STUDIES ON THE ENVIRONMENTAL STATE OF THE SZIGETKÖZ AFTER THE DIVERSION OF THE DANUBE

edited by

ISTVÁN LÁNG
ILONA BANCZEROWSKI
ÁRPÁD BERCZIK

MTA Szigetköz Bizottság, Budapest • 1997

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CONTENTS

PREFACE

The construction of the Bős–Nagymaros barrage system at Bős (Gabčikovo) has seriously affected the so-called Little Hungarian Plain in Northwestern Hungary, and within this, particularly the Szigetköz region. In its Resolution 69/1992 (XI. 6) OGY, the Hungarian Parliament commissioned the Government to work out a conception for the rehabilitation and development of the Szigetköz, with especial view to problems related to environmental protection, landscape preservation and regional development. In pursuance of this commission, the Government, under its Resolution 3016/1993, invited the President of the Hungarian Academy of Sciences (a) to co-ordinate the related ecological research; (b) to synthesise the results of ecological research conducted so far, and to formulate ecological requirements for the region with the involvement of the regional bodies concerned.

The findings of environmental monitoring, along with the conclusions drawn from them, will be used in support of the Hungarian position to be taken during the proceedings at The Hague International Court of Justice.

The constructions at Bős (Gabčikovo) involved water management interventions that have brought about significant changes on the Hungarian side, particularly in the Szigetköz region which had formerly been interwoven by a whole system of river branches. These interventions included the so-called variant C of the barrage system construction and the diversion of the Danube, both arbitrarily carried out by the Slovak party, as well as the building of the temporary river-bed sills to make up for at least part of the ensuing catastrophic water loss.

There are two reasons justifying the yearly survey and discussion of the results and observations of the research supported by the Ministry for Environment and Regional Policy and co-ordinated by the Hungarian Academy of Sciences. The first is the fact that since the diversion of the river the natural course of water has been different each year and the continual hydraulic-engineering and water-management interventions have impeded the development of more balanced processes. The other circumstance calling for an annual survey and assessment of research results is the obligation of a continuous exchange of data under the Hungarian–Slovak monitoring agreement.

The present volume contains the papers, reporting on the 1994 results, presented at the conference organised jointly by the Ministry for Environment and Regional Policy and the Hungarian Academy of Sciences on 21 February 1995.

István Láng

Member of the Hungarian Academy of Sciences
Chairman of the Academy's Szigetköz Committee

GEOLOGICAL AND HYDROGEOLOGICAL ASSESSMENT OF NATURE CONSERVATION AREAS

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From as early as the mid-1960s, within the framework of the geological mapping of lowland areas, the Geological Institute of Hungary has been collecting data describing the *state of the environment*. It has been completed by a study of the relationship between the effects of human activities and the geological setting of the given region. The complex geological map series compiled on the basis of the collected data and thorough multidisciplinary analysis of samples facilitates to answer questions – within the limits of the given scale – related to the geological properties of superficial formations, their vulnerability to pollution and their features concerning the biological environment.

The 1:100,000-scale investigation of the Szigetköz started in 1982 associated with the complex geological mapping of the Little Hungarian Plain (Kisalföld). Geological base maps were compiled in 1:25,000-scale, integrated to 1:100,000- and 1:200,000-scale sheets for publishing. Printing of the related Mosonmagyaróvár and Győr-North atlases took place in 1991. Between 1982 and 1987, 364, at most 10-m-deep shallow boreholes were penetrated in the related area in a network with spacing of 1000–1500 m. This network was completed by some 24, at most 50-m-deep boreholes and one medium-deep (400 m) drilling. A group of 50-m-deep boreholes has been converted to groundwater observation wells, thus establishing the basis of the groundwater monitoring network of the Geological Institute in the Szigetköz. The medium-deep borehole Halászi A-1 has also been equipped for the observation of ground and deep subsurface waters.

The printed atlases include the following thematic groups:

- geological maps,
- hydrogeological maps,
- geomorphological map,
- engineering-geological maps,
- agrogeological maps,
- environmental-geological map,
- geophysical maps.

In the frame of a contract awarded in 1991 by the Ministry for Environment and Regional Policy we have proceeded to collect geological information on nature conservation areas in the related region and processed it with the aid of a computer. The regional, spatial (GIS) database of the Szigetköz was set up by 1994 as a consistent part of the complex geological database of the Little Hungarian Plain (Figure 1). As a result, base data of the afore-mentioned map variants and their digital versions became available for environmental protection experts in a uniform format. In co-operation with the Austrian and Slovak Geological Institutes, the Geological Institute of Hungary launched an international project (the so-called DANREG Programme) aiming at the integration of geological, hydrogeological and environmental-geological knowledge accumulated along their common border as well as organising and representing them in a uniform system. This project is to be completed by 1996, resulting in a GIS database closely associated with the *Environmental-geological Information System of the Little Hungarian Plain* (Figure 2).

Progressive growth of geological knowledge in detail from the area (between 1992 and 1994 superficial formations were already represented to 1:25,000 scale) enabled us to make a geological assessment of the protected areas. Some 45 sites have been evaluated according to the following criteria:

- topographic positioning,
- assessment of land use and land resources management on the basis of infrared aerial images,
- geomorphological setting of the micro-region,
- description of the geological environment including profiles,
- position and quality of groundwater,
- type of the soil profile,
- engineering-geological features,
- assessment of the geological setting in terms of nature conservation.

Thus our database can be regarded as a fundamental document reflecting the state of the environment just before the fatal day of the Danube's diversion in October 1992. It can serve as a reference for studying the effects of the "C" variant for designing the geological rehabilitation programme. An eventual new study of this site and an interpretation of the changes could provide indispensable information for making a prediction concerning the biological changes of the habitat.

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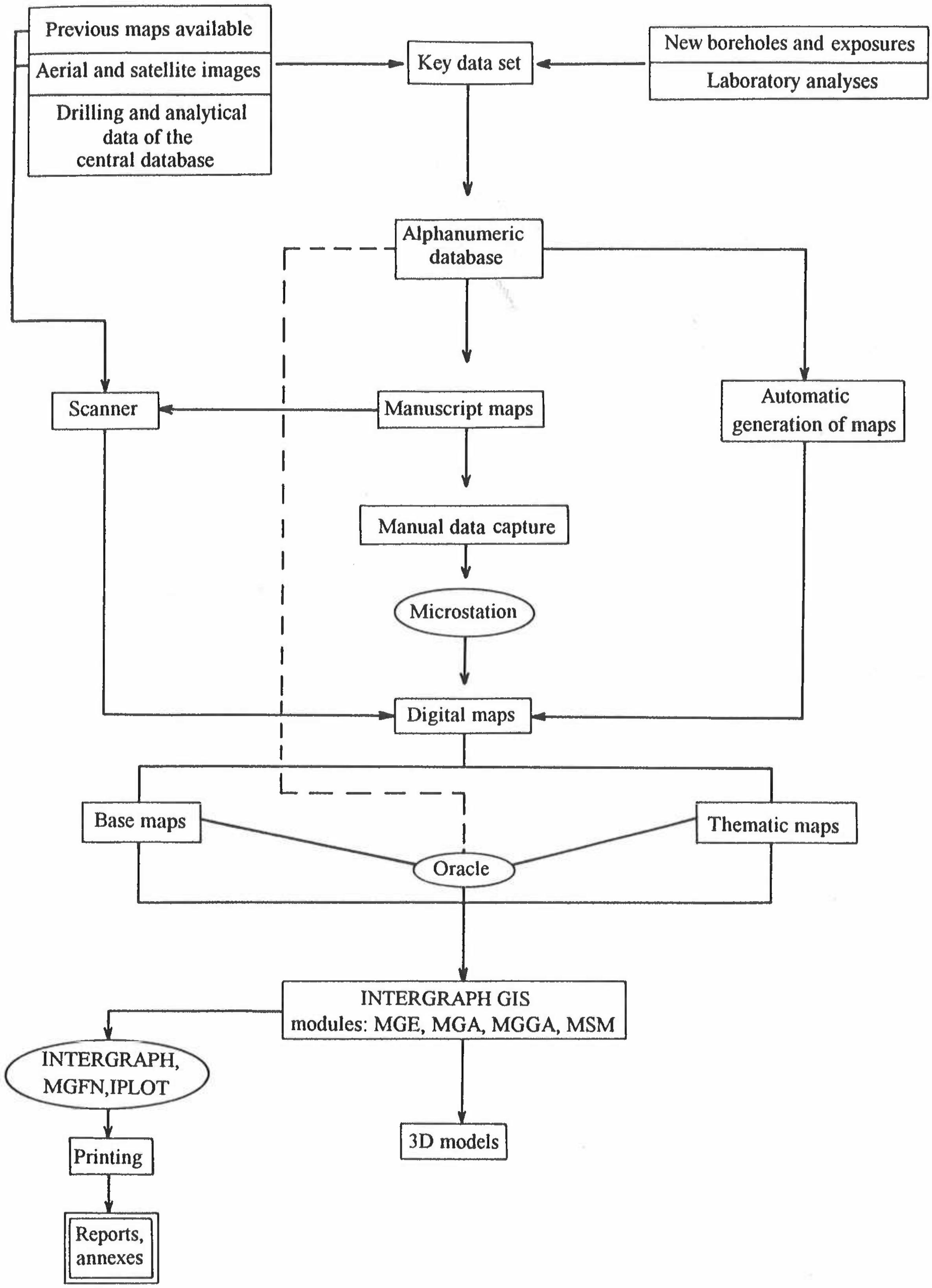

Figure 1

Digital database architecture of the Little Hungarian Plain

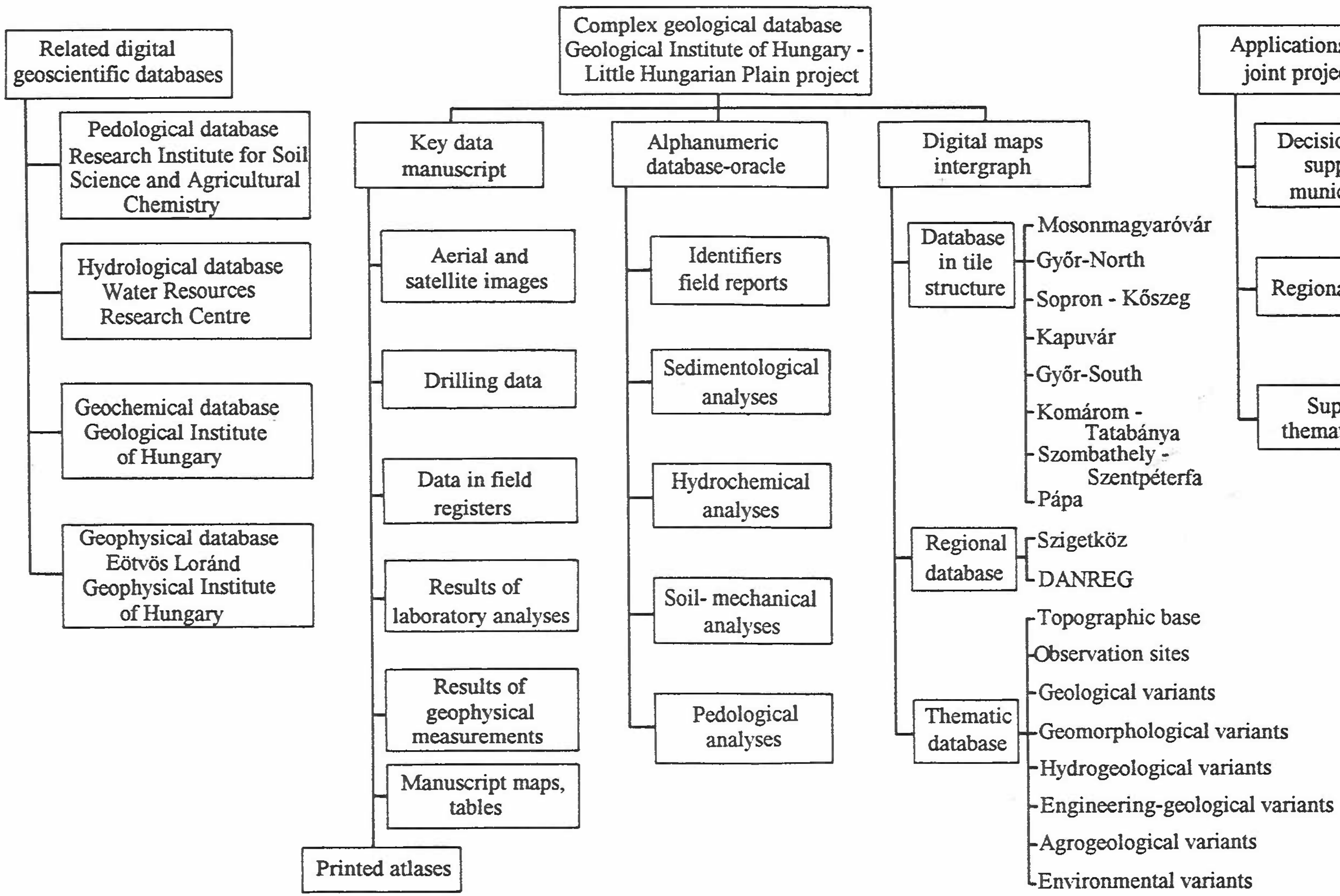

Figure 2

Architecture of the environmental information system of the Little Hungarian Plain

HYDROLOGICAL CHANGES IN THE SZIGETKÖZ

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Along the Danube reach at the Szigetköz (Figure 1), basic changes have occurred in the quantitative conditions of surface and subsurface waters since the diversion of the river in October 1992. Similarly, changes have been observed in the channel and in water quality as well. Changes in the hydrological conditions have also determined the changes of other environmental elements.

The state of surface and subsurface waters of the area was basically determined, under natural conditions, by the hydrological regime of the river. Although the altered conditions of the period 1993–1994 can be compared to the statistical indices of preceding periods, an exact comparison can rather be made on the basis of comparing the expectable conditions, that would have occurred without the diversion of the river, to the ones actually observed. Experiences of earlier periods provide a sound basis for estimating the quantitative parameters of surface and subsurface waters as they would have occurred without the diversion of the Danube, thus allowing an easy comparison with the actual conditions.

The rate of flow of the main channel of the river was subject to the most pronounced changes, since only 10–20% of the flow expectable under original conditions (i.e. without the diversion of the river) was carried by the channel in the past two years and water levels dropped by three metres on average (Figure 2), as compared to the expectable levels at undisturbed conditions.

Water supply from the main channel to the side river arms of the flood plain has actually diminished to zero (Figure 2). Without diversion, the flood plain would have been inundated for a period of 32–36 days annually, while no water levels permitting inundation occurred after the diversion of the river. The side river arms of the flood plain would have, without diversion, received refreshing supply from the main channel for 63–70 days in the last two years (and for 205–207 days through the opened upper end of the side arm system of Rajka). In the actual situation there was refreshing flow of only 2–4 days' duration from the main river through the opened end of the Rajka side arm system. A part of the water released at Dunacsúny to the Mosoni Danube and of that of the seepage flow interception channel was diverted to the flood plain: since August 1993 this rate was approximately 10 m^3/s and was increased since the middle of July 1994 until the middle of October to 15 m^3/s by pumping operations. Since October the Slovak partner has supplied 10–15 m^3/s more water to the flood plain. Water supplied to the flood plain raised the water level of the main channel by 0.5–1.0 m. From the flow discharged into the flood plain between Dunakiliti and Dunaremete about 6–7 m^3/s was infiltrating, on the average, into the groundwater. Most of the 4–5 m^3/s flow, discharged into the river arm outside the flood levee, has also exfiltrated from the channel. The effect of the supplementary flow release to the flood plain on the rise of the groundwater level was negligible, while that on the outside of the flood levee is still disputed.

In the area between Rajka and Ásványráró the groundwater level, near to the Danube, has lowered by three metres on the average (Figure 3A) as compared to the expectable water level corresponding to undisturbed channel flow conditions. In the middle of the area (Figure 2D) between the Danube and the Mosoni Danube this subsidence was already less than half a metre. Under conditions without diversion, the groundwater level of the Szigetköz area would have reached the upper fine-particled topsoil, with the exception of the upper part of the area (Figure 3B). After the diversion of the river, the area with no groundwater supply to the soil cover has expanded (Figure 3C) to include the middle of the Szigetköz too.

Direction of the groundwater flow between Rajka and Ásványráró has also changed substantially: earlier it pointed towards S–SW, towards the Mosoni Danube, while after diversion it has shifted towards the East in the area of the Szigetköz which is near to the Danube, thus rejoining the main channel of the Danube. Most of the infiltrating water, provided by supplementary flow to the flood plain, was seeping back to the main channel, while in other areas of the Szigetköz, further off the Danube, the likely source of recharge to the groundwater is the reservoir.

The channel surface covered by water in the main channel and the side arms of the river have substantially decreased and the area left dry became overgrown by the vegetation. Upstream of the confluence of the tailrace canal with the main channel at Szap up to Dunaremete, fine sediment, an order of magnitude finer than before, has been deposited due to decreased flow velocities. The depth of this sediment layer was half a metre on the average and reached two metres at certain locations. Along this river reach of about 10 km length, the drinking water production potential from bank-filtered resources has been severely damaged.

The quality of surface water was determined by that of the water in the Dunacsúny reservoir. The dissolved oxygen content of the water released to the main channel, to the Mosoni Danube and to the side river arms outside the levee was sometimes lower than before the diversion of the river. Suspended solids content was also reduced somewhat.

No substantial changes in the quality of subsurface waters were expected during these two years, after the river diversion. In the flood plain artificial supplementary water discharge has basically altered the earlier situation: the quality of seepage flow from the side arms to the groundwater indicated anaerobic processes at certain locations.

