or equal to the diversity profile of B on the whole range of the scale parameter. Curves of two diversity profiles may intersect. This means that one of the communities is more diverse for the rare species while the other on is more diverse for the dominants.

A program, DivOrd 1.50, was presented to calculate and display the diversity profiles of communities (Tóthmérész, 1993b). Eight methods are included in the package. Mathematical background of the methods was also discussed. In this paper the new release of the program is discussed.

Rarefaction Diversity: Finite and Infinite Samples

Generally, a community may be characterized by an abundance vector

$$n=(n_1,n_2,\ldots,n_i,\ldots,n_s)$$

where n_i is the abundance of the i-th species of the community. Frequently enough to know the relative abundances of species; thus the community may be characterized by the

$$p=(p_1,p_2,\ldots,p_i,\ldots,p_s)$$

relative abundance vector, where p_i is the relative abundance of the species i.

The rarefaction diversity or species-individual curve for a spatially completely random, infinitely large community is defined by

$$S(m)=S-\sum_{i=1}^{s}(1-p_i)^m$$

Smith and Grassle (1977) presented the minimum variance unbiased estimation of S(m) as:

$$\hat{S}(m)=S-\sum_{i=1}^{S}\binom{N-n_i}{m}\Big/\binom{N}{m}$$

where

$$\binom{N}{m}=\frac{N!}{(N-m)!\,m!}$$

This is, however, not simple to calculate because of the factorials. It is vital to use a good numerical approximation of the factorial function to ensure the correct result for very small and very large figures as well. The direct calculation is nonsense, especially when the data set is based on percentage covers of the vegetation, which is a continuous variable. I applied a fast and especially robust and reliable procedure which is based on the calculation of logarithm of the gamma function (Macleod, 1989).

Changes in the arrangement of the menu

The main menu has changed a little (Fig. 1). There is a new option called "Data Management" which includes the "Data Input" which was in the main menu in the 1.50 release. The "Other Samples to Compare" and "Result to Disk in HG Format" options also moved here from the main menu (Fig. 2).

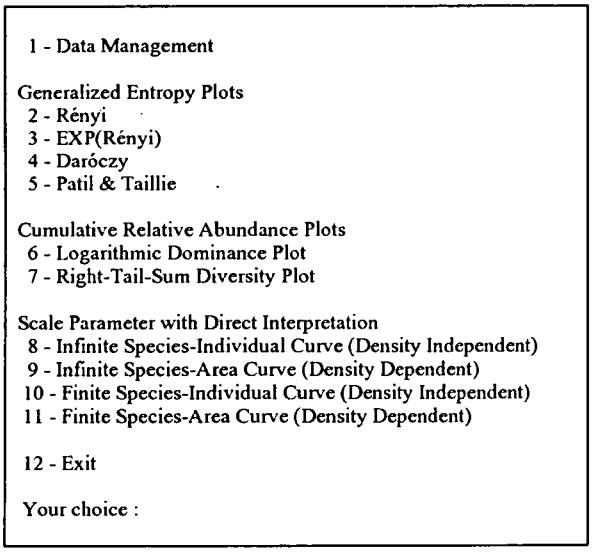

Fig. 1. Main menu of the DivOrd 1.60.

I also changed the naming convention of the diversity orderings. The EXP(D(α)) version of the D(α) Rényi diversity index family is simply mentioned as EXP(Rényi). Sometimes this is more favourable than the Rényi index family itself, because it produces the number of species of the community when the value of the scale parameter is zero; and it is easier, or just more straightforward, to interpret the number of species than the logarithm of it. As a diversity profile this was proposed first by Patil and Taillie (1979); they derived it in a unified framework alongside many other diversity index families. Hill (1973) also mentioned Rényi's original paper and used it after a proposal of Orlóci (Orlóci, 1991, p. 5, footnote 12), but he did not recognized at all that it may be useful for diversity ordering. Indeed at that time, even the idea of diversity ordering was not invented and published.