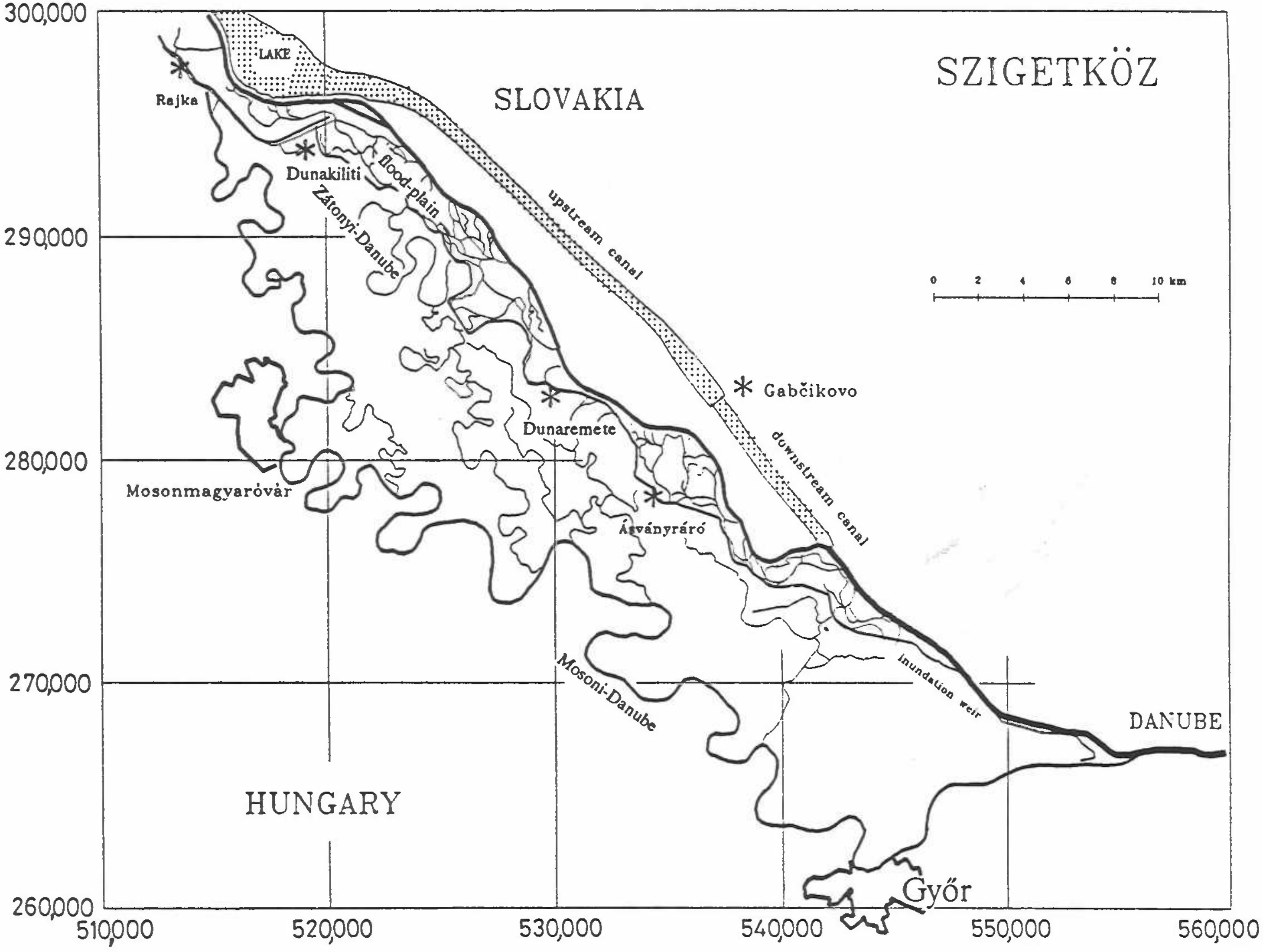

Figure 1

Sketch of the surface water system of the Szigetköz

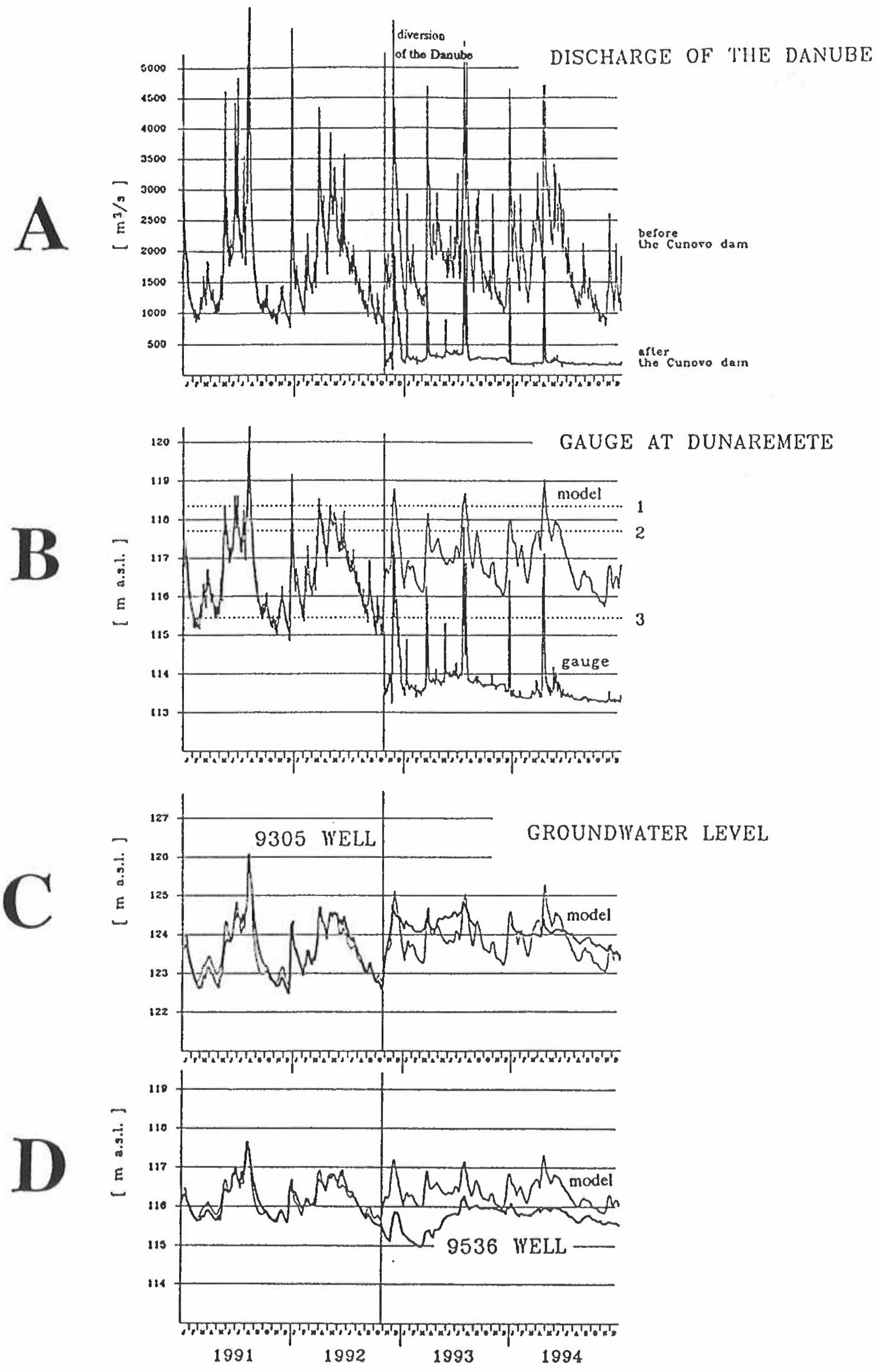

Figure 2

Changes as a result of the diversion of the Danube

A = Rate of river flow at Rajka (the upper curve shows that of Pozsony/Bratislava); B = Water level at Dunaremete: 1 – Water inundates the flood plain, 2 – Water flows over the filling-weirs into the side arm system, 3 – Water flows across the opening at Rajka into the flood plain; C–D = Time series of water levels in two characteristic observation wells (curves with a thin line indicate conditions that would have occurred without the river diversion)

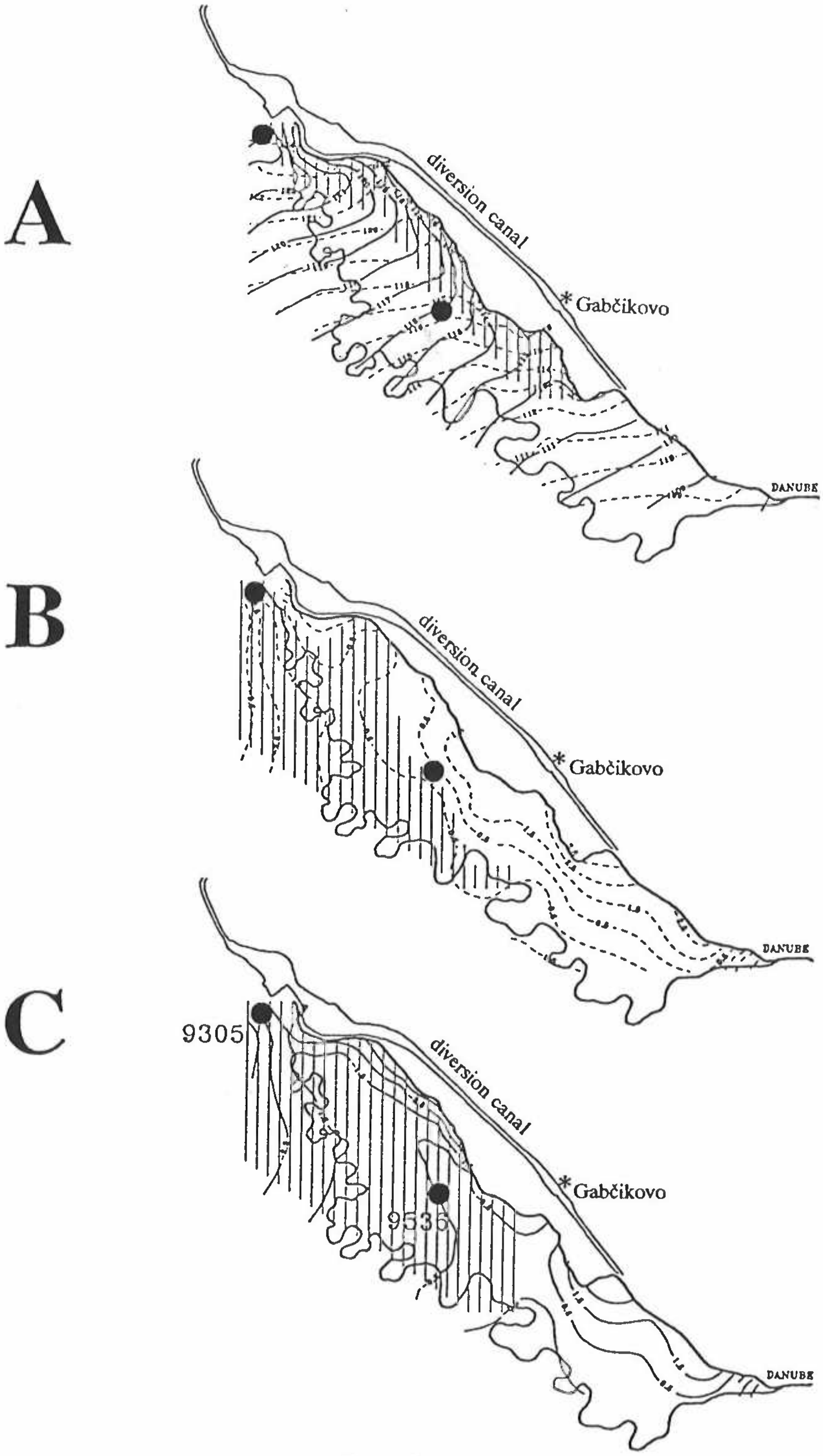

Figure 3

Changes in the groundwater table due to the diversion of the Danube

A = Contour lines of the groundwater table (continuous line: on the 14th of July, 1991 at Danube flow of 2050 m^3/s; dashed line: on the 12th of July, 1994 at Danube flow of 200 m^3/s; shaded area corresponds to area with larger than 0.5 m groundwater subsidence); B–C = Position of the groundwater table as compared to the bottom of the fine-particled topsoil layer (B: on the 14th of July, 1991; C: on the 12th of July, 1994; the groundwater table does not reach the topsoil over the shaded area)

STUDY OF GROUNDWATER QUALITY IN THE SZIGETKÖZ

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In the pre-dam situation, groundwater in the Szigetköz was recharged primarily from the gravel bed of the main Danube channel. The quality of the bank-filtered water was suitable for drinking water supply.

After the damming, the groundwater recharge pattern has been modified: the reservoir and the side arm system have also become the recharge area of the alluvial aquifer, while the main Danube channel has lost its dominant recharge function along significant river sections.

The modified recharge pattern can influence the quality of the groundwater. Hungarian observations have focussed on the quality of groundwater recharged from the side arm system of the Szigetköz.

A set of 70 observation wells in 11 groups were established along the banks of the side arms and canals (Figure 1). The range of horizontal distances of the observed wells from the surface water was 1.8–61.6 m, the depth of well filters varied between 1.2 and 14.8 m (see Table 1).

In 1994 three series of water sampling were carried out in the observation wells and in the adjacent surface waters.

Figures 2 and 3 illustrate the characteristic iron, manganese, ammonium, nitrite and nitrate concentrations in the observation well groups.

The results of the water quality measurements indicate that water quality changes of a reductive character took place in the major part of the wells. The prevailing reducing conditions resulted in high dissolved iron and manganese concentrations (exceeding the limit values for drinking water), in decreased nitrate content and increased ammonium concentration in some wells. From among the nitrogen species, the nitrite concentrations were typically below the limit value. Nitrite is a transient nitrogen species of the oxidising/reducing processes.

Figure 4 illustrates the cross-sectional distribution of nitrate at a representative well group established at the Dunaremete side arm.

In the water of the side arm, nitrate concentration varied between 3.8 and 7.9 mg/l. In the infiltrated water, nitrate content decreased significantly, especially in the deep layers (wells No. 3/2 and 3/1). Simultaneously, the dissolved iron concentration shows an increase in the course of infiltration: the mean dissolved iron content was 0.08 mg/l in the surface water and 2 mg/l in the observation well No. 3/1.

Because toxic elements were present below the limit values for drinking water – although in some wells arsenic levels were around 20% of the 50 mg/l maximum allowable concentration –, iron and manganese leaching can be considered as the main quality problem of recharge in the side arm system.

Dissolution of iron and manganese can be a restricted process if iron and manganese supply is negligible from the surface water. The dissolved iron and manganese concentration is very low in the aerobic environment of the surface water in the side arms. The rate of sedimentation is an uncertain parameter. Both the dissolved and the solid iron and manganese supply from the surface water is disregarded in the following estimation of iron and manganese depletion from the aquifer.

The input parameters of iron and manganese leaching are:

– mean iron concentration in the solid filtration matrix	9000	mg/kg
– mean manganese concentration in the solid filtration matrix	180	mg/kg
– equilibrium dissolved iron concentration	25	mg/l
– equilibrium dissolved manganese concentration	5	mg/l
– water flow in the aquifer	100	m/year

The above parameters resulted in 0.1 m/year and 1.5 m/year depletion rate of iron and manganese, respectively.

Conclusions

The water quality has shown reducing conditions in a major part of the studied observation well groups along the Szigetköz side arm system. The reducing conditions resulted in elevated concentrations of iron, manganese and ammonium in some cases. Iron and manganese leaching can be temporary if a negligible supply from the surface water is assumed.

Table 1

Characteristic parameters of the observed well groups

Identification number of well group	Range of horizontal distances of the observed wells from the surface water (m)	Range of depth of well filters of the observed wells (m)
1	1.8–17	1.3–14.5
2	2.1–27.5	1.2– 8.0
3	4.5–18.5	2.5–14.8
4	10.3–61.6	3.3–14.7
5	2.8–30	1.7–14.3
6	4.3–13.6	1.2– 8.3
7	6.4–23	13.5–11
8	4.9–23.8	1.3– 4.1
9	7.1–45	3.1–14.7
10	3.6–23.5	2.8–11.1
11	17	7.1–10.6

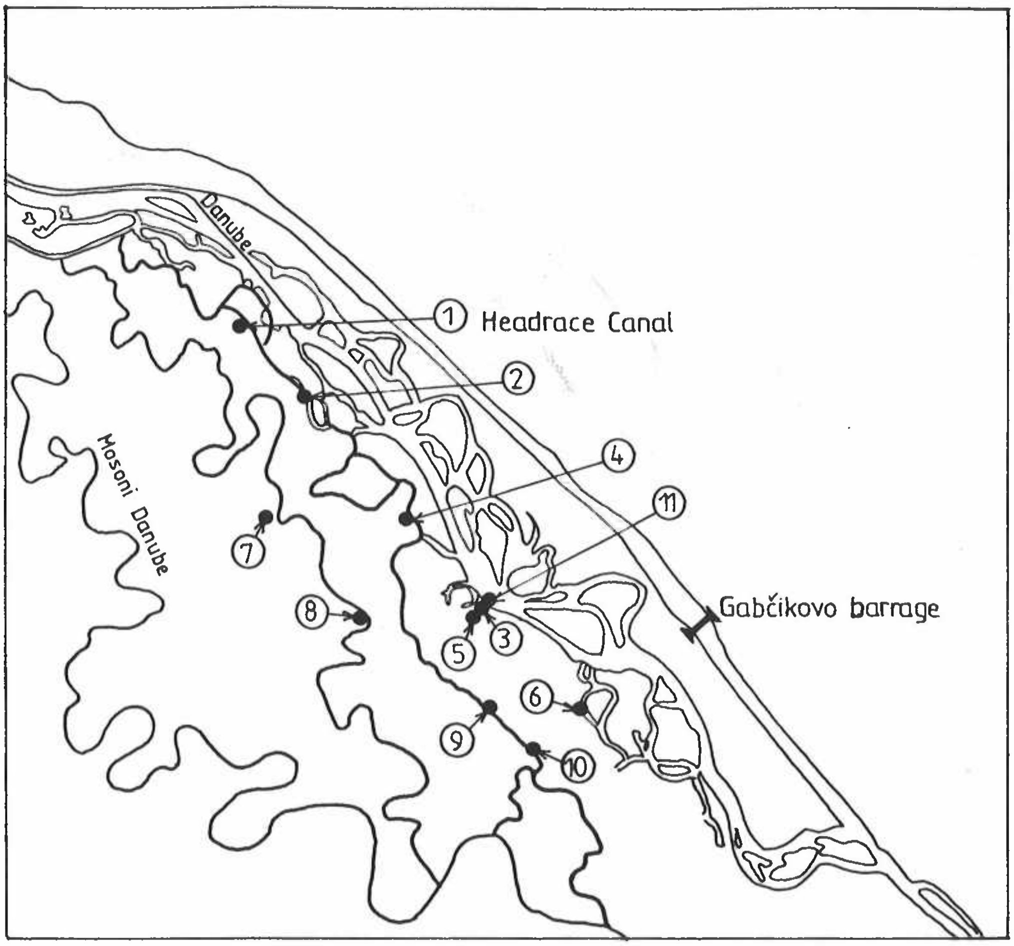

Figure 1

Location of the observation well groups (for the explanation of the identification numbers see Table 1)

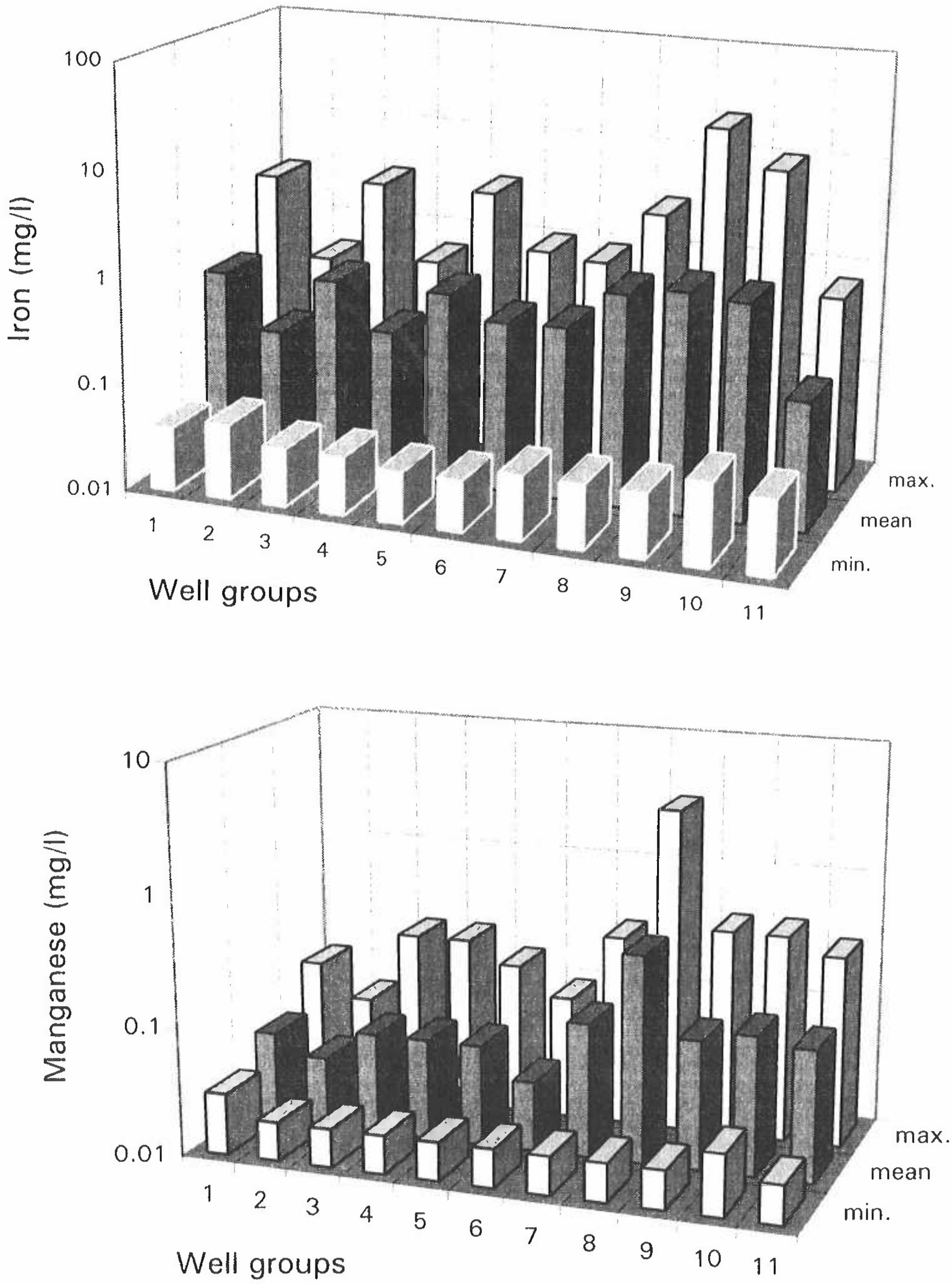

Figure 2

Characteristic iron and manganese concentrations in the observation well groups

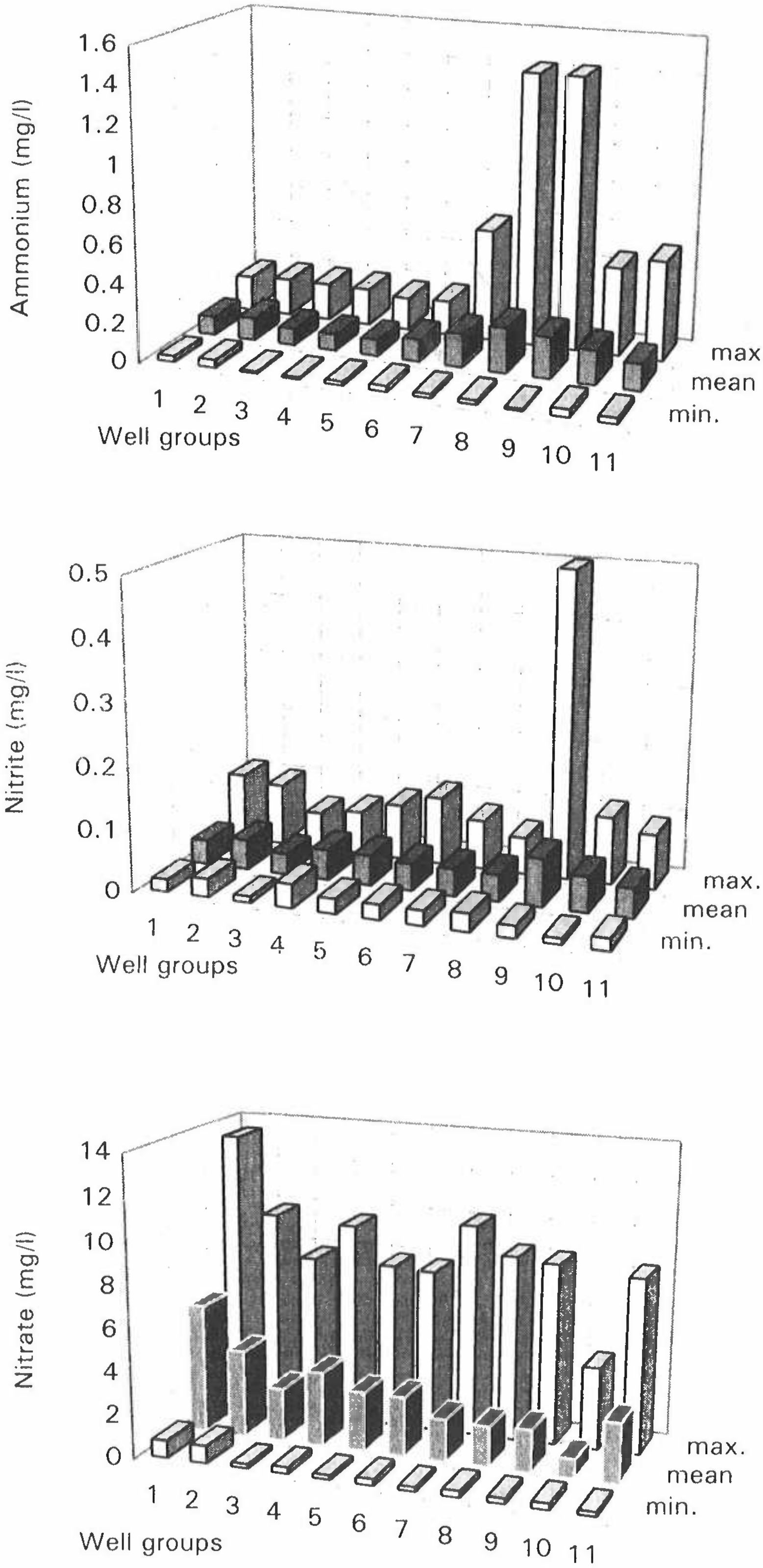

Figure 3

Characteristic ammonium, nitrite and nitrate concentrations in the observation well groups

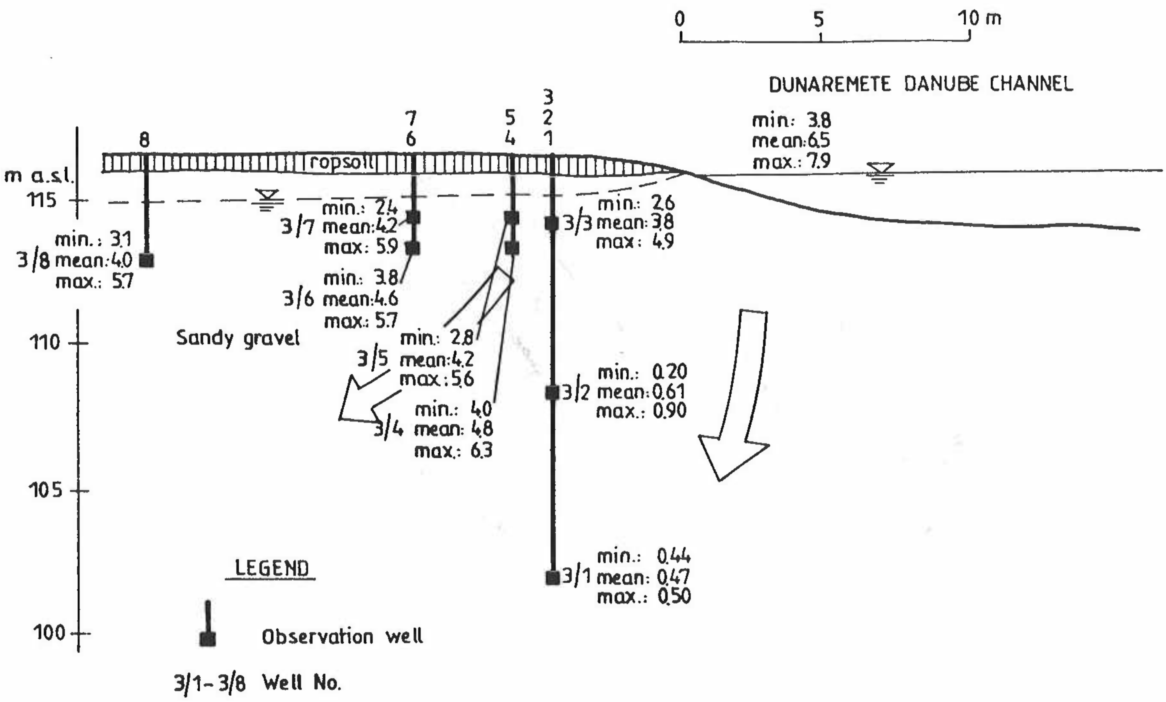

Figure 4

Cross-sectional distribution of nitrate concentration (mg/l) at well group No. 3

THE STATE OF THE SZIGETKÖZ WATER SYSTEMS

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The water quality of the Szigetköz region's natural and man-made wet areas is determined, in addition to the spatial and temporal changes, by the anthropogenous influences.

Because of the October 25, 1992 diversion of the Danube's main arm into an artificial bed and the operation of the Gabčikovo power station, the existing system of monitoring the state of the environment on the affected Hungarian side was expanded with a monitoring programme geared to record the effects of the artificial encroachment on surface water quality.

Within the framework of this programme, biweekly water quality examinations took place at 40 sampling sites along the Danube, the Mosoni Danube, and in the wet areas between the flood walls (in the flood plain) and outside (on the protected side). Apart from determining salt, oxygen and organic nutrient content characteristics, experiments, although with lesser frequency, also ranged from inorganic and organic micro-pollutants to biological and bacteriological parameters.

The water quality of the average 2500 m^3/s volume of water arriving into the main bed of the Danube in Hungary has improved from the standpoint of organic material pollutants as a result of the aggregate integrated effects of the encroachments occurring in the water shed over the past ten years.

The long-term development of organic pollution for the Danube's 1848 river km section is shown in Figure 1 by the indication of minimum and maximum values of the average annual concentrations of COD (chemical oxygen demand). An opposite tendency can be seen in Figure 2 for the same section with the increase in concentrations of NO_3.

The drastic decline in water volume equivalent to one tenth of the earlier middle water level occurred in a period which was characterised by overall favourable water quality changes.

The *Danube's main bed* responded to the drastic artificially introduced change in water volume – as compared to the period prior to the diversion – by causing more extreme changes in the dissolved oxygen content at the Rajka cross-section (1848 river km); the minimum values measured in the summer months of 1993–1994 had not occurred previously.

We registered the "acceptable" water quality class III accorded by the Hungarian National Standard 12749/93 due to the minimum value for DO_2 of below 6 mg/l. The development of oxygen saturation over time for the Danube cross-section at Rajka can be seen in Figure 3. Below the mouth of the power station's tailrace, the fluctuation in the water's dissolved oxygen was greater. On the basis of the factors decisive for the dissolved oxygen content registered for the Danube water, the tendencies in the change of water quality can be considered unfavourable.

The examination of parameters indicating the plant nutrient and the organic matter pollution of the water does not show significant changes as a result of the effects of the artificial decline in water volume which occurred in the main bed.

Prior to the diversion, an increase in the chlorophyll-a concentrations indicating algal blumes (propagation of algae) could be registered along the Szigetköz stretch of the river. Figure 4 indicates the development over time of measured differences in maximum values of chlorophyll-a at the cross-section near the edge of the national border and below the mouth of the tailrace near Medve for the years 1993 and 1994. As a consequence of the encroachment in the Danube bed, the maximum values for chlorophyll-a at the Rajka cross-section significantly exceeded the maximum concentrations measured at the 1806 river km – an occurrence which has not been seen in the past 20 years.

The quality of the Danube water consequential to the diversion definitely determines the state of the region's water quality, accordingly, the monitoring of the water quality discharged from the Slovak side is of increased significance.

The water supply for the *flood plain side arms* has been catastrophically affected by the Danube diversion. With the exception of inundation periods, water remains only in the deeper-bedded arms and is supplemented by the groundwater seeping towards the main branch. Various damage-mitigating water supplements occurred to improve the water supply of the side arms. The effect of these could be felt all the way to the side arm system of the Lower-Szigetköz (across approximately 20 km).

The differences in water supply in the *flood plain side arm* system could be clearly observed in the water quality conditions. For the area of the side arm system locally and temporarily affected by water supplement, the water quality followed the quality of the water supplied.

Table 1 shows average and scattered values before and after the Danube diversion for several characteristic water quality parameters in the affected Cikolasziget side arm system (Doborgaz 46.2 dam km). It can be seen that there is no significant difference in water quality, but during the period of 1994 affected by water supplement, an average NO_3 concentration for the Danube's main bed is typical. In territories less affected by water supplement, areas of standing water developed. After the diversion of the Danube, the pH value fluctuated more markedly; the average values for organic material, dissolved oxygen and NO_3 became lower. Table 2 presents the measured average and scattered values for the Ásvány arm system at 23.8 dam km before and after the diversion of the Danube for the years 1993 and 1994.

The difference between the extreme values for dissolved oxygen content was great at those sites where stagnant waters occurred and the transfer of water was also slow. This can be perceived well from the data in Table 3 where water quality indicators appear as minimum and maximum values, using the year 1989 as for the time before the diversion as a reference and 1993 and 1994 as the years after the diversion.

With the development of the flood plain water supplement system, the possibilities of access for pollutants became limited to one site.

An example of this is given in Figures 5 and 6 where minimum and maximum concentrations can be seen for suspended material and the quantity of anion-active substances (tenzids) dispersed over time along the longitudinal section of the flood plain water supplement after the diversion of the Danube.

On the protected side of Upper-Szigetköz, the water quality of the branch has followed the changes of the supplied water since the water supplement of the Kiliti-Cikola branch. In Lower-Szigetköz, the diversion of the Danube has had less influence on the water supply of the channels, accordingly, the water quality has not changed either, in comparison to earlier periods.

Table 4 gives data on the water quality of the Kiliti-Cikola branch and the Lipót oxbow lake, characteristic of the water areas of the protected side before and after the diversion. As a suitably long homogeneous data series was not available, the water quality characteristics are shown by using data reflecting individual points in time. The change in water quality at the Lipót oxbow lake is notable, where under the influence of water supplement, the character of water quality changed and a loss in balance occurred.

The water quality of the *seepage canal* is of key importance, because the present damage-mitigating water supplement can only be resolved from the Slovak seepage water discharged at the edge of the reservoir. As regards the development of water quality, the discharged reservoir water is determinant, due to the proportion of quantities. The pollution of the seepage water, because of the filtering effect, is of a significantly smaller degree, but the dissolved oxygen content is lower, as can be seen in Table 5.

The *Mosoni Danube* water supplement occurring through sluice no. VI began immediately after the diversion and within the framework of the damage-mitigating water distribution; a continuous volume of water ranging from 8 to 23 m^3/s was released.

From the standpoint of water quality, the river can be separated into three easily identifiable reaches. To the mouth of the Lajta above Mosonmagyaróvár, the quality of the Danube's feeder water and possible seepage water is determinant. Apart from the partially treated sewage water discharges at Mosonmagyaróvár, the slowing of flow velocity due to morphological attributes has a water quality changing effect. Below Győr, on the other hand, in addition to the water quality of the Rába and Rábca rivers, the city's discharges of the presently still untreated sewage water is determinant.

The data of the 1993 and 1994 examinations show that the water quality of all three reaches is unstable, which is shown primarily by the oxygen content. In the case of unfavourable water movements in the tributaries and the Danube's main arm, below the cities, a critical condition can also develop.

Figures 7 and 8 show the development of concentrations for COD average, minimum and maximum values characteristic of dissolved oxygen and organic material pollution along the longitudinal section in 1993 and 1994.

The water quality data and evaluations presented and presumed as risks do not substitute applied research and the relating targeted examinations and analysing evaluations.

Table 1

Water quality change in the Danube's inundation area prior to and after the diversion in the Cikolasziget branch (at Doborgaz 46.2 dam km)

Water quality parameters	1985–1989 n = 27		1993 n = 36		1994 n = 33	
	average	standard deviation	average	standard deviation	average	standard deviation
pH	8.01	0.185	8.33	0.379	8.39	0.350
Conductivity (μs/cm)	376	36.5	339	39.7	3.43	41.0
COD_{KMnO_4} (mg/l)	3.9	1.288	4.21	1.788	3.57	1.117
Dissolved O_2 (mg/l)	10.16	2.36	11.01	2.40	10.75	2.26
NH_4^+ (mg/l)	0.37	0.237	0.22	0.178	0.096	0.042
NO_3^- (mg/l)	3.49	2.54	3.32	3.65	8.71	3.00
PO_4^{3-} (mg/l)	0.29	0.217	0.09	0.059	0.13	0.081

Table 2

Water quality change in the Danube's inundation area prior to and after the diversion in the Ásványi branch (at VIZIG ship port, 23.8 dam km)

Water quality parameters	1985–1989 n = 27		1993 n = 36		1994 n = 33	
	average	standard deviation	average	standard deviation	average	standard deviation
pH	8.11	0.30	8.06	0.45	8.03	0.41
Conductivity (μs/cm)	343	52.5	387	53.6	358	42.0
COD_{KMnO_4} (mg/l)	6.6	2.24	3.4	1.3	2.8	1.19
Dissolved O_2 (mg/l)	12.08	3.71	9.14	2.22	8.74	2.05
NH_4^+ (mg/l)	0.41	0.31	0.38	0.29	0.17	0.09
NO_3^- (mg/l)	4.7	4.27	2.72	2.40	2.39	1.96
PO_4^{3-} (mg/l)	0.29	0.18	0.11	0.10	0.12	0.06

Table 3

Water quality change in the Danube's inundation area prior to (1989) and after the diversion (1993, 1994)

Water quality parameters	1989		1993		1994	
	minimum	maximum	minimum	maximum	minimum	maximum
pH	7.27	8.78	7.04	8.44	7.10	9.06
Conductivity (µs/cm)	254	415	218	508	216	456
NH_4^+ (mg/l)	0.01	1.27	0.0	1.28	0.04	0.50
NO_3^- (mg/l)	0.0	7.5	0.05	14.4	0.47	14.6
PO_4^{3-} (mg/l)	0.04	1.31	0.01	0.64	0.01	0.59
Dissolved O_2 (mg/l)	6.19	18.80	3.18	19.9	3.51	19.95
COD_{KMnO_4} (mg/l)	1.9	12.0	2.0	13.5	1.4	8.7
Chlorophyll-a (mg/m^3)	4.0	292.8	1.0	151.0	0.6	146.3
Number of the sample places	15		12		10	
Number of samples	87		378		316	

Table 4

Water quality in protected surface water at two locations in the Szigetköz prior to and after the diversion

Water quality parameters	Kiliti-Cikola branch at Doborgaz			Lipóti dead branch at Lipót		
	1992 (08.10)	1993 (08.09)	1994 (08.08)	1992 (08.10)	1993 (04.21) August: dried up	1994 (08.15)
pH	9.1	8.51	8.68	7.68	9.43	7.71
Conductivity (µs/cm)	518	305	315	420	951	349
Dissolved O_2 (mg/l)	9.12	7.28	7.30	2.0	12.82	4.64
COD_{KMnO_4} (mg/l)	14.5	3.1	4.9	9.3	12.4	2.8
NH_4^+ (mg/l)	0.04	0.01	0.18	0.31	3.38	0.08
NO_2^- (mg/l)	0.17	0.04	0.05	0.007	0.07	0.03
NO_3^- (mg/l)	0.3	3.4	4.8	0.2	1.4	3.6
PO_4^{3-} (mg/l)	0.24	0.04	0.02	0.12	0.18	0.06
Total Fe (mg/l)	0.29	0.04	0.08	0.88	–	0.18
Mn (mg/l)	0.0	0.06	0.05	0.21	–	0.05
Suspended solid (mg/l)	32	4	24	6	–	26
Chlorophyll-a (mg/m^3)	72.9	11.9	25.2	9.2	72.2	2.4

Table 5

Average 1993 and 1994 values for the seepage canal water quality

Parameter	Sluice I (Reservoir water)		Sluice II (Seepage water)		Danube, Rajka	
	1993	1994	1993	1994	1993	1994
Dissolved O_2 (mg/l)	10.3	9.5	6.43	5.91	9.4	9.33
COD_{KMnO_4} (mg/l)	3.62	3.60	1.75	2.04	3.6	3.4
NH_4^+ (mg/l)	0.27	0.13	0.09	0.08	0.25	0.14
PO_4^{3-} (mg/l)	0.16	0.20	0.04	0.05	0.18	0.17

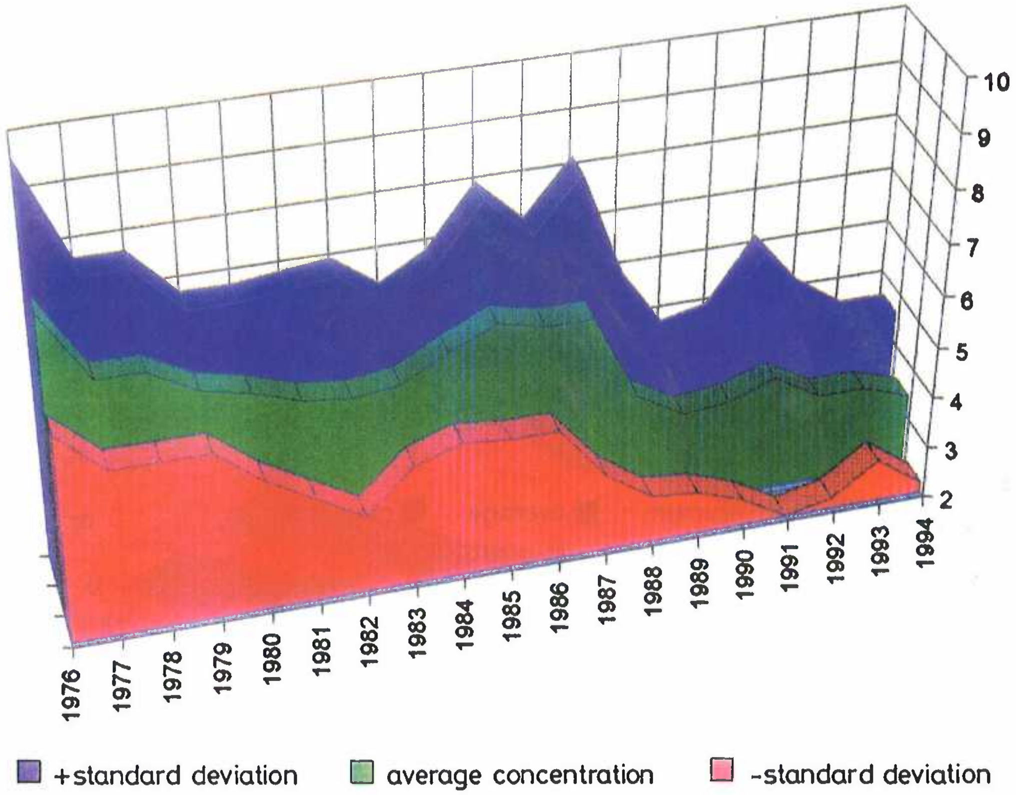

Figure 1

Average concentration and associated standard deviation of chemical oxygen demand between 1976 and 1994