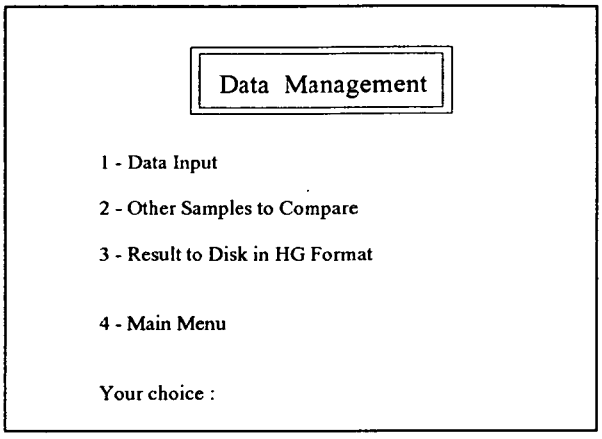

Fig. 2. Data management of the DivOrd 1.60.

And finally there are four new options in relation with the rarefaction diversity orderings. In the 1.60 release this group of methods of ordering is mentioned as "Scale Parameter with Direct Interpretation" indicating that in this case the scale parameter has a definite physical meaning which is related to the size of the sample in which the species were found. The new options are the following:

8 - Infinite Species-Individual Curve (Density Independent)

9 - Infinite Species-Area Curve (Density Dependent)

10 - Finite Species-Individual Curve (Density Independent)

11 - Finite Species-Area Curve (Density Dependent)

The density dependence and independence is represented in the same way as it was in the 1.50 release (Tóthmérész, 1993b) and the finite and infinite versions were discussed in the previous section.

The input of the samples' identity number also has changed a little (Fig. 3); it provides more information. Besides the total number of samples the file name and the label of the data set are also displayed on the screen.

```
File Name : demo-2.dat

Label    : Demo data for NuCoSA; DEMO-2.DAT.

There are 20 sample units.

How many curves do you want to draw (less than or equal to 4) ?
3

Please type the identity number of the sample sites:
 1.: 3
 2.: 12
 3.: 18
```

Fig. 3. The screen of identity number input of the compared sample sites.

Datafiles distributed with DivOrd

There are some changes in the demo files distributed with the program. All the previously distributed demo files can be found, just their name has changed and there are some new ones. This was motivated by a standardization; now, all the demo files are identical with the files of the NuCoSA package (Tóthmérész, 1993a).

There are 5 files distributed with the package. DEMO-1.DAT file contains a data set of 10 by 18 size. DEMO-2.DAT contains a data set of 20 by 56 size. DEMO-3.DAT is a data set of 10 by 20 size; this data set is a truncated version of the DEMO-4.DAT data set, which was registered at the "Rejtek Project" Research Area (Tóthmérész, 1989). It describes the changes of the vegetation along a transect and the vegetation is extremely low in diversity in the first half of the plot while it is more diverse in the second half. DEMO-5.DAT file is one of the data sets presented in the paper of the 1.50 release (Tóthmérész, 1993b).

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TISCIA 28, 67-72

LINEAR ALGORITHM TO CALCULATE INDIRECT SPATIAL STATISTICS FOR COMPLETELY RANDOM MULTI-SPECIES COMMUNITIES

Zs. Erdei, B. Tóthmérész and A. Erdei

Erdei, Zs., Tóthmérész, B. and Erdei, A. (1994): Linear algorithm to calculate indirect spatial statistics for completely random multi-species communities. - Tiscia 28, 67-72.

Abstract. We present a linear algorithm to calculate the diversity of species combinations (or "species list - number of plots" diversity) for completely random communities in an indirect spatial series analysis. It serves as a null model to compare completely random multispecies patterns to real ones which are observed on the field. An efficient algorithm to derive explicitly all the possible species combinations and their frequencies is also proposed. Turbo Pascal algorithms to IBM-compatible PC's and results about the running time of the algorithms are also presented.

Keywords: spatial statistics, indirect spatial series analysis, null model.

Zs. Erdei, B. Tóthmérész, Ecological Institute, Kossuth L. University, Debrecen, POBox 71, H-4010 Hungary; A. Erdei, Student of Computing Science, Eötvös L. University, Budapest

Introduction

A spatial point pattern is a set of locations within a region of interest, which have been generated by some unknown mechanisms (Diggle, 1983). Communities of sedentary organisms, like plants, typically can be viewed as multispecies point patterns. Sometimes the "multidimensional point pattern" terminology is used which is rather confusing. Nowadays the multi-type point pattern terminology also tends to be more popular. In mathematics and biomathematics the period of the last 20 years was the golden age of pattern analysis of one- and two-species patterns (Greig-Smith, 1983; Kershaw, 1964). However, hardly any attention was paid to multispecies point patterns.