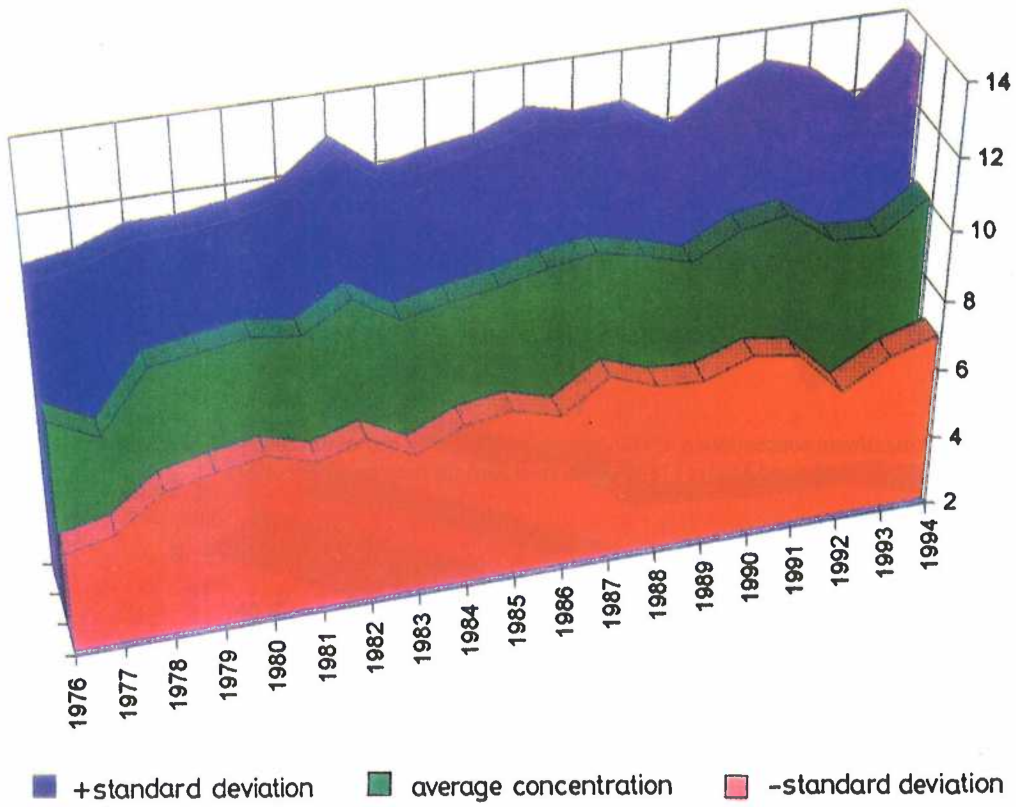

Figure 2

Average concentration and associated standard deviation of NO_3 between 1976 and 1994

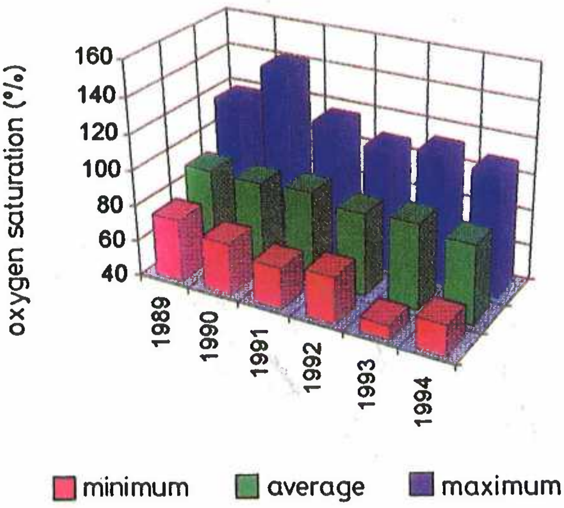

Figure 3

Extremes and average of saturating oxygen in the main Danube bed at Rajka (1848 river km) for the years 1989–1994

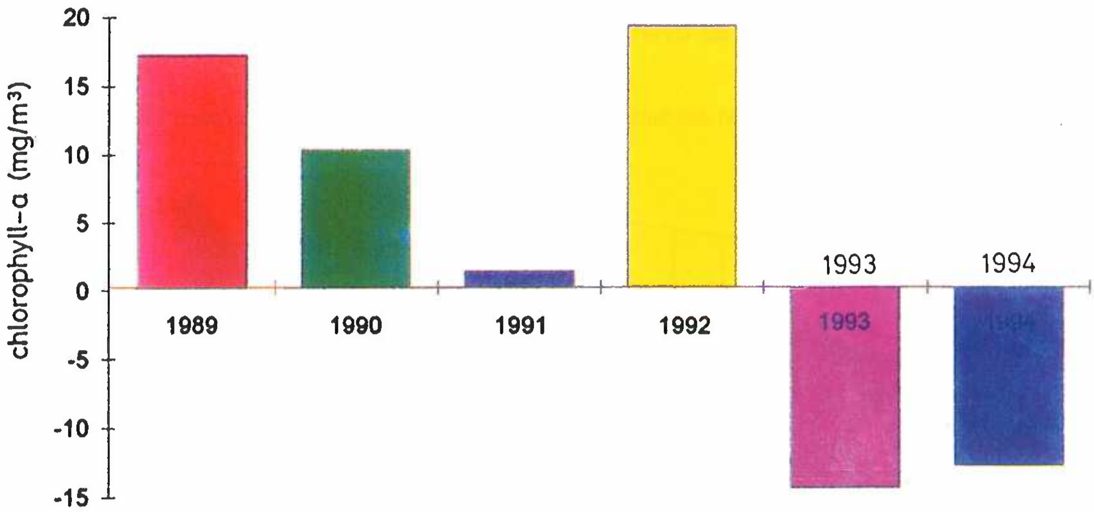

Figure 4

Difference in maximum concentration of chlorophyll-a in the main bed of the Danube between stations at Rajka and Medve (1848–1806 river km) for the years 1989–1994

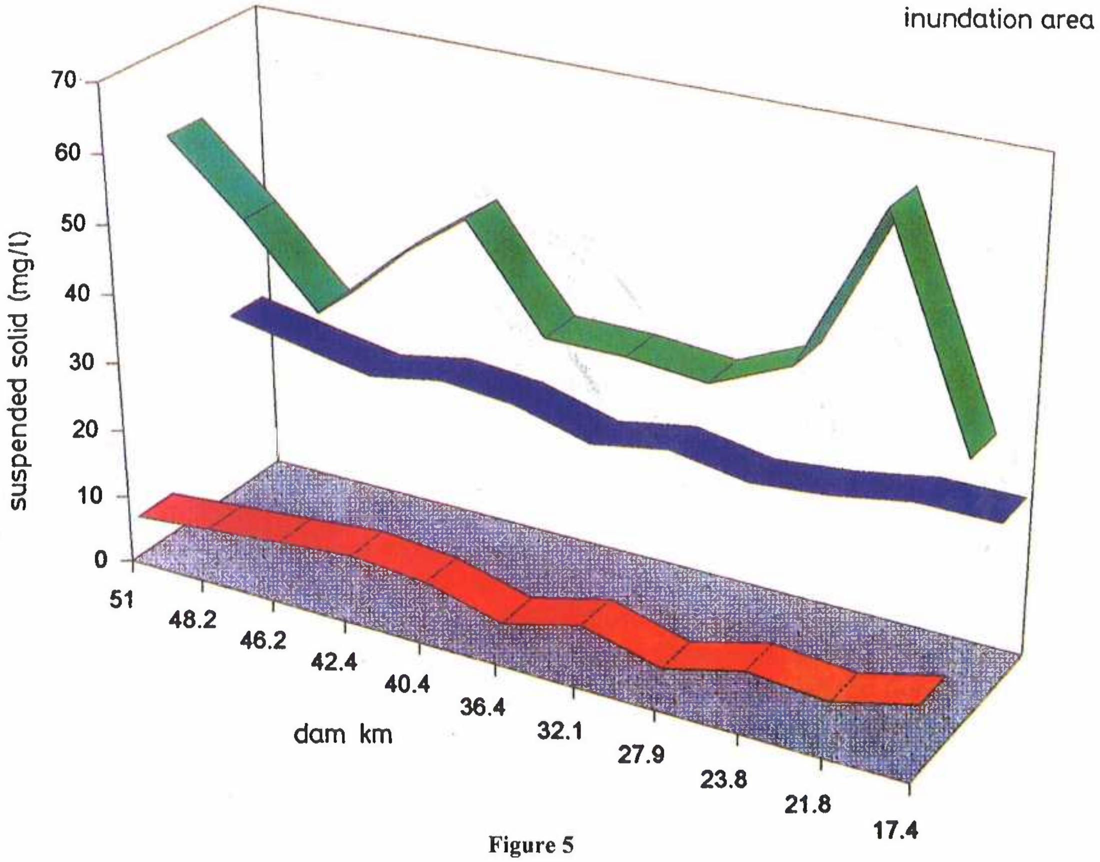

Figure 5

Annual extremes and average concentration of the suspended sediments in the inundation area

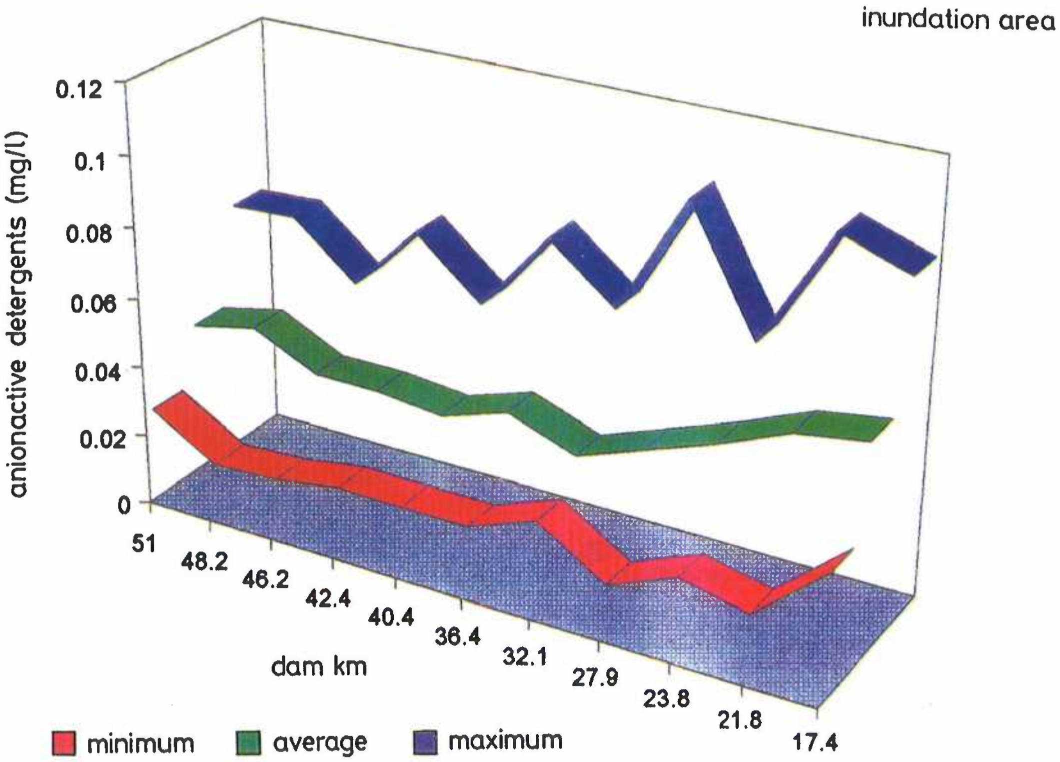

Figure 6

Annual extremes and average concentration of detergents in the inundation area

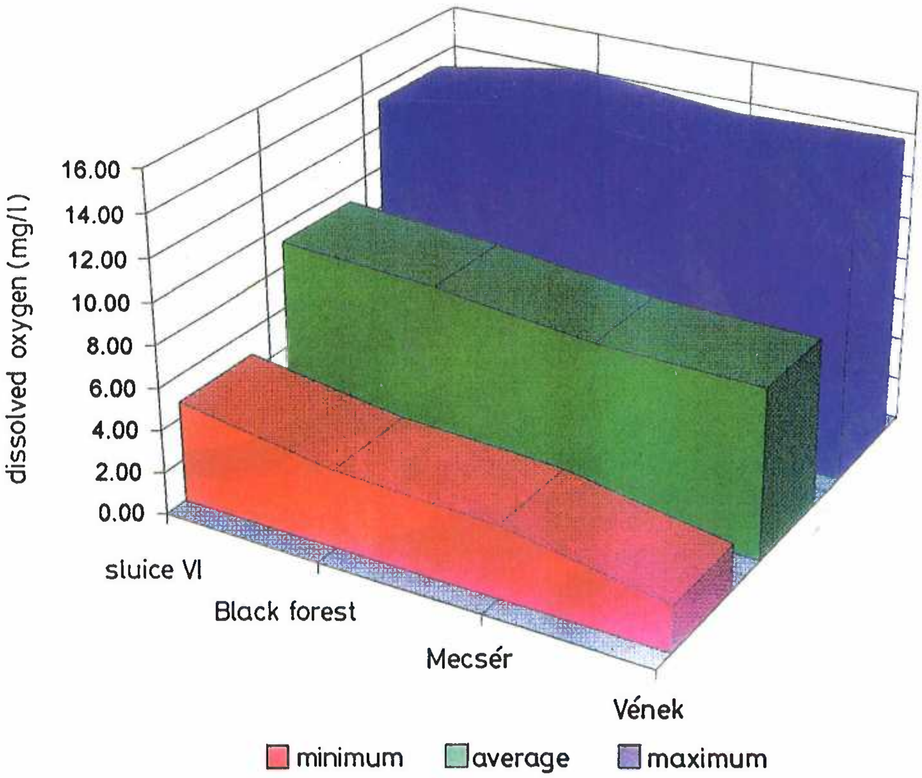

Figure 7

Extremes and average concentration of dissolved oxygen in the Mosoni Danube in 1994 from sluice No. VI to the mouth of the Danube

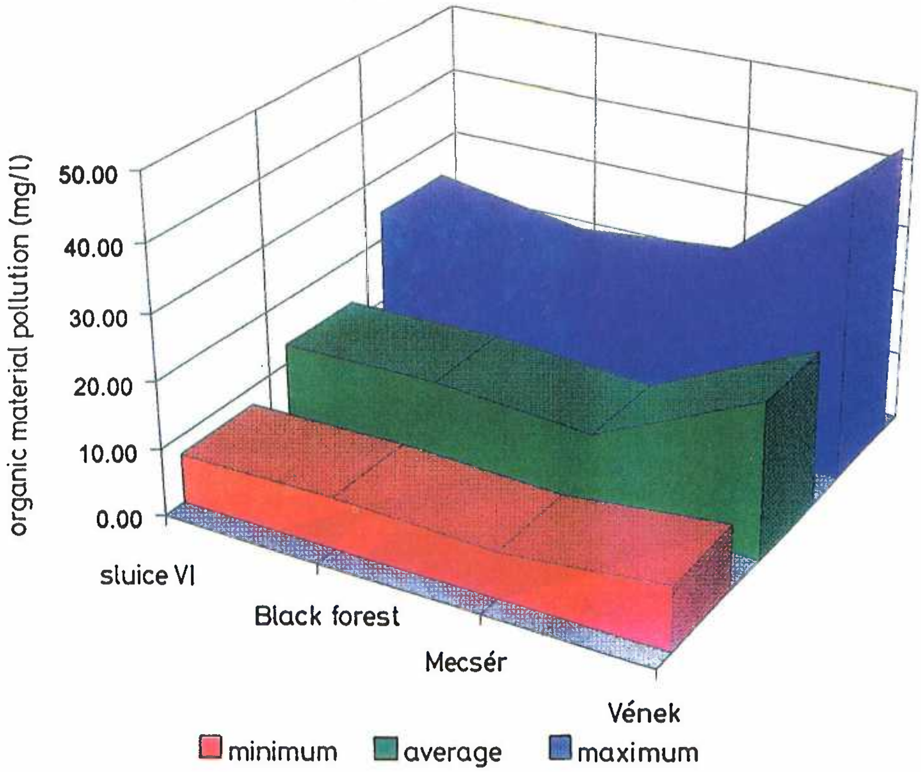

Figure 8

Extremes and average concentration of dissolved oxygen in the Mosoni Danube along the long profile in 1994

A NATIONAL PARK DEVELOPED FROM A LANDSCAPE CONSERVATION AREA

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In the first half of the decade of 1980–1990, the woodlands and meadows most valuable in regard of nature conservancy in the Szigetköz region were declared to be protected by the County Council of Győr-Moson-Sopron. On initiative of the Committee for Environmental Protection of the County Council, the President of the National Administration of Environmental Protection and Nature Conservancy established the Szigetköz Landscape Conservation Area (by Decree 1/1987. III. 19). At that time the water supplementary system to be established on the flood plains and the outside slopes for the total territory of the Szigetköz, serving especially the interests of the Landscape Conservation Area, had already been projected and the process of implementation started.

On the whole, the Landscape Conservation Area covers 9158 hectares, two thirds of it being woodland. The major part of the strictly protected 1326 hectares is also wooded, whereas some minor part is taken by the water surface of the Danube's branch system and the ecosystem of aquatic flora and fauna.

Roughly half of the Landscape Conservation Area is located in flood plains: partly in that of the Danube's main branch, and partly in that of the Mosoni branch of the river. The latter flood land lying below Kunsziget–Dunaszentpál is confined by flood defences. Only one tenth of the Conservation Area is to be found on the outside slope: 40% spreads over the so-called integral flood land (i.e. flood land not divided by dams) of the Mosoni branch of the Danube, extending from the state frontier to the region of Kunsziget and Dunaszentpál. The territory covered by the Conservation Area belongs to 21 local governments.

More than one third of the forest stands located here is composed of autochthonous tree species characteristic of the landscape. Euramerican poplar stands covering two thirds of the wooded areas belong to the first generation; under the trees, the components of the one-time original ecosystem – shrubs and ground cover vegetation consisting of herbs – are mostly still to be found.

Two plant species have been placed under strict protection, the number of protected ones amounting to 45. Four species are listed in the Red Data Book. The fauna of the Conservation Area comprises the following: approximately 40 mammal species, 170–200 species of birds (breeding in or migrating through the region), 67 fish species (roughly 75% of the fish fauna present in Hungary), the majority of amphibians living in the country, and several reptile species. Exploration of the invertebrate fauna is being carried out: each year researchers identify several species that have been unknown in this region up to now.

In 1991 the Decree No. 28/1991/IV.30/OGY stated: "In accordance with the Hungarian conception presented at the Budapest meeting (February 1991) for the state of the Danubian region, the Parliament initiates that ... by the end of 1995 the Austrian Republic, the Czech and Slovakian Republic and the Hungarian Republic should establish the common Danubian National Park in order to protect the rivers, the system of their branch arms, the fauna and flora of high value, the surface and underground stocks of water, the forests, soils and other renewable resources present in the concerned area."

According to the Decree of the Parliament referred to above, in June 1991 a two-day trilateral consultation took place in Mosonmagyaróvár and Hédervár, respectively, where the participating professional leaders in charge of nature conservancy (under-secretaries of state, deputy ministers representing three states at that time) presented their oral contributions testifying mutual concord.

– In June 1992 the leaders of nature conservancy in the three countries concerned (Austria, Hungary and Slovakia) carried out negotiations on the common possibilities of nature conservation. The competent representatives of the regional authorities were also drawn into the talks.

– In November 1992 in the framework of the Vienna talks for specialists of nature conservation, the Austrian, Hungarian and Slovakian experts composed the map covering the areas to be protected in the three-frontier regions.

– In November 1993 the last trilateral conciliatory talks referring to nature conservation areas of the frontier regions took place in Austria (Deutsch Altenburg).

In the course of the state-controlled compensation for landed properties and in the framework of the transformation processes in Hungarian agriculture, it became possible to draw up the conception for expanding the Landscape Conservation Area, and thus to carry out preparations for the establishment of the National Park. Edited by the Hungarian Directorate of the National Park, a report entitled "Studies on the Planned National Park of the Szigetköz" was elaborated. (It was published by the National Park in two volumes in 1993.)

In the same year – partly based on the latter work – the University of Horticulture and Food Industry presented the "Plan for the Regional Landscape Development Covering the National Park of the Danube Region". The University had been commissioned by the Ministry for Environment and Regional Policy to work out the plan.

The most urgent tasks can be summarised as follows: implementing the expansion of the Landscape Conservation Area, simultaneously presenting proposals for considerable growth of the scope of resources and objects worth being protected by the authorities of local governments, furthermore the establishment of a so-called "Nature Park" in the Szigetköz region, if it is made possible by the modernisation of Hungarian legislation relating to nature conservancy.

In our opinion, the development of long-term projects for organising and promoting the establishment of the National Park of the Danube region – extending over the frontier territories of four states (Austria, the Czech Republic, Hungary and Slovakia) and constituting a natural unit as planned originally – should not be given up.

NATURAL VALUES OF THE SZIGETKÖZ LAND CONSERVATION DISTRICT

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The Szigetköz is situated in the heart of the Little Hungarian Plain (Kisalföld), occupying a 375 square km (145 square miles) large territory between the Old Danube and the Mosoni Danube branch. The Szigetköz Land Conservation District was founded in 1987 to preserve the specific river system, the typical flora and fauna of the Szigetköz. Its area is 91.57 square km (35.35 square miles) of which 13.25 square km (5.11 square miles) are strictly protected. Some 65% of the Land Conservation District is forest, 22% is kept away from cultivation, the main part of it is made up of the water course and the Danube branches. We can differentiate 3 main parts of the Land Conservation District which touches 21 local governments' area:

- forests along the banks of the Mosoni Danube branch,
- flood plain of the Old Danube, and
- separated areas between the two branches.

The first period of the exploration of the Szigetköz's fauna and flora has been accomplished. However, this area has not been explored properly yet. Both the Land Conservation District and those areas which are not under nature preservation yet may have surprises in store.

The water, the Danube has played a main role in the formation and the present state of the Szigetköz. This holds true for its varied fauna and flora as well. The forests along the banks of the Mosoni Danube branch are known the best from a botanical aspect. Our related knowledge originates mostly from the studies written by Ervin Werner (teacher of the Kossuth Lajos Secondary School at Mosonmagyaróvár). Some 40% of the forests along the banks of the Mosoni Danube branch are still in a natural state. About 95% of *Fraxino pannonicae–Ulmetum* has vanished already. The most beautiful pieces of the remaining ones exist here in the area of Rajka, Bezenye, Feketeerdő, Halászi, Mosonmagyaróvár, Máriakálnok and Kimle settlements. These forests are rich in geomorphological values, too. The Mosoni Danube branch's old meanders have remained beautiful.

Some inch differences in the height of the terrain have great importance in the life societies which are primarily influenced by subsoil. That is why a large number of forest types have developed like a mosaic, characterised by various soft-stalk plants. Such type-creating plants are: *Circea lutetiana, Aspurela odorate* and *Allium ursinum*. Characteristic of these forests is the large number of Fagetalia species the spread of which in the plane is interesting. Such species are: *Galanthus nivalis, Asarum europaeum, Anemone silvestris*, etc.

There are some nationwide rarities as well: for example, the *Lilium bulbiferum*, which grows in hundreds, is a high-alpine species and has only a slight population in Hungary in the Bükk Mountains. *Lilium bulbiferum* is preserved to a greater extent. The existence of the *Ophrys apifera* population (being an orchid species protected to a greater extent) was not confirmed in other areas of Hungary in the last years. So, it is of outstanding importance to save the Szigetköz population which consists of more than a thousand stocks. *Ophrys insectifera* is endangered very much, it is already a ruined rarity, so it is protected to a greater extent, too.

The nationwide situation of *Querco robori–Carpinetum* is tragic. Except for the Szatmár–Bereg Plain and some small areas of the Szigetköz, this joining is actually depopulated. The level of its shrub and grass is similar to *Fraxino pannonicae–Ulmetum*. Small spots exist in the area of Bezenye, Feketeerdő, Halászi and Mosonmagyaróvár.

The Old Danube's flood plain is rich in landscape and zoological values. Mostly *Populus hybrida* plants were planted in place of the former foreshore forests and meadows in the last ten years. The natural vegetation has remained in spots only. Such areas are: Pálfy forest in Kisbodak, Old-willowy and some little holms in the area of Dunasziget and Ásványráró. A large spread of the foreshore is prosperous for the fauna.

Research of the less inferior animal species has not finished yet, but it is already visible that there are many rare species which are preserved by Hungarian law and international conventions as well.

The Szigetköz is the fish-crib of the Danube. Some 65 fish species are identified and this is 80% of the native species. Freshwater fishes with the most different ecological demand are found here, from the species of clean mountain rivers as *Salmo gairdneri* to the loachs (Cobitidae) which are typical in marshes.

Almost every species of amphibians lives in the Szigetköz. *Rana esculenta, Rana ridibunda, Bombina bombina, Rana arvalis, Hyla arborea* are all frequent here.

Less reptiles live here in the watered areas than amphibians, but their typical species, the *Natrix natrix* is frequent. All amphibians and reptiles are protected in Hungary.

Birds are the most typical animals of the Szigetköz and the foreshore. Their large number is due to the relative quiet and the richness of feeding stuffs. The number of those species which breed or live in the Szigetköz for a longer period during migration is about 200–220. Some pairs of *Ardea purpurea* (purple heron), *Milous migrans* (black kite), *Ciconia nigra* (black stork) and *Pasio flammeus* (short-eared owl) nest in this area regularly.

Pine marten (*Martes martes*), ermine, albino rabbit (*Oryctolagus cuniculus*) and some species of bats are also frequent here from among the protected mammals.

The great variety of the Szigetköz can mainly be found in those separated areas which do not connect directly to the two larger units, that is, the forests joining the Mosoni Danube branch's meander and the Old Danube foreshore. There are a large number of living places of different types in the Szigetköz's relatively small area.

Fraxino pannonicae–Ulmetum, Querco robori–Carpinetum, etc. (which species' composition is similar to that of the forests existing along the banks of the Mosoni Danube branch) have remained wedged in between agricultural areas.

Marsh meadows that were characteristic of this landscape in the past have only remained in a small area in the Upper-Szigetköz, but in the Lower-Szigetköz they are more spread. These areas are the living place of lapwring (*Vanellus vanellus*), curlew (*Numenius arquata*), snipe (*Gallinago gallinago*). The North Field Vole (*Microtus* sp.), a Glacial relict, which was found by the research workers of the Hungarian Museum of Natural Science, lives in a place like this.

Preserved and rare species, like *Epipactis pallustris, Gentiana pneumonanthe, Iris sibirica* grow in thousands and tens of thousands in these meadows.

Butterfly and moth species not known before have been found in the meadows bordered by reeds.

Dry grasses have developed on higher levels where *Jurinea mollis, Orchis morion* and *Orchis ustulata* grow. These plants are found together with a special fauna.

The more than a hundred kilometre long system of drainage canals and the Old Danube branches is probably unique in Europe. This system, however, is only preserved in a small part as yet.

Relicts of *Alnatea glutinosae,* which are rare nationwide, can be found in several places here. Tearing Old Danube branches would develop mortlakes. There are such lakes at Lipót and Dunaszeg villages. The Lipót mortlake is valued as a water-fowl preservation area of international importance.

Summary

The Szigetköz Land Conservation District was founded in 1987 to preserve the specific river system, the typical flora and fauna of the Szigetköz. Its area is 3535 square miles, of which 511 square miles are strictly protected. We can differentiate three main parts of the Land Conservation District which touches 21 local governments' area:

- forests along the banks of the Mosoni Danube branch,
- flood plain of the Old Danube, and
- separated areas between the two branches.

Forty per cent of the forests along the banks of the Mosoni Danube branch are still in a natural state. The geomorphological values have still remained in this area. The most beautiful *Fraxino pannonicae–Ulmetum* and *Querco robori–Carpinetum* which have disappeared almost everywhere in Hungary can still be found here. A large number of Fagetalia species grow in these forests, the spread of which in the plain is interesting from a botanical aspect. The growth of an orchid, the *Ophrys apifera,* was not confirmed in other areas of Hungary in the last years. Hence, it is a national interest to save the population growing here. Natural life societies were driven back into the foreshore of the Danube. One of the causes is that *Populus hybrida* was planted here in the place of the former shrub-willows, meadows and soft-wood parklands. The separated areas have preserved the mosaic style of the former Szigetköz landscape, flora and fauna. There are forests, fenwoods, marshlands, meadows, Old Danube branches, mortlakes. These small and easily damageable areas constitute the richest treasury of the Szigetköz species because of their variety.

DAMAGE TO BUILDINGS IN THE SZIGETKÖZ AFTER THE DIVERSION OF THE DANUBE*

(CRACKING OF HOUSES IN THE VILLAGE OF LIPÓT)

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The antecedents

A hydroelectric power station has been built in Slovakia at Gabčikovo. Therefore, the Danube has been diverted from its original main bed into a canal covered by water-proofing membrane (Figure 1). After the diversion of the Danube, reports on house cracking damage arrived from several settlements in the Szigetköz. One of the most flagrant cases is the village of Lipót where from the about 230 houses more than 100 have been damaged according to the inhabitants' reports.

The Ministry for Environment and Regional Policy (Hungary) commissioned the Eötvös Loránd Geophysical Institute of Hungary to study the hydrogeological and soil mechanical problems in the area in 1993 and 1994 in co-operation with the Geological Institute of Hungary and the Geotechnical Department of the Budapest Technical University.

The course of investigations and their methods

As a working theory, we started off from the knowledge on the regional geology, geophysics and hydrogeology of the area. The main point is that the river entering the plain near Bratislava deposited a gravel and sand alluvial fan of 500–600 m thickness and 3000 km^2 extension during the Quaternary period. Till the diversion, the Danube flowed on the surface of this deposit and recharged one of the largest freshwater resources in Europe with its high quality water. A close correlation was observed between the water level in the river and the water table in the wells drilled on the two large islands of the alluvial fan. It is also significant that the gravel and sand are overlain by fine-grained formations in some places.

We have gained the experience in other regions of our country as well that the volume of overlying clay might strongly depend on its water content ("swelling clay"). The water content, on the other hand, might strongly depend on the depth to the water table, which is determined here by the water level in the Danube. Based on these, our tasks might be grouped into three areas:

* The authors would like to express their thanks to the Ministry of Environment and Regional Policy for getting this task. We are also grateful to István Láng, Member of the Hungarian Academy of Sciences, and to the team led by him who co-ordinated our work, helped us and made it possible to publish this study. Finally, we owe thanks to our colleagues: Miklós Juhász at the Geotechnical Department of the Budapest Technical University, György Tóth and Zoltán Kuchen from the Geological Institute of Hungary, and János Stickel from the Eötvös Loránd Geophysical Institute of Hungary, whose analysing and interpreting studies were used. Thanks are due to László Verő, from the Eötvös Loránd Geophysical Institute of Hungary, for the English translation.

1. Study of the geological structure in detail (mapping the thickness and extension of clayey overburden). This has been solved by geophysical methods (electromagnetic profiling, DC resistivity profiling, ground penetrating radar and engineering geophysical sounding).

2. We have analysed the changes in time and space of data from monitoring wells located in a few kilometre vicinity of the village. This task was performed by the geologists of the Geological Institute of Hungary, based on data from wells drilled by this Institute (their location map can be seen in Figure 2).

3. Samples were taken from different depths, from different soil types and their mechanical properties in function of water saturation were studied by the Geotechnical Department of the Budapest Technical University.

Finally, these three data sets were united and conclusions were drawn. Let us now briefly discuss the most important results of the individual stages of the work.

Results of the geophysical measurements

The location of geophysical profiles and soundings can be seen in Figure 3. There are both qualitative and more accurate ones among the methods listed above. We present an example for each of them. Profiling methods are qualitative, but they well reflect the sudden vertical and lateral changes in the geology of the area.

In Figure 4 results of horizontal resistivity profiling are shown. In the upper part of the figure, apparent resistivity values for four investigation depths are plotted (measurements were carried out at 5 m intervals). In the lower part of the figure, a resistivity pseudo-section is plotted down to a depth of 5 m (with strong vertical exaggeration). As interpretation we concluded that the resistivity of the coarse-grained sand and gravel is up to several hundred Ohmm, while that of fine-grained clay is about 10 Ohmm. There are sections within the about 1 km long profile where gravel can be found on the surface underlain by clay (e.g. around stations 200 and 800). In another section – between stations 400 and 500 – clay can be found down to the depth of 5 m. Finally, there is a section where the overburden consists of clay and it is underlain by gravel (between stations 550 and 600).

Engineering geophysical sounding assures a better vertical and lateral resolution, but it is a more expensive method. With the computer-controlled equipment, a tube is pushed down into the soil (here down to a depth of 10 m). The cone resistance with a standard cone and the total power required to penetrate the layers are continuously measured while the tube is pushed down; after that radiometric measurements are carried out within the tube. Values of bulk density and natural gamma activity of the rocks can be determined from them. An expert system (built into the computer) interprets all the measured parameters simultaneously and translates them into geological terms (e.g. clay, sandy clay, sand, gravel, etc.). Thickness of the individual layers or depth to a boundary can be determined with an accuracy of 10 cm. The water level can also be measured if filter section is implemented. Soil and groundwater samples suitable for laboratory analysis can be taken.

Figure 5 shows a geologically interpreted section of engineering geophysical soundings (for the location see Figure 3). This section represents a line which runs close to the most severely damaged houses. It can be seen that there is a 1–2 m thick clay overburden everywhere, underlain by sand and gravel. It is very important to observe where the water table at the time of measurements was. At the two edges of the figure the water table can be found in clay, while in the middle of the profile it is located in the underlying sand and gravel layer. In this section drying up of the overlying clay has already begun.

Data from water level monitoring wells

Water level data from monitoring wells had been studied continuously also prior to the diversion of the Danube and we have data of two years after it too. Figure 6 shows a section of three years of the data set from one well in the village of Lipót, while the calculated model of the water level that could be without the diversion is also shown. It can be stated from this figure and from Table 1 that the average water level has significantly dropped in the wells after the diversion (more pronounced close to the Danube, less significant further away: the average drop in the water level changes between 0.7 and 1.3 m inside the village of Lipót).

Fluctuation in the water table was larger prior to the diversion, but what is even more important, the high water level lasted much longer. It occurred only three times after the diversion (in November–December 1992; in July–August 1993 and in April 1994) that a significant volume of water flowed in the bed of the Old Danube.

The third essential statement is that in spite of the water table fluctuations, even the lowest water levels were located within the clay overburden (where it can be found at all in the near surface) prior to the diversion. After the diversion, however, there are areas where *even the highest water level does not reach the bottom of the clay overburden.* The serious consequences of this will be discussed later.

Laboratory analysis of soil samples

Soil samples were taken from three depths at some stations along the integrated geophysical profile measured inside the village of Lipót. The selection criteria were to get samples from each characteristic layer both from below and above the water table. Grain size frequency distribution and compressibility analysis of the about 20 samples were performed in a laboratory.

Summarising the results, it is important to emphasise:

1. Within the layers – which seem to be more or less homogeneous in the geological section – formations of different properties can be found according to the grain size frequency distribution analysis; e.g. among the plastic and hard versions of lean and fat clay, silty clay can be found as well. The clay layer is underlain by silty mud, silty sand and sand. The permanently water-saturated zone consists of beds of sand, pebble and sand of different compactness as well as of larger-size gravel.

2. Modulus of compressibility for clayey and silty formations is lower than 10; while this modulus for coarse-grained formations is 10–40 times higher. Measure of compressibility is primarily determined by compactness in sandy and gravel soils, on the other hand, it is determined by the so-called initial water content in clayey soils. As a consequence, mechanical properties of coarse-grained soils are less influenced by changes in water saturation. However, in clayey soils the water content is decisive. It means that the formations in the uppermost 4–5 m thick zone behave very differently under load, depending on their water content.

3. A permanent drop in the water level might cause a sinking of several centimetres in the clay layers as a consequence of compression. It is of even greater importance that these clays might lose 5–20% of their volume due to drying up, while changes in the volume of coarse-grained rocks are negligible compared to this.

A summarising assessment of the investigations

Geology of the near-surface layers in this area is highly variable both vertically and laterally. In some places gravel, in others clay can be found in the uppermost 2–5 m depth interval.

The clay is of swelling type which might lose 5–20% of its volume when drying up. On the other hand, the volume – and thus the load-bearing capacity – of sand and gravel is practically less dependent on water saturation.

It can be deduced from the data of the monitoring wells that the annual fluctuation in water level is about 2–3 m (both before the diversion and after it) – in close correlation with the water level in the Danube – first of all in areas close to the river. In the village of Lipót the average water level after the diversion is, however, 70–130 cm lower than before.

Boundary between the clay overburden and the terrace gravel was determined by geophysical measurements. Comparing the thickness of layers and depth to the boundary with water table data (Figure 7), it can be stated that water level fluctuation took place within the clay overburden prior to the diversion, at present, however, there are areas where the water table does not reach the clay even during high water level (see the area marked in Figure 8). Here a drying up process has already taken place with the associated sinking of the relief. This might cause damage to houses, particularly if it is taken into account that the thickness of layers might change within the dimensions of a house.

The situation is presumably the worst in those areas where the water table can be found within the clay in some period of the year, while in the gravel in another period. Here the surface sinks due to the drying up of clay in one period of the year; then the groundwater reaches the clay in the other period, it begins to swell and the surface rises. This kind of change is presumably even more harmful to the houses than the previous case.

We deem it necessary to emphasise that the water level, of course, also fluctuated prior to the diversion and damage to poorly founded houses occurred earlier, too. The drop in the water level, however, causes a substantial change, because clay becomes dry in certain areas. When the lower part of the clay is in contact with the water, the capillary fringe rises the water high above the water table. When the water table sinks, however, into the underlying gravel layer, this capillary rise practically ceases to exist and the drying up and volume decrease of clay start intensively.

Summary

The reason for the unusually high number of house cracking in some settlements in the Szigetköz after the diversion of the Danube was studied using geophysical, hydrogeological and soil mechanical methods. The conclusion was drawn that "swelling clay" can be found on the surface in some areas which began to dry up permanently as a consequence of an average drop of e.g. 70–130 cm in the water table in the village of Lipót. This is equivalent to a 5–20% decrease in volume. Sinking of the relief associated with this could be the reason for house cracking.