Juhász-Nagy developed a brand new way of analyzing multispecies point patterns from the 60-s onward (Juhász-Nagy, 1963, 1967, 1976; Juhász-Nagy and Podani, 1983; Podani et al., 1993). He was especially interested in the partial and multiple association of species in a community. The methods developed by him needs large sample size and a lot of computations (Bartha, 1990; Szollát and Bartha, 1991).

Analyzing one-species spatial point patterns the hypothesis of complete spatial randomness (CSR) has crucial importance. This asserts that (i) the number of individuals in any finite region follows a Poisson distribution and (ii) given n individuals x_i (i=1,..,n) in a region, the x_i's are independent random sample from a uniform distribution on a region. CSR acts as a dividing hypothesis between patterns which are classifiable as regular or aggregated.

Using a multi-species CSR hypothesis we can derive the spatial characteristics of a random multi-species community and we can use this one just as in the case of the one-dimensional pattern; i.e. we can compare the characteristics of a random community to the actual one studied on the field.

In this paper we propose an effective algorithm to calculate the multi-species random characteristics, especially the "species list - number of plots" diversity. We also studied the computing time for an algorithm which explicitly calculate all the possible species lists and we proved that without an efficient algorithm it is very easy to waste inordinate computing time even for very small communities. Throughout he paper we use synonymously the terms "species lists", "floristic

composition" or "species combinations".

General description of the algorithm

The abundance vector of a community is denoted by $n=(n_1,n_2,...,n_i,...,n_S)$, where n_i is the abundance of the i-th species of the community. $N=\sum n_i$ is the total number of individuals. When the CSR hypothesis is valid then the distribution of individuals in the sampling plots can be described by a Poisson distribution. Thus the probability that we find zero individual of the i-th species in a plot is

$$p(n_i = 0) = q_i = \exp(-\lambda_i), \quad \lambda_i = n_i \frac{t}{A} \qquad (1)$$

where t is the plot size and A is the total studied area. This was recognized very early by the botanists (Stevens, 1935). Clearly,

$$p_i = 1 - q_i$$

is the probability that we find at least one individual of the species i in a randomly chosen sample plot of size A.

For a multi-species community the probability of the floristic composition vectors can be calculated as a multiplication of the probability of presence and/or absence of the species:

$$\prod_v = p_1 p_2 \cdots p_{i-1} p_i (1-p_{i+1})(1-p_{i+2})\cdots(1-p_s) \qquad (2)$$

where the species 1,...,i are present and species i+1,...,S are absent in the plot. There are 2^S possible species list vectors and evidently

$$\sum_{v \in 2^s} \prod_v = 1$$

The "species list - number of plots" diversity, $H(2^S)$, for a community of S species is defined as

$$H(2^s) = \sum_{v \in 2^s} \left(\prod_v \log \prod_v\right) \qquad (3)$$

where the summation is taken from 1 to 2^S (Czárán 1992).

It is evident that a direct calculation of (3) is very time-consuming because the computing time is increased by 2^S as S increases. We prove, however, that there is a linear algorithm to calculate (3). For a community having species S+1, the "species list - number of plots" diversity can be calculated in the following way when the diversity H(S) of a community having S species is known:

$$H(2^{s+1}) = H(2^s) + p_{s+1} \log p_{s+1} + (1-p_{s+1}) \log(1-p_{s+1})$$

$$= -\sum_{i=1}^{s} \{p_i \log p_i + (1-p_i)\log(1-p_i)\} \qquad (4)$$

Evidently

$$H(2^1) = p_1 \log p_1 + (1-p_1)\log(1-p_1) \qquad (5)$$

Proof of (4) is in the appendix. The computing time of our algorithm to calculate (3) increases linearly with S.

Algorithm implementations

Two functions are presented. CSR_Lin_Div and CSR_Diversity. The source code is written in Borland's Turbo Pascal 7.0.

function CSR_Lin_Div calculates and returns the Shannon diversity of the species combinations for CSR pattern without the calculation of the species combinations and it has a linear growth of running time as S increases. All the indirect spatial statistics can be calculated using this procedure which are related to the "species list - number of plots" diversity; e.g., florula evenness, distinctiveness, etc. It is defined as data_type which is an extended variable in the presented subroutine. We propose to use extended variables because the rare species combinations have very small contribution to the overall "species list - number of plots" diversity.

function CSR_Diversity presents all the species combinations and their relative frequencies, thus the computing time grows with 2^S as S increases. This procedure may be useful when the species combinations are directly utilized; e.g. in the case of global space series analysis (Tóthmérész, 1994b).