Table 1

Data of the water level monitoring wells

Identification number of the well	9440	9441	9442	9443	9446	9444
Distance from the Danube (m)	0	800	1500	3100	3900	4400
Before diversion						
Maximum water level (m)	117.1	116.9	116.0	115.7	115.6	115.3
Minimum water level (m)	114.1	114.2	114.0	113.7	113.9	113.7
Average level (m)	115.4	115.4	114.8	114.6	114.6	114.4
Fluctuation (m)	3.0	2.7	2.0	2.0	1.7	1.6
Standard deviation	0.56	0.29	0.26	0.28	0.14	0.14
After diversion						
Maximum water level (m)	115.3	115.2	114.2	114.4	115.0	114.5
Minimum water level (m)	113.1	113.4	112.9	113.7	113.8	113.6
Average level (m)	113.9	114.2	113.6	114.0	114.4	114.0
Fluctuation (m)	2.2	1.8	1.3	0.7	1.2	0.9
Standard deviation	0.33	0.24	0.13	0.05	0.09	0.04
Average drop in water level (m)	1.5	1.2	1.2	0.6	0.2	0.4
"Drying up" drop of water level (m)	1.8	1.7	1.8	1.3	0.6	0.8

Figure 1

Map of the Szigetköz with the line of the diverted Danube

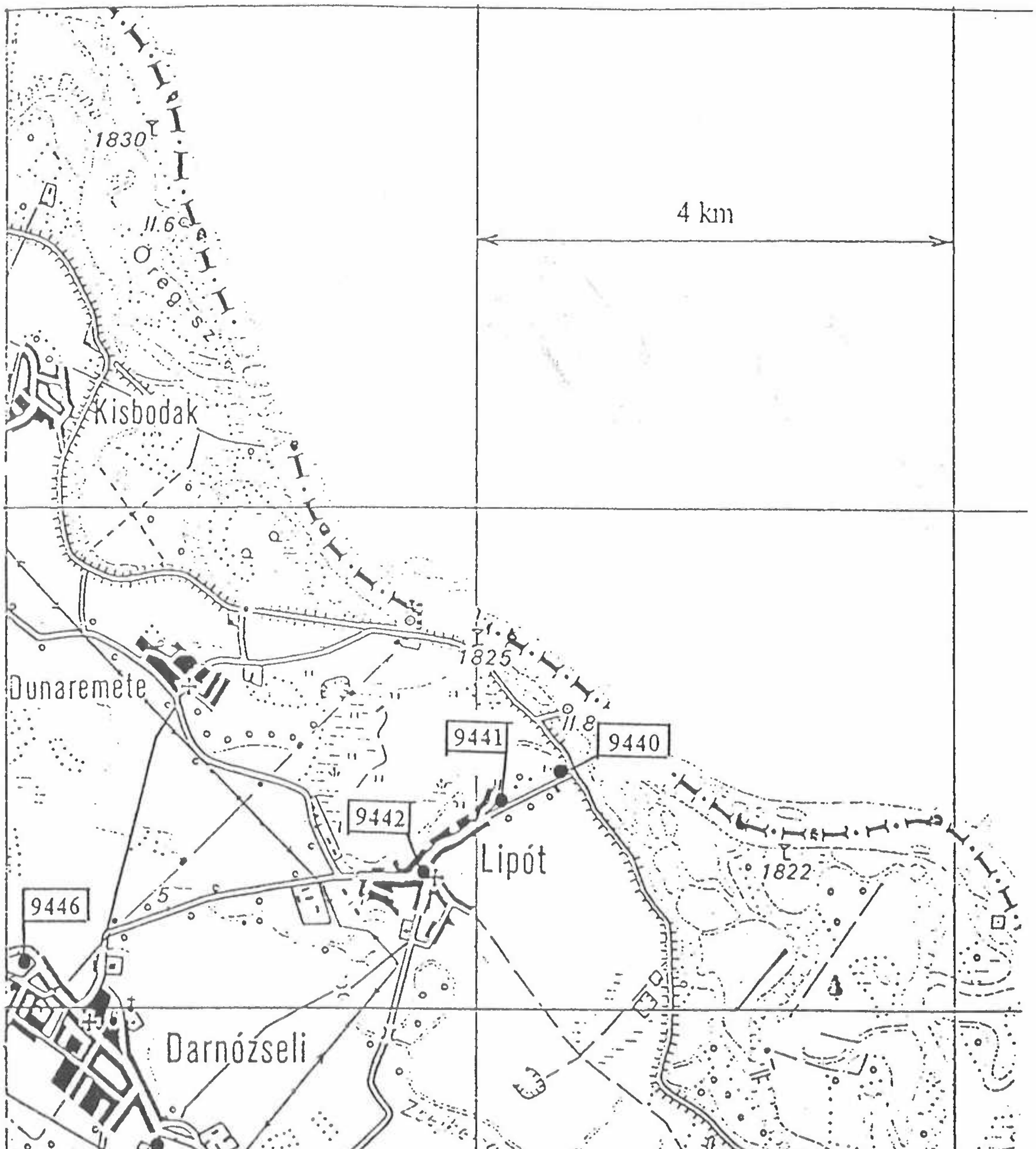

Figure 2

Map of the surrounding of the village of Lipót with the location of the water table monitoring wells in its vicinity of some kilometres

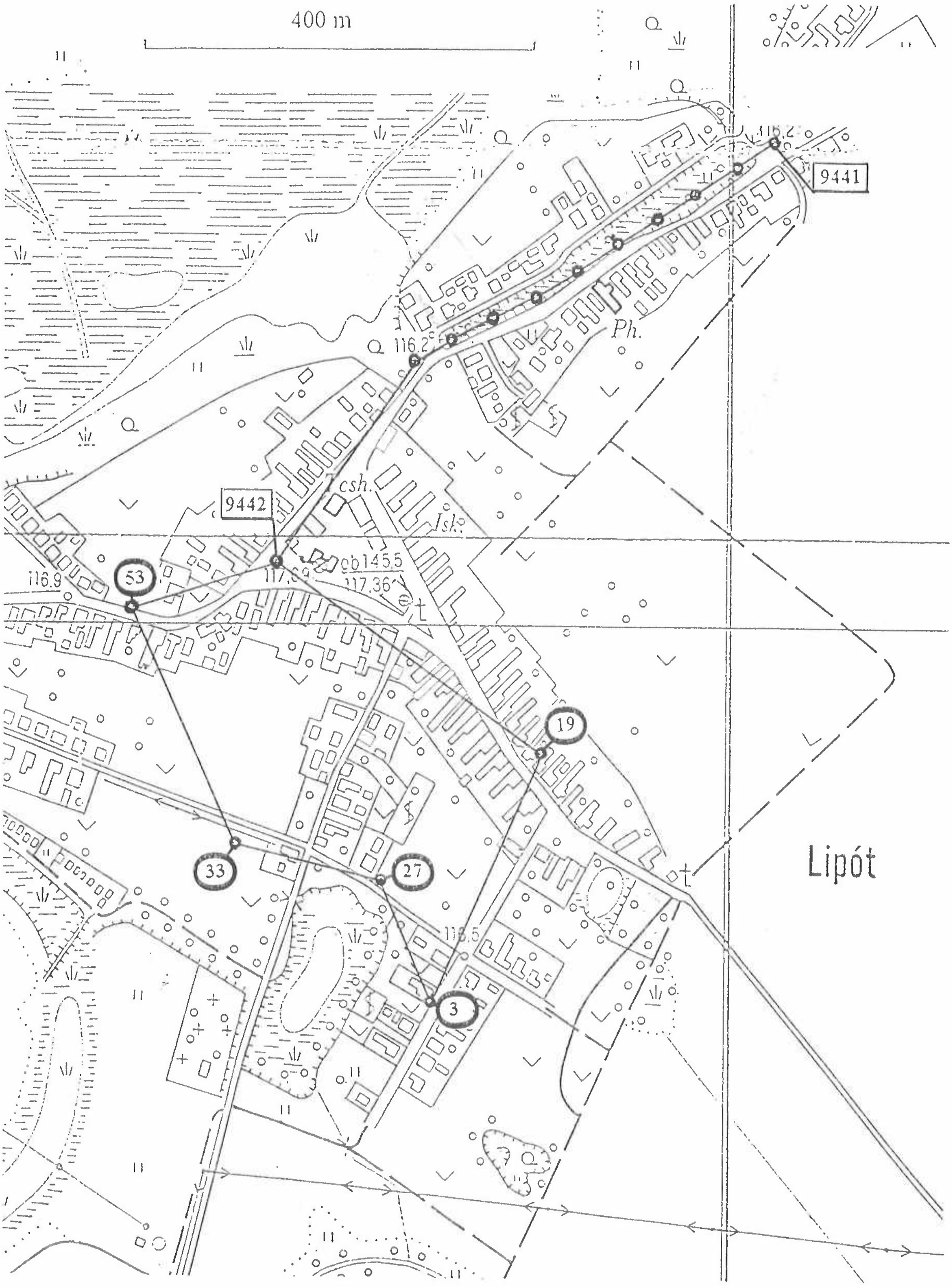

Figure 3

Location of geophysical measurements in the village of Lipót (circles are the places of engineering geophysical soundings, resistivity profiling was carried out along the line between wells No. 9441–9442)

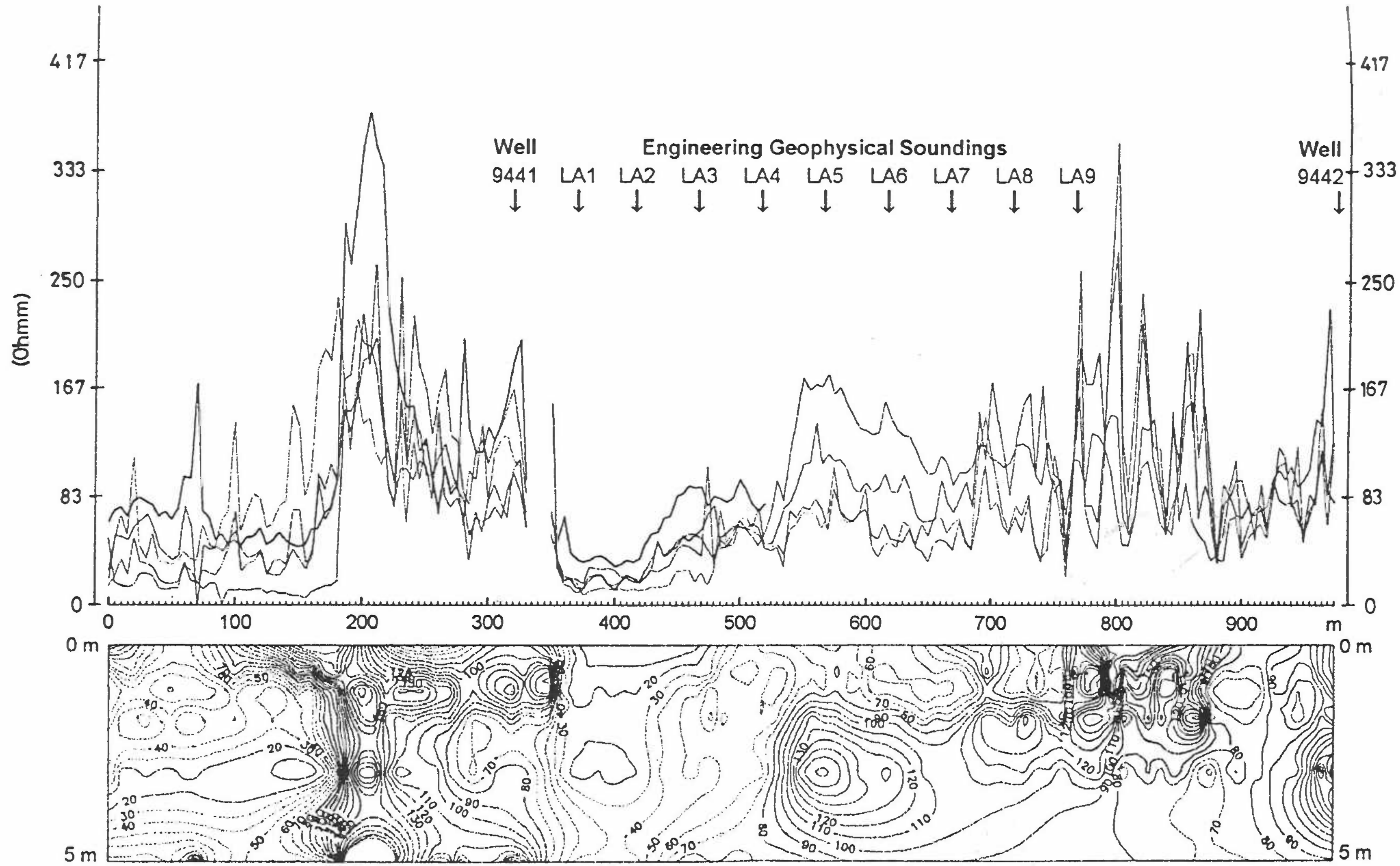

Figure 4

Horizontal resistivity profile and pseudo-section measured in the village of Lipót

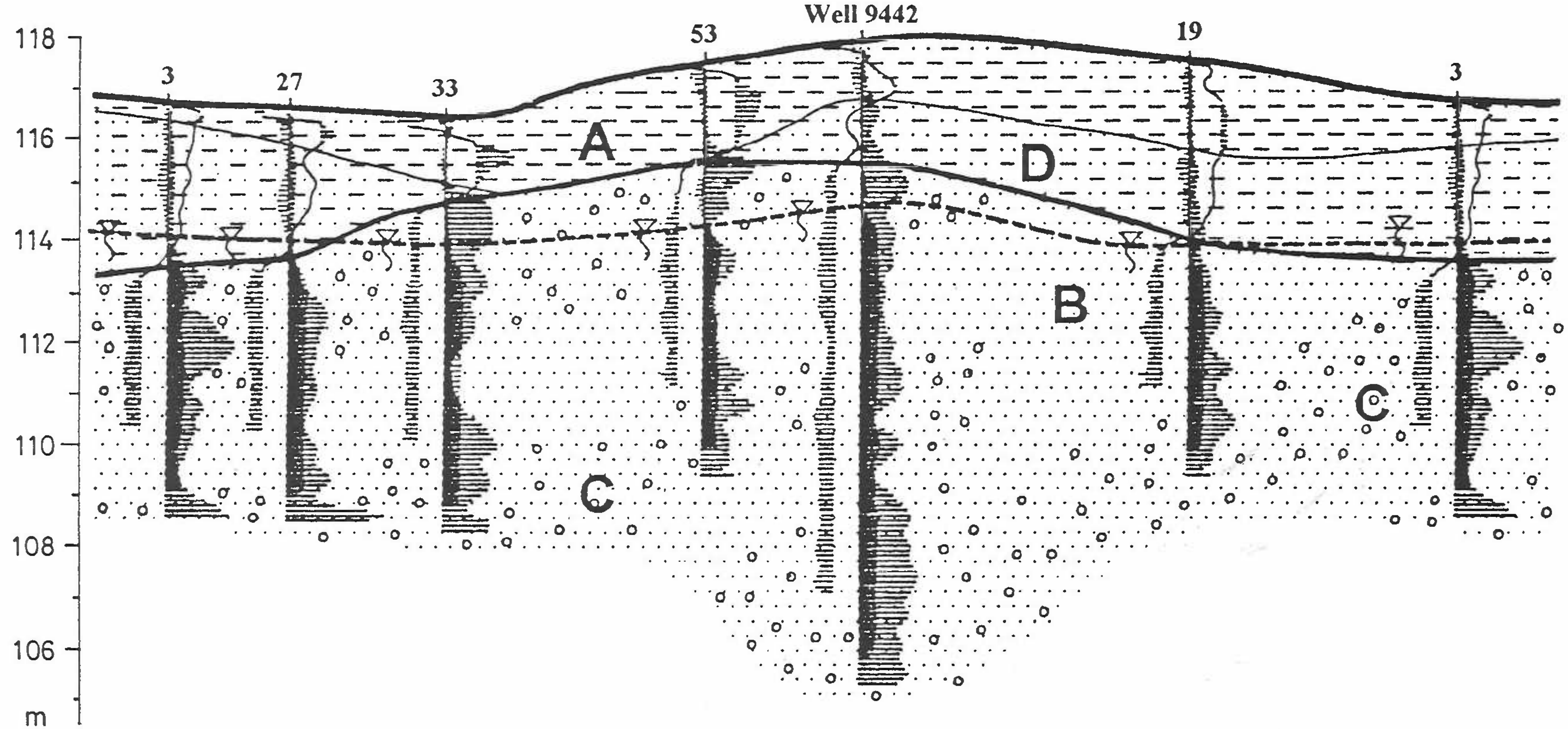

Figure 5

Geologically interpreted section of engineering geophysical soundings measured inside the village of Lipót (for the location see Figure 3)

A: clay; B: sand; C: sandy gravel; D: silty sand

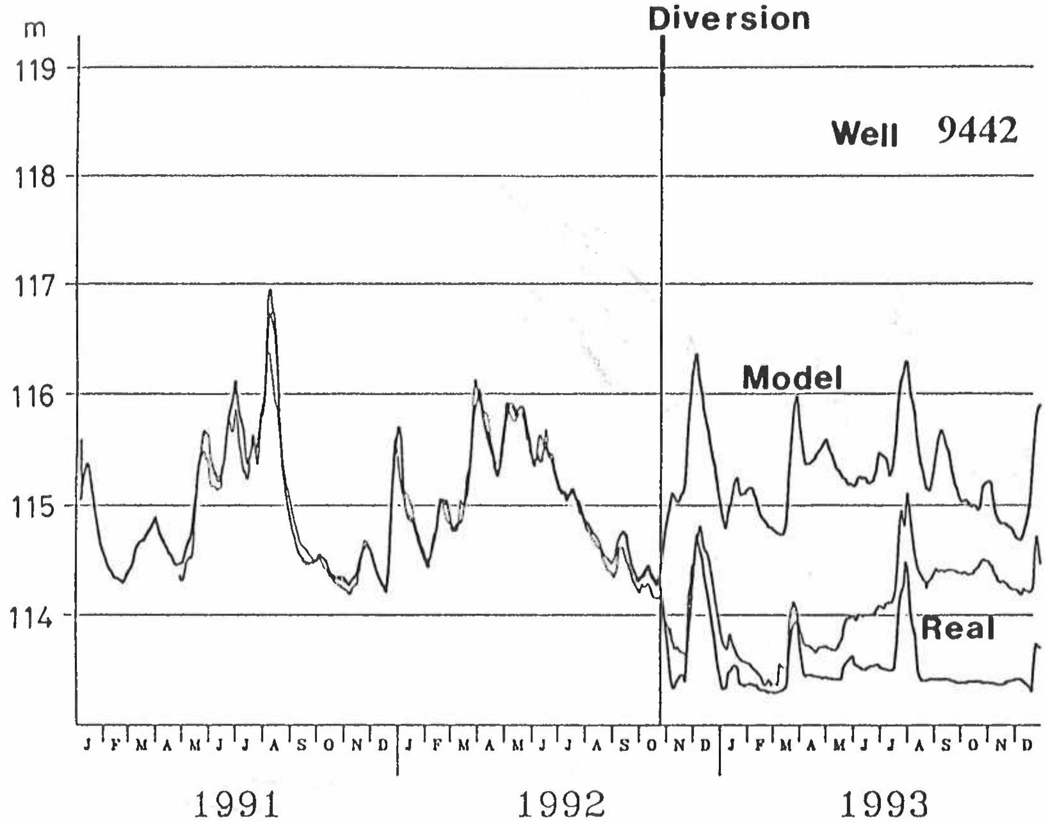

Figure 6

Diagram of the water level from well No. 9442 before and after the diversion (a calculated model of the water level that could be without the diversion is also shown)