Both functions return the "species list - number of plots" diversity in logarithm of 2; it can be modified easily in the source code. The program can be run in most 286, 386, and 486 IBM compatible PCs with or without built-in mathematical coprocessor. Although input data information provided through a keyboard in an interactive fashion is nice, it is more convenient and efficient to read all input information from a file. In the driver to the procedures we did not present any special data input-output procedures.

Major scalars and vectors

The major scalars and vectors are summarized next.

message = A label to remember what data set is used during the calculations.

Species = Total number of species of the studied community.

plot_size = Area of the sample plots in standard units.

total_size = Area of the whole study area in standard units.

n = The abundance vector of the studied

community; i.e. n[i] is the number of individuals of the i-th species.

function CSR_Lin_Div:

lambda = Parameter of the Poisson distribution; average number of the species in the plots which size is plot_size.

Rel_Fr = A matrix with two rows. In the first row (Rel_Fr[i,0]) are the relative frequencies of the plots where the species i is missing and in the second one (Rel_Fr[i,1]) are the relative frequencies of the plots where the species i is present.

function CSR_Diversity:

SC_Frequency = Relative frequency of the species lists or species combinations.

ListStr = The species combinations are in this string variable in a "0/1" form, where "0" means that the species where missing from the plot while "1" means that the species where present.

Case demonstration

3-species community
plot size = 0.2000000000

relative frequency	Species Combination
6.69044737400155E-0008	000
5.87218293072251E-0004	100
3.27824225584282E-0006	010
2.87730209078975E-0002	110
2.21158009230573E-0006	001
1.94109633362172E-0002	101
1.08364880634898E-0004	011
9.51114875855356E-0001	111

Diversity of Species Combinations :
H1 = 0.3342899617
H2 = 0.3342899617

4-species community
plot size = 0.2000000000

relative frequency	Species Combination
3.98324036839300E-0007	0000
3.27931257830673E-0003	1000
5.60018268143305E-0006	0100
4.61050496820707E-0002	1100
2.12988347416320E-0006	0010
1.75348535894881E-0002	1010
2.99448073486243E-0005	0110
2.46528891835199E-0001	1110
8.72303062951313E-0007	0001
7.18147573802028E-0003	1001
1.22640264063998E-0005	0101
1.00966982495757E-0001	1101
4.66430269431993E-0006	0011
3.84001593674454E-0002	1011
6.55771300596408E-0005	0111
5.39881823753949E-0001	1111

Diversity of Species Combinations :
H1 = 1.8796904272
H2 = 1.8796904272

Fig. 1. Example runs for the 3-species and 4-species communities; plot size is 0.2 unit.

The run of the program is demonstrated on a small data set to make it possible to recalculate the result by tedious work using a pocket calculator. Actually, the three species community is identical with three dominant species of the shrub community of the NE-slope of the "Rejtek Project" Research Area while the four species community is from the plateau area (Tóthmérész, 1994a). The aim of the case demonstration is to illustrate the performance and output of the program, and not to thoroughly solve a biological problem. We tried to keep the format of the output as simple as possible. The

3-species community
plot size = 0.1000000000

relative frequency	Species Combination
2.58658991222063E-0004	000
2.39753088544691E-0002	100
1.57031523756926E-0003	010
1.45553775810097E-0001	110
1.25080600209370E-0003	001
1.15938209128305E-0001	101
7.59362632263790E-0003	011
7.03859299653606E-0001	111

Diversity of Species Combinations :
H1 = 1.3339804687
H2 = 1.3339804687

4-species community
plot size = 0.1000000000

relative frequency	Species Combination
6.31129176032372E-0004	0000
5.66376310894350E-0002	1000
1.81805573292660E-0003	0100
1.63152606173046E-0001	1100
9.58904632099549E-0004	0010
8.60522518452213E-0002	1010
2.76225871013929E-0003	0110
2.47885529206502E-0001	1110
4.96091787129072E-0004	0001
4.45193546629410E-0002	1001
1.42906167532580E-0003	0101
1.28244218529046E-0001	1101
7.53735892254506E-0004	0011
6.76403770029278E-0002	1011
2.17124150184361E-0003	0111
1.94847552383130E-0001	1111

Diversity of Species Combinations :
H1 = 2.8694726582
H2 = 2.8694726582

Fig. 2. Example runs for the 3-species and 4-species communities; plot size is 0.1 unit.

output is arranged into two blocks or columns. The first block contains the relative frequency of the species combinations. The second one contains the species list of the plots. "0" means that the species were absent and "1" means that the species were present. Thus "0000" means that the plot was empty; i.e. there were no one species present in the

sample plot. "1000" means that the first species was present and the others were absent. "0100" means that the second species was present while the others were absent, etc.

The output is presented in the Fig. 1 for the plot size of 0.2. In the case of three-species community the relative frequency of the "full" plots, where all the species are present is 0.9511. In the case of four-species community it is 0.5399. The diversity of species combinations is especially low for that plot size in the case of three-species community.

For the plot size of 0.1 the output is presented in the Fig. 2. The diversity of species combinations is much higher this case, although the plots where all the species of the community were present are still dominant.

Source Code of the Algorithms

```
{$N+,E+}
Program Linear_Algorithm;
Const Ln2=0.69314718056;
  MaxSpeciesN = 256; {max num of species }

Type
  StringL   = String[159];
  data_type  = extended;
  IntRowVector = array[1..MaxSpeciesN] of integer;

var
  message          : StringL;
  species          : integer;
  H1, H2, plot_size, total_size: data_type;
  n                : IntRowVector;
{------------------------------------------------------------ }
function CSR_Lin_Div(
    plot_size, total_size : data_type;
    Species : integer;
    var n : intRowVector) : data_type;

var i      : integer;
    lambda, sum_piLOGpi : data_type;
    Rel_Fr   : array[1..MaxSpeciesN,'0'..'1'] of extended;

begin
{ Calculation of the relative frequency of the plots where species
'i' where absent
(Rel_Fr[i,'0']) and present (Rel_Fr[i,'1']) }
  for i:=1 to species do begin
   lambda:=n[i]*(plot_size/total_size);
   Rel_Fr[i,'0']:=exp(-lambda);
   Rel_Fr[i,'1']:=1.0-Rel_Fr[i,'0'];
  end;
{--- End of calculation of relative frequencies                  }
{ Calculation of the "Species Combination - Number of Plots"     }
{ diversity by the linear algorithm.                             }
  sum_piLOGpi:=0.0;
  for i:=1 to species do begin
  sum_pilogpi:=sum_pilogpi
    +Rel_Fr[i,'0']*ln(Rel_Fr[i,'0'])/ln2
    +Rel_Fr[i,'1']*ln(Rel_Fr[i,'1'])/ln2;
  end;
  CSR_Lin_Div:=-sum_piLOGpi;
end;
{------------------------------------------------------------}

function CSR_Diversity(plot_size,
      total_size : data_type;
      Species : integer;
      var n : intRowVector) : data_type;

var
  ListStr          : String;
  i, i_flt         : integer;
  lambda, SC_Frequency,
  sum_piLOGpi      : data_type;
  Rel_Fr  : array[1..MaxSpeciesN,'0'..'1'] of extended;

begin
{ Calculation of the relative frequency of the plots where }
{ species 'i' where absent (Rel_Fr[i,'0']) and             }
{ present (Rel_Fr[i,'1'])                                  }
  for i:=1 to species do begin
    lambda:=n[i]*(plot_size/total_size);
    Rel_Fr[i,'0']:=exp(-lambda);
    Rel_Fr[i,'1']:=1.0-Rel_Fr[i,'0'];
  end;
{  ------ End of calculation of relative frequencies. --------- }
{ Generation of all the species combinations and their         }
{ relative frequencies.The species combinations are in         }
{ the "ListaStr" string in a "0/1" form, where "0" means that  }
{ the species where missing from the plot while "1" means      }
{ that the species where present.                              }
{ The relative frequency of a species combination is           }
{ in the "SC_Frequency" variable.                              }
  sum_piLOGpi:=0.0;
  ListStr:='';
  for i:=1 to species do
    ListStr:=ListStr+'0';
  i_flt:=0;
  repeat
    SC_Frequency:=1.0;
    for i:=1 to species do
      SC_Frequency:=SC_Frequency
        *Rel_Fr[i,ListStr[i]];
   sum_piLOGpi:=sum_piLOGpi
  +SC_Frequency*LN(SC_Frequency);
{-------------------------------------------------------------------}
{ Print a species combination and its relative frequency.          }
    writeLn(SC_Frequency,'  ',ListStr);
{-------------------------------------------------------------------}
    inc(i_flt);
    inc(ListStr[1]); { increment the first binary digit }
    i:=1;
    while (ListStr[i]='2') AND (i<species) do begin
      dec(ListStr[i],2); { set up '0' because of overflow }
      inc(i);          { increment the next binary digit }
      inc(ListStr[i]);
    end;
    until (ListStr[species]='2'); { all species combinations are
counted }
  CSR_Diversity:=-sum_piLOGpi/ln2;
end;
{------------------------------------------------------------ }
procedure DataInput;
begin
{Number of individuals of the dominant shrubs on the NE-slope:}
 message:='3-species community'; species:=3;
 n[1]:=1135; n[2]:= 489; n[3]:= 441;
{Number of individuals of the dominant shrubs on the plateau:}
{
 message:='4-species community'; species:=4;
 n[1]:=1127; n[2]:= 339;
 n[3]:= 231; n[4]:= 145;
}
```

```
 plot_size := 0.2;
{ plot_size := 0.1; }
 total_size := 25;

end;

BEGIN
  DataInput;
  writeLn; writeLn;
  writeLn(message);
  writeLn('    plot size = ', plot_size :20:10);
  writeLn('relative frequency    Species Combination');
  writeLn('----------------------------------');

  H1:=CSR_Lin_Div(plot_size, total_size, Species, n);
  H2:=CSR_Diversity(Plot_Size, total_size, Species, n);

  writeLn;
  writeLn('Diversity of Species Combinations :');
  writeLn('    H1 = ', H1 :20:10);
  writeLn('    H2 = ', H2 :20:10);
  readLn;
END.
```