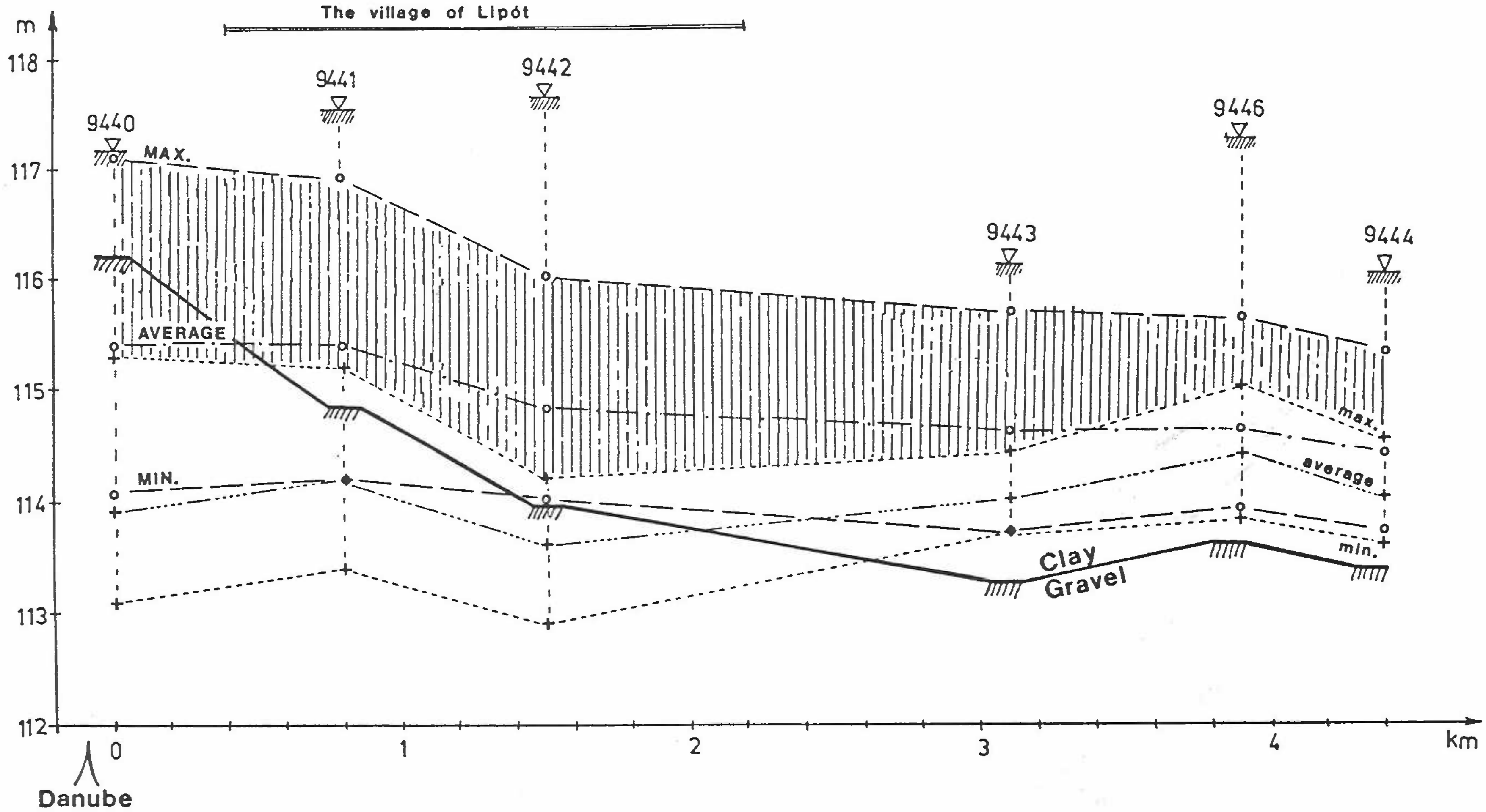

Figure 7

Diagram of the observed water levels in the monitoring wells versus distance from the Danube. Maximum, minimum and average levels are shown both before (in capital letters) and after (in lower case) the diversion. The "drying up" zone is hatched. The boundary between the clay overburden and terrace gravel is also shown

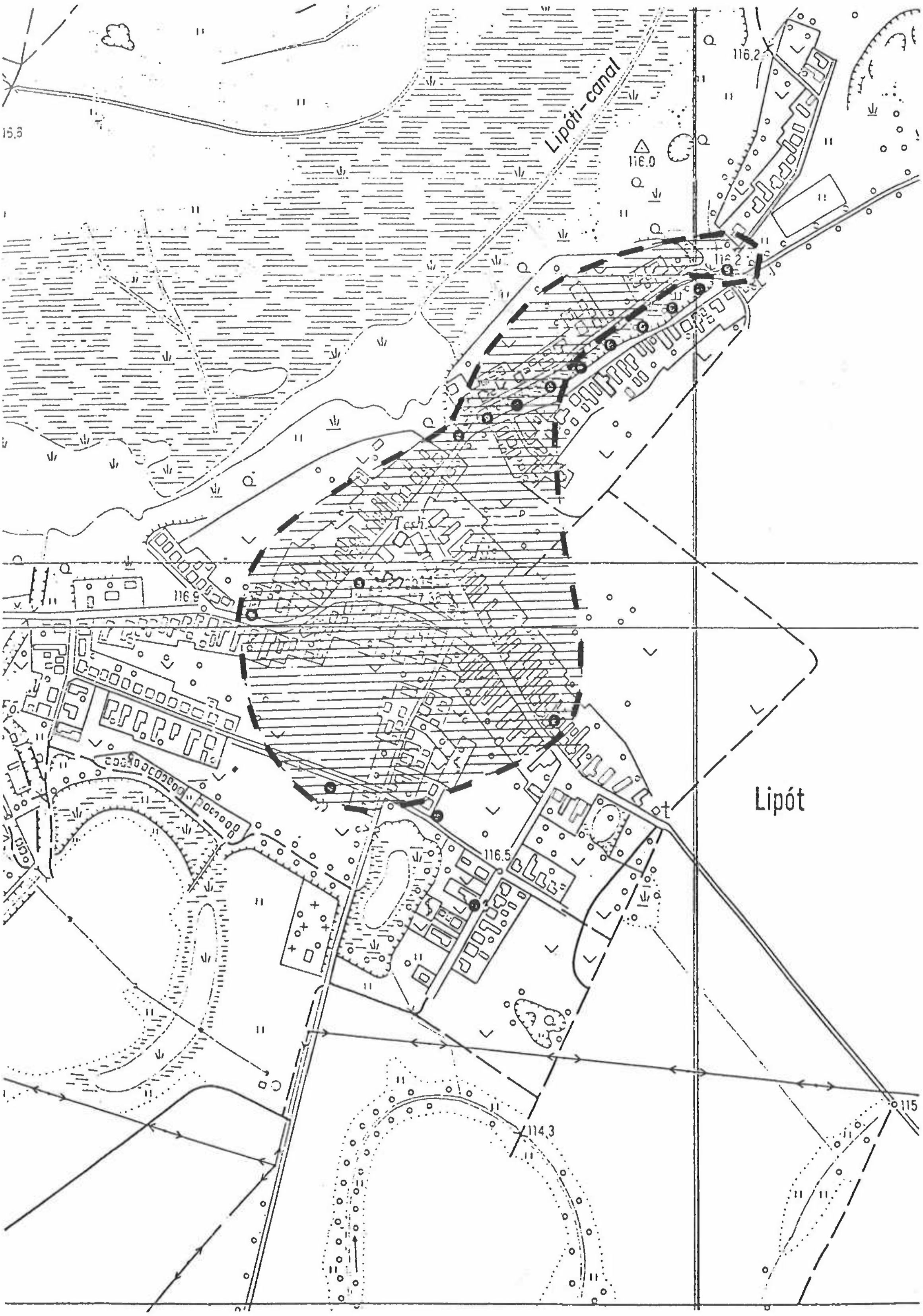

Figure 8

Site map of the village of Lipót with the area of zone where the water level is already in the sandy-gravelly layer (not any more in the clayey upsoil!)

CHANGES OF THE HYDROBIOLOGICAL CONDITIONS IN 1993–1994*

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The hydrobiological changes having been monitored since the diversion of the Danube in October 1992 were surveyed in both 1993 and 1994. We based these investigations on our previous studies on the hydrobiological status of the area, which partly included the effect of the water engineering manipulation in connection with the construction of the Gabčikovo–Nagymaros river barrage system.

On the basis of the experience we gained in our previous studies, two basic principles are to be mentioned as an introductory evaluation of the hydrobiological changes in 1993 and 1994.

Relationship between hydrobiology and water quality

The hydrobiological status is not equivalent with the water quality status, though there is a close relationship between them. The hydrobiological status is a complex system which is formed by the relationships of the environmental conditions (ecological characteristics) of the water bodies and their communities. The water quality status is a characterisation, an evaluation for the purpose of the utilisation of the investigated water on the basis of selected parameters.

However, this difference does not mean that knowledge on the hydrobiological status is only valuable and necessary for science, and that from a practical point of view it is enough to focus merely on the water quality status. On the one hand, the hydrobiological status includes water quality (but without overstressing its parameters), on the other hand, it also characterises (as generally as possible) the area where the reactions take place and the water quality changes occur due to external effects. Through this process, the water quality status is in close correlation with the hydrobiological status.

The information value of hydrobiology

While following the changes of the hydrobiological conditions in the surface waters of the Szigetköz region, an obvious question arises: why should the hydrobiological consequences of the changes in the hydrological regime be monitored? The reason for carrying out such studies is as

* The study was supported by the Hungarian Ministry for Environment and Regional Policy.

follows: when, for example, water disappeared from an area, it led to the ultimate disappearance of aquatic life; or when, at another site, the water body considerably shrank, or the light, heat or sediment conditions and the dynamics of the water changed, not the previously recorded 255 algae, but another 180 could be found, and the dominance structure and production characteristics of the zooplankton basically differed from those of the previous period. In this case, the focus is not on the genetical variety, on biodiversity, though that is also important in the mentioned biological systems.

The importance of hydrobiological changes cannot be recognised in its integrity, unless we are aware of the fact that the natural, economic and social relationships and processes in the Szigetköz region are basically determined by the special hydrographical and hydrological conditions of the area. As a result, any changes influencing the water bodies can trigger a chain reaction with direct or indirect effects.

An extremely difficult horizontal and vertical interaction network with special dynamics has developed in the surface water system of the Szigetköz region, including both the dike-protected and the non-protected parts of the flood plain. The disturbance of any part of the network can cause extended perturbations through multiple reactions.

It is important to remember that in these systems water is the medium of life, a solvent, as our waters are weak solutions transferring essential substances and the products of metabolism. Good examples of these processes are the material fluxes to and from the flood plain forests between the side arms, when they are overflooded or after floods, similarly to those which follow the artificial separation of a side arm, resulting in an important decrease in the water mass and the discontinuance of water movements.

Short characterisation of the hydrobiological changes

After these general remarks, some important changes in the hydrobiological status since the diversion of the Danube (October 1992) are discussed here with special emphasis on the years of 1993 and 1994.* The investigations were carried out at 43 sampling sites.

In the main arm (the so-called Old Danube, a 41 km stretch of the abandoned river bed between 1852 and 1811 river km) the following changes have taken place:

- an approximately 90% water loss and disconnection with the underground waters,
- channel erosion,
- the beginning of stagnant water area development,
- fast invasion of macrophyton communities (including Elodea nuttallii, a new exotic species indicating sedimentation),
- spreading of willow shrubs.

* The following researchers participated in the monitoring and evaluation of the hydrobiological changes: Anna Abaffy-Bothár (research area: planktonic Crustacea: Cladocera, Copepoda), Árpád Berczik (river ecology), Magdolna Csutor-Bereczky (planktonic protozoa), Mária Dinka (sediment chemistry), Gábor Guti (fisheries ecology), Keve Tihamér Kiss (phytoplankton, trophity), János Nosek (macroinvertebrates), Nándor Oertel (biomonitoring), Miklós Puky (littoral fauna), Borbála Ráth (macrophyton communities). Water chemistry analysis was carried out by the laboratory of the Hungarian Danube Research Station of the Hungarian Academy of Sciences.

Trophity increase

The above findings refer not only to the 41 km stretch examined, but also to the more than 30-year-long trophity changes of the 180 km Danube section between Rajka and Göd. From the end of the 1950s to the end of the 1970s, the amount of the suspended matter decreased by 50%, while transparency increased by 100–200% at Göd (1668 river km) due to the retention capacity of the Austrian river barrages which were built during that period.

These tendencies continued even if in certain periods they were less intensive. As a result, between 1970 and 1980 the algae count increased by 8–10 times. Trophity increase was indicated not only by the algae count (or the chlorophyll-a content) but also by the continuous polytrophy of the water from spring to autumn with 60–100 million individual/litre, which replaced the previous trophic pattern with two peaks (beginning of summer, autumn). On the basis of long-term, continuous monitoring, the algae count has doubled in the first 200 km of the 400 km long Hungarian Danube section. Along the second 200 km section from Göd (1668 river km) to Baja (1480 river km), a similar absolute increase has occurred, so altogether the algal count has tripled along the Hungarian Danube section. Calculating with the average velocity, four days are needed for the water to flow across Hungary. The analysis of the phytoplankton composition also provides opportunities for the characterisation of the trophity increase. This, however, is not discussed here in detail. The only result we mention is that in 1994 new phytoplankton (and zooplankton) species characteristic of lentic (standing or slowly flowing) waters were found in the samples. It is almost certain that they originated from the reservoir of variant C of the Gabčikovo river barrage.

Flood plain

Here the main changes are as follows: considerable water loss in the Cikola and Ásványi side arm systems, dried out river bed sections, stagnant waters, invasive macrophyton communities, the dominance of lentic conditions, lack of floods. The effect of the above-mentioned phenomena can also be detected in the vertical distribution of dissolved oxygen and the phyto- and zooplankton community structures in the remaining water bodies.

The effect of separation was investigated in the Schisler lake, a previously formed oxbow lake in the Cikola side arm system. The most important results of the studies were the following: sediment chemistry studies showed that the water and organic matter content of the sediment decreased with depth from the surface to the lowest investigated layer (35 cm). The concentrations of seven heavy metals in the sediment (one centimetre layers) were also measured. Characteristic trends were found (e.g. the heavy metal concentration considerably decreased from the tenth centimetre downwards).

The passive biomonitoring of heavy metals revealed that their concentrations in mollusc tissues were inversely correlated with the intensity of the connection between the four sites on the dike-protected or non-protected side of the flood plain and the Danube. Consequently, the heavy metal concentrations were the highest in the Schisler oxbow lake, which had a (surface) connection with the Danube. The Cd, Cu and Pb concentrations increased in the Schisler oxbow lake due to its separation and fast sedimentation.

Main arm flood plain

The loss of fishery has gradually increased. The previously 120 tons/year annual catch has gradually declined and the species composition of the fish communities changed after the separation of the side arms and the diversion of the Danube. The Mosoni Reach is the only water body which has not been reached by the damaging effect. Its general situation has become better and stabilised, though the pollution of the lower section is still causing problems. The loss of fishery in the Danube after the Gabčikovo river barrage had been put into operation (the diversion of the Danube) has been calculated as follows:

Damage type	Loss in million Ft
Fish kill (November, 1991)	15 – 21
Fish kill (winter, 1992–1993)	7 – 10
Fish kill (July, 1994)	1.5 – 1.7
Potential production loss (1993)	15 – 20
Potential production loss (1994)	15 – 20
Additional fish stock supply (1993)	6
Additional fish stock supply (1994)	3
Total	62.5 – 81.7

Short evaluation of the water supply

Flood plain

According to our knowledge, the water supply was 10–15 m^3/s in 1994, 50% of which filtered into the ground. It helped the survival of certain remaining water bodies but, naturally, could not restore the previous fundamental connection between the side arm systems and the main arm or the previous dynamics of the flood plain waters which determine their characteristic life conditions. The complete or partial lack of dissolved oxygen, which resulted in catastrophic situations in certain areas, was only insignificantly improved by the water supply. It could not support a higher water table either, which is of utmost importance in the water supply of the surface waters in many areas.

Protected part of the flood plain

Complete drying out and/or a considerable water loss characterised the overwhelming majority of the waters. Water supply efforts to improve the situation at least to a certain extent have been made since 1993.

The main axis of the water supply system has been created along the Zátonyi and Gázfüi Danube by connecting certain parts of the two previous river beds, which is an important tool to lessen the water loss. Along this approximately 35 km long stretch, five sites (Zát 1–5) were selected for monitoring water supply efficiency. The study revealed that the permanent presence of the water (due to the water supply) provided survival opportunities for several plant and animal groups and certainly improved the situation. Still, there is a basic difference between the original and the present status, namely: sections which had been typically lentic throughout most of the year became permanently lotic. This phenomenon is especially characteristic at four sites (Zát 1–3 and 5). Only Zát 4, a dead end branch of the system, means a really important refuge for the fauna and flora of the previously lentic sections.

Due to the present hydrodynamic conditions, the current velocity is high and as a consequence, the chemical characteristics of the water change only slowly, over a longer river stretch. Changes in the species composition and abundance of the phyto- and zooplankton communities reflect the above-outlined conditions.

The drying out and refilling of the strictly protected Lipót mortlake might be the most catastrophic example of the disappearance of valuable natural areas, in spite of the sham results of the water supply. The drying out of the mortlake was a consequence of the diversion of the Danube, because the diversion completely changed the water balance. There was no more temporal surface inflow, while the sharp decrease of the water table stopped the sub-surface inflow at the same time, which used to determine the water chemistry of the lake with its solvent characteristics and indirectly the basic environmental conditions of the plants and animals in the Lipót mortlake. In 1994 water from the main arm was pumped continuously into the lake. Although there was water in the lake, on the one hand a considerable amount filtered into the sediment, which had been filled by groundwater earlier, while on the other hand, it maintained a chemically new environment, which was similar to that of the main arm. This effect can already be seen in the composition of the macrophyton and to a certain extent also of the plankton communities. If these conditions become permanent, the local fauna and flora, on which the protection was based, can disappear in a few years.

The latest hydrobiological investigations indicated a strong decrease in the volume of the previously extremely variable surface water system of the Szigetköz region, a separation between the individual water bodies and a decline in the number of habitat types and communities. In the Szigetköz region, everything is in connection with water, so its fauna and flora, its biological status and sophisticated interactions are all important elements in any rescue operation of the area. The rescue strategy can only be successful if it targets the entire highly developed functional system.

Closing remarks

Having discussed the hydrobiological changes in 1993–1994, we would like to point out how unfounded a common critical remark is. According to a misleading counter-argument against the monitoring of the hydrobiological and ecological changes, there are no original natural, social, etc. values in the area, as everything is artificial due to the more than a hundred-year-old water regulation activity. We would like to emphasise again that till the end of the 1960s river regulation for flood protection and navigation had created a sustainable balance between economic, social, nature conservation and landscape protection interests, which could be kept by continuous maintenance. This situation of semi-natural water bodies has been eliminated by the water engineering manipulation in connection with the construction of the Gabčikovo–Nagymaros river barrage system, which has almost completely neglected the fact that environmental and landscape protection and nature conservation are first-class social priorities with a firm legal background and very important elements in decision-making processes, at least in the developed industrial countries.

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CHANGES IN THE NATURAL VEGETATION OF THE SZIGETKÖZ FOLLOWING THE DANUBE DIVERSION

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Changes of certain vegetation characteristics have long been used for the assessment of habitat properties (Clements 1920). The validity of this approach was also approved by the modern indicator theory (Juhász-Nagy 1970). Weaver (1924) was among the first scholars who used permanent quadrats to examine vegetation changes in prairies. On the influence of Braun-Blanquet (1928), this method became the general tool for studying vegetation dynamics. This sort of earlier research experience was taken into account in setting up the botanical monitoring system of the Szigetköz region in 1986. With this activity, our ultimate aim was to regularly collect and analyse signals of plant populations, communities and the regional flora, which indicate environmental changes. Thus our activity covered the registration and interpretation of the changes in three main areas, namely in the flora, and in certain indicator populations and communities.

Methods

Coenological indication: Vegetation of permanent quadrats was sampled yearly, when both species composition and abundance (A–D) were recorded. Based on these data it was possible to detect habitat changes (e.g. drying) occurring in the course of 5–10 years. A more effective way of data analysis is when species group spectra are also computed from the coenological tables of consecutive years. We introduced the measurement of the proportions of species groups formulated according to the moisture preference index (W value, Zólyomi–Précsényi 1964) and nature conservation rank (TVK value, Simon 1988) of the species.

Appropriate *indicator populations* can reflect habitat changes even more rapidly and sensitively. They can make it possible to study a large number of properties: like e.g. morphology, ecophysiology, phytomass production (Cairns 1979, Naveh–Steinberger–Chaim 1979, Kovács–Podani–Tuba–Turcsányi 1986). During our monitoring activity in the Szigetköz, we followed the changes of leaf surface area and shoot height of several indicator species (e.g. *Nuphar lutea, Plantago altissima, Phragmites australis, Quercus robur, Alnus incana, Salix alba*). Our study sites in the Szigetköz are listed in Figure 1.

The *flora* of the Szigetköz as well as the current status and vitality of the populations of protected and endangered rare plant species have regularly been monitored since 1986. As a result, the flora list has continuously been changing.

The study area

These sediments are characterised by a high carbonate content and a very heterogeneous grain size composition both vertically (stratification) and horizontally (patchiness). This highly diverse alluvium provided the matrix for the initial steps of soil development, i.e. humification and soil structure formation. As a result of these, various soil types occur in the Szigetköz, like crude alluvial soil, typical alluvial soil, humic alluvial soil and intermediates of these (Várallyay 1992).

In addition to the highly diverse geomorphology and soil properties, the regular yearly inundation is the most important ecological factor responsible for the development and long-term survival of the region's natural vegetation.

The Szigetköz is the largest seminatural flood area in the entire Danube Valley today. Its unique status explains the outstanding importance of its wetland habitats. Due to the region's particular geological, geomorphological, climatic, hydrological and soil properties, a great habitat diversity has developed, which in turn supports a high biodiversity. This is reflected equally in the large variety of plant communities, the high species diversity within communities and the unique species composition.