Conclusions

The algorithms presented in the paper are appropriate for determining the diversity of species combinations in the case of completely spatially random multispecies communities. The function CSR_Lin_Div may be used when the species combinations themselves are irrelevant. This is a very fast linear algorithm. The function CSR_Diversity may be used to identify all the species combinations. This algorithm is, however, very time-consuming because the run-time grows exponentially as the number of species of the community grows. The code presented here is a Turbo Pascal implementation of the procedures.

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We are indebted to Dr. Tamás Czárán who focused our attention on the calculation of the "theoretical" value of "species list - number of plots" diversity (i.e. the value for an infinitely large community). The research was supported by the Hungarian Research Fund (OTKA) F 006082 to the first author and T 5066 to the second author.

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Appendix

For a 1-species community the "species list - number of plots" diversity is defined as

$$H(2^1) = p_1 \log p_1 + (1-p_1)\log(1-p_1)$$

Evidently, for a 2-species community it can be calculated

$$H(2^2) = H(2^1) + p_2 \log p_2 + (1-p_2)\log(1-p_2)$$

because

$$H(2^2) = p_1 \log p_1 + p_2 \log p_2 + (1-p_1)\log(1-p_1) + (1-p_2)\log(1-p_2)$$

Now we prove for a (S+1)-species community that the "species list - number of plots" diversity can be calculated as it was indicated by (4); i.e. we prove that

$$H(2^{s+1}) = H(2^s) + p_{s+1} \log p_{s+1} + (1-p_{s+1})\log(1-p_{s+1})$$

We know from (3) that

$$H(2^s) = \sum_{v=1}^{2^s} (\prod_v \log \prod_v)$$

To get $H(2^{S+1})$ we have to multiply all the Π_V's (we have 2^S of them) by both p_{S+1} and $(1-p_{S+1})$; i.e.

$$H(2^{s+1}) = \sum_{v=1}^{2^s} (\prod_v p_{s+1} \log(\prod_v p_{s+1}) + (\prod_v (1-p_{s+1}) \log(\prod_v (1-p_{s+1})))$$

Using the basic identities of logarithm we get

$$= \sum_{v=1}^{2^s} (\prod_v p_{s+1} \log \prod_v + \prod_v p_{s+1} \log p_{s+1} + \prod_v (1-p_{s+1}) \log \prod_v + \prod_v (1-p_{s+1}) \log(1-p_{s+1}))$$

$$= \sum_{v=1}^{2^s} (\prod_v p_{s+1} \log \prod_v + \prod_v p_{s+1} \log p_{s+1} + \prod_v \log \prod_v - \prod_v p_{s+1}) \log \prod_v + \prod_v (1-p_{s+1}) \log(1-p_{s+1}))$$

Rearranging the expression we get

$$= \sum_{v=1}^{2^s} (\prod_v \log \prod_v) + \sum_{v=1}^{2^s} (\prod_v p_{s+1} \log p_{s+1} + \prod_v (1-p_{s+1}) \log(1-p_{s+1}))$$

$$= H(2^s) + p_{s+1} \log p_{s+1} \sum_{v=1}^{2^s} \prod_v + (1-p_{s+1}) \log(1-p_{s+1}) \sum_{v=1}^{2^s} \prod_v$$

Because

$$\sum_{v=1}^{2^s} \prod_v = 1$$

thus

$$= H(2^s) + p_{s+1} \log p_{s+1} + (1-p_{s+1}) \log(1-p_{s+1})$$

and we have proved the proposition.

Table 1. Example run-times of the calculation of the diversity of species combination by direct calculation of all the species combinations

Number of species	IBM PC/XT	AT/20 MHz	386DX/33 MHz + 80387	486DX2/66 MHz
10	42 minutes	4 minutes	10 seconds	1.6 second
20	6 weeks + 2 days	4 days + 8 hours	3 hours + 41 minutes	2 minutes
30	183.5 years	18 years	30 weeks + 1 day	1 day + 22 hours
40	278'432 years	27'269 years	789 years	7 years + 16 weeks
50	422'000'000 years	41'300'000 years	1'100'000 years	10'073 years

Book review

FOISSNER, W., BERGER, H. AND KOHMAN, F. (1992): TAXONOMISCHE UND ÖKOLOGISCHE REVISION DER CILIATEN DES SAPROBIENSYSTEMS II: PERITRICHA, HETEROTRICHA, ODONTOSTOMATA. - INFORMATIONSBERICHTE DES BAYERS. LANDESAMTES FÜR WASSERWIRTSCHAFT 5/92, PP. 502.

Manuals on biological water qualification usually have rich lists of Ciliata species, so in Bavaria, in the series "Wasserwirschaftverwaltung" made for water conservancy practice already the second volume on these protozoan organisms, which in majority are water quality indicators has been out. Similarly to the first volume, Foissner and his fellow researchers revised great taxonomic units, a subclass (Peritricha) and two orders (Heterotrichida and Odontostomatida) in conformity with recent requirements. The extent of this volume of 95 species is of 502 pages, and also this volume is based on formerly published papers, completed with the presentation of establishment and results of some other hydrobiologists - ecologists who are working on protozoa. Dendrograms which help identifications, introduce clearly the relationships, photos of living specimens, drawings of different authors, the lightmicroscopical and scanning-electronmicroscopical exposures of preparations made by up-to-date methods give extremely comprehensive knowledge of species. Introduction of species is so varied, that occasionally a scientist may become suspicious, whether it is the same species in every case, or not and may become unsure, whether it is possible to come to know Ciliata, at all? In case I should not admire the work and should not respect the authors, I would say: less would be more.

Unfortunately, I have my doubts about, whether a specialist of water conservancy (not a protozoologist) has enough time to give himself up entirely to identify a species. (Not rarely when such a book with relatively few species comes out, the "occurrence" of these species increases abruptly.)

Though in the fore-part there is an arrangement titled Konversionsfaktoren, Produktivität, Nomenklatur, but I think it would have been more fortunate to put it to the end of the evaluation. In my opinion this is the least successful part of all. I can recommend this book of wonderful get-up to all those who deal with protozoology, though it is rather difficult to handle it, because of its weight and extent. I had my book rebound into two volumes, so it is easier to handle and is worth the money.

The book is in German, its price is 80 DM.
Subscription: Bayerisches Landesamt für Wasserwirtschaft, Lazarettstr. 67, 8000 München 19.

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