Results

Changes in the flora

Compared to our survey in 1986, the list of vascular plant species known from the area – the complete flora – increased considerably from 767 species in 1986 to 1008 species in December 1994. Our studies have revealed that this change is the result of not only the greatly intensified botanical research in the area, but is also due to the rapid invasion of weeds as a consequence of intensive agriculture and silviculture nearby. This colonisation process has amplified following the diversion of the Danube. The partly exposed Danube bed and the silty, sandy and gravelly bottoms of dried-up tributaries and oxbow lakes provide optimal conditions for the establishment of colonising weeds and adventive species (see Hahn et al., pp. 75–82 in the present volume). Compared to the weed list given by Czimber (1993) there are further weeds (e.g. *Chenopodium* and *Amaranthus spp.*, *Leonorus marrubiastrum*, *Lappula squarrosa*) and adventive species (e.g. *Parthenocissus quinquefolia*, *Tagetes patula*, *Lycopersicon esculentum* and *Mimulus guttatus*) involved in this invasion process.

Although the Danube diversion contributed to a higher diversity of the vascular flora, equitability decreased simultaneously, as the proportion of native floristic elements declined, while the ratio of weeds and adventive species became higher.

In the rich flora of the Szigetköz the proportion of protected, endangered, red-listed or endemic species is relatively high. Most of these have survived in small fragmented habitats, or live in populations of decreasing vigour and abundance in biotopes rapidly degrading and drying after the diversion of the Danube.

In summary, it can be stated that the values of the higher flora are threatened most seriously or are already disappearing in the Middle-Szigetköz.

Changes in the indicator populations

Indicator populations react to habitat changes fairly rapidly and sensitively. We studied several morphological features of these. The size of the assimilatory leaf area is an excellent indicator of the water regime of a given habitat. Measurements on the leaf area of forest forming dominant tree species (*Quercus robur, Alnus incana* and *Fraxinus pennsylvanica* at Dunasziget, and *Salix alba* at Kisoroszi) started in 1989 at two localities: one within the Szigetköz (Dunasziget), the other outside it (Kisoroszi). After the diversion of the river, leaf area measurements on *Salix alba* were extended to further two sites in the Szigetköz: to a flood area at Dunaremete influenced by the diversion, and to a control plot situated downstream of the place where the service canal flows into the main river (at Vének). Samples for the leaf area measurements were collected in autumn after leaf-fall. In each case, sample size was 200 leaves, and the average leaf area was calculated for these.

The results are summarised in Table 1. Leaf area proved to be a sensitive indicator in most species, particularly in the case of *Salix alba.* The influence of the river diversion is clearly reflected in the leaf area values, especially in the considerable decrease in 1993. At Dunasziget, for *Quercus* and *Alnus* the leaf area reached an average value for two years after the diversion (i.e. in 1993–1994), but it was 21–27% lower than the value for the years prior to it (i.e. in 1989–1992). For *Fraxinus* this trend could be observed only in 1993, as the higher precipitation in 1994 proved to be beneficial for this species.

Leaf area data of *Salix alba* are particularly informative, as leaf size remained practically the same (9.4 cm^2) in the control area, but decreased by 28% (to 6.8 cm^2) on the site at Dunaremete influenced by the river diversion. Some positive effect of the supplemental water input through pumping in the summer of 1994 could be detected: average leaf area was 7.1 cm^2 in areas with improved water regime, but only 6.0 cm^2 on sites not influenced by water recharge. However, it should be noted that the beneficial effects of water replenishment by pumping are restricted to a very small area.

Consequently, the decrease of the average leaf area indicates that trees experience a suboptimal water supply, which in turn markedly lowers their photosynthetic activity and biomass production. These can finally lead to the death of the flood plain willow forests within a few years.

Several herbaceous species (*Nuphar lutea, Plantago altissima* and *Phragmites australis*) are involved in our botanical monitoring studies carried out since the year following the Danube diversion. According to certain morphological characteristics and changes in several organ sizes of these plants, a general habitat drying was detected as a result of the drop of the groundwater table. Thus, for example, the mean leaf size of *Nuphar lutea* was 50% and 75% lower than that of the control samples in 1993 and 1994, respectively. The same trend can be observed for leaf width and length (Figures 2 and 3). Mean leaf size at Győrzámoly is significantly higher than that at Dunaremete.

In summary, although there are surviving and even flowering *Nuphar lutea* individuals – appearing as curious "terrestrial" forms of a floating aquatic macrophyte –, the species' complete extinction is anticipated within three years in the terrestrialised wetlands of the Szigetköz. This change is further accelerated by the mass invasion of native marsh meadow species and alien weeds in the exposed beds of the former oxbow lakes. These newcomers can rapidly outcompete the suffering aquatic plants.

Communities of common reed (*Phragmites australis*) are typical of shallow aquatic habitats and are under protection throughout the country. In stands occurring in the Szigetköz both plant height and stem diameter have decreased, thus reflecting unfavourable changes in habitat water regime. Shoot height was 10–25% lower on sites influenced by the Danube diversion (at Cveklapos and Lipót) than on control plots (at Kisbajcs, Figure 4). This phenomenon unambiguously indicates the beginning of habitat transformation under the protected marsh-reed phytocoenoses. Additional water was diverted towards the reed stand at Lipót in 1994. The beneficial effects of this intervention are well reflected in the reed growth data of 1994 (Figure 5).

The general habitat drying, commenced with the Danube diversion, is shown even more clearly for flood area meadows in the Middle-Szigetköz by the shoot height and leaf area values of the dominant tall plantain (*Plantago altissima,* Figure 6). These parameters were 200–300% higher on the control plot (at Szőgye) than on sites affected by the river diversion (at Dunasziget–Nyáros). In other words, the average leaf area and shoot height of tall plantains growing in "treated" meadows at Dunasziget decreased to the half or even one third of those of the control samples.

These results on common reed and tall plantain clearly indicate the rapid drying of wet habitats, which will ultimately lead to the destruction of these meadows of high biodiversity.

Changes in the plant communities

We have data on the vegetation and plant communities of the Szigetköz since 1986. These have been collected regularly as part of our botanical monitoring system. Results obtained during the first six years prior to the Danube diversion clearly showed that although the whole biota and vegetation in the Szigetköz had undergone certain changes, it still uniquely preserved the original flood plain vegetation in Europe. Flood area willow woods were in a more natural state in the Szigetköz even in the years of our monitoring studies than those elsewhere in the Danube Valley 30 years ago (Figure 7 and Simon et al. 1993).

The reason behind the above slight changes must be that in the past few years both the main Danube bed and its tributaries carried less water than what the original vegetation is adapted to. During previous years drought periods occurred frequently in the Szigetköz. In spite of these, no essential changes in the degree of naturalness and species composition of the characteristic dominant phytocoenoses appeared until the autumn of 1992.

In summary, it can be stated that the above two factors are responsible for the slow habitat drying that occurred in the past ten years. The resulting limited changes in the natural vegetation warned us that the plant communities on the flood plain and on the protected areas outside it could not tolerate any further drying without irreversible damage. This holds particularly true for the Middle-Szigetköz.

The influence of the Danube diversion in October 1992 on the vegetation of the Middle-Szigetköz was clearly reflected in the changes that occurred during 1993–1994. Botanical indications from these two years unambiguously showed habitat degradation, first of all drying and the invasion of weeds, and the first steps of vegetation pattern transformation. The tendency, the extent and the speed of degradation could be clearly recognised already during the first two years of the change.

After the river diversion, the proportion of water demanding species (e.g. *Impatiens glandulifera*) decreased, while the frequency of weedy or disturbance tolerant elements (*Fraxinus pennsylvanica, Urtica dioica, Rubus caesius*) increased in the hardwood gallery forests it the Dunasziget–Nyáros sample area. These show the beginning of habitat drying on the flood plains. The new ecological situation after the Danube diversion is favourable for species with wide tolerance range. In competitive interactions, species with higher degree of drought tolerance can succeed, while the abundance of hygrophilous plants declines.

Willow woods are even more influenced by water shortage, so the transformation of vegetation pattern is more pronounced in them (Dunaremete, white willow thicket, Figure 8). In the herb layer, the proportion of water demanding species (e.g. *Myosotis palustris, Myosoton aquatica, Poa* *palustris*) decreased substantially. Simultaneously, the ground cover of meadow components (e.g. *Agrostis stolonifera, Cirsium arvense, Bidens tripartitus*) became higher. With the substantial drying of biotopes, the vegetation succession speeded up towards the formation of willow-poplar gallery forests.

In summary, it can be declared that the water supply of the flood plains along the main Danube bed has worsened considerably in consequence of the diversion of the river. The original flora and plant communities are threatened there by a process of degradation which has already started. In areas along the Mosoni Danube, the degree of water shortage is smaller, so the degradation of vegetation is also less profound, at least for the time being.

Summary

The high diversity of plant communities is a characteristic feature of the entire Szigetköz, but most particularly of the flood areas along the main Danube and the Mosoni Danube. The community spectrum reflects the almost natural state of the region, and also shows that it preserved its ecological potential until the diversion of the river. Our biological monitoring studies carried out between 1987 and 1992 revealed that no essential changes occurred in the species composition and naturalness of the characteristic and dominant plant communities. The measurements and field surveys made after changing the course of the Danube clearly indicated the process of degradation, which consists of habitat drying, mass invasion of weeds, increasing abundance of drought resistant species, and significant decline of the assimilatory leaf area and other growth measures of plants.

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Table 1

Results of leaf area measurements (cm^2)

	1989	1990	1991	1992	Average leaf area	1993	1994	Average leaf area	Species
Dunasziget hardwood forest, impacted	55.6	46.1	35.1	42.6	44.8	27.6	39.0	33.3	Qercus robur
	37.4	31.1	20.6	25.2	28.6	18.3	27.7	33.0	Alnus incana
	16.2	21.4	16.2	25.0	19.7	12.3	23.5	17.9	Fraxinus pennsylvanica
Kisoroszi softwood forest, control	11.9	14.5	8.7	8.4	10.9				Salix alba
Dunaremete softwood forest, impacted						6.5	6.0 7.1*	6.8	Salix alba
Vének softwood forest, control						9.4	9.4	9.4	Salix alba

* The effect of the water pumping.

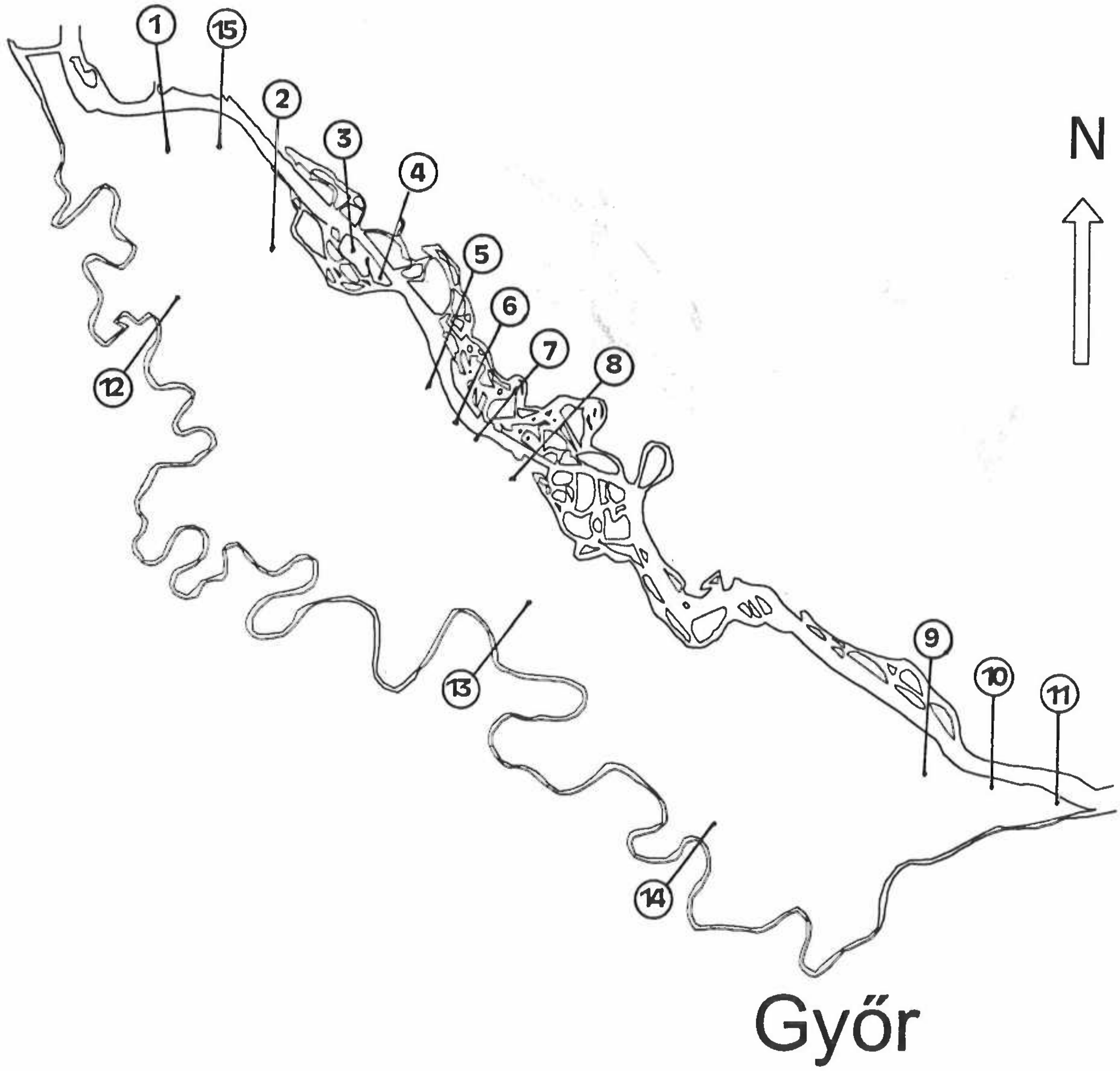


Figure 1

Study sites of botanical monitoring

1. hardwood forest; 2. reed-stand; 3. mesophilic meadow; 4. hardwood forest; 5. planted softwood (poplar) forest; 6. swamp; 7. willow woods; 8. reed-stand; 10. mesophilic meadow; 11. willow woods; 12. oak-hornbeam forest; 13. hardwood forest; 14. pondweed; 15. willow woods

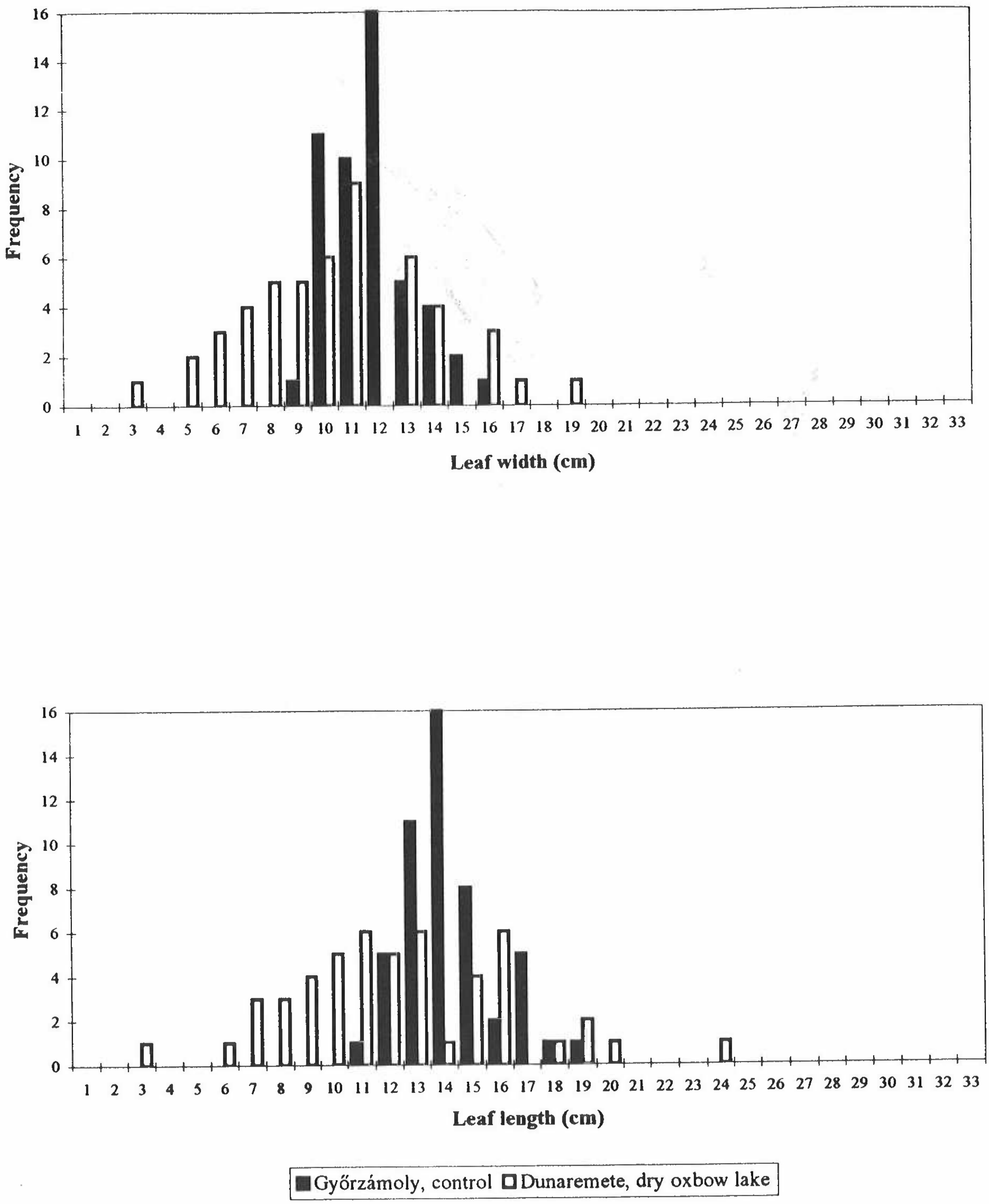
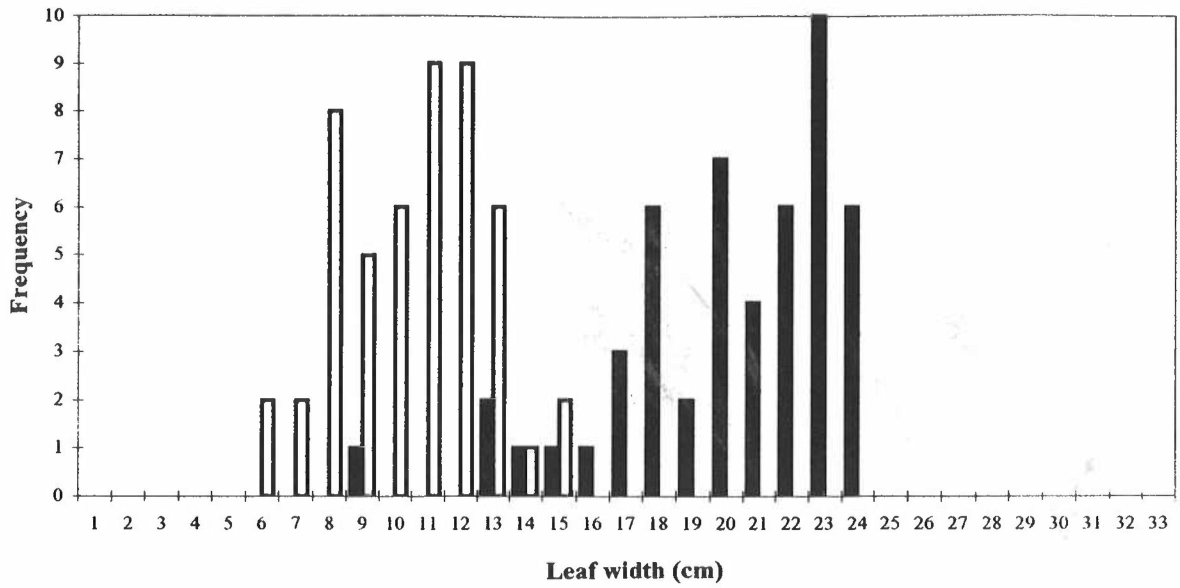


Figure 2

Leaf width and leaf length of *Nuphar lutea* in 1993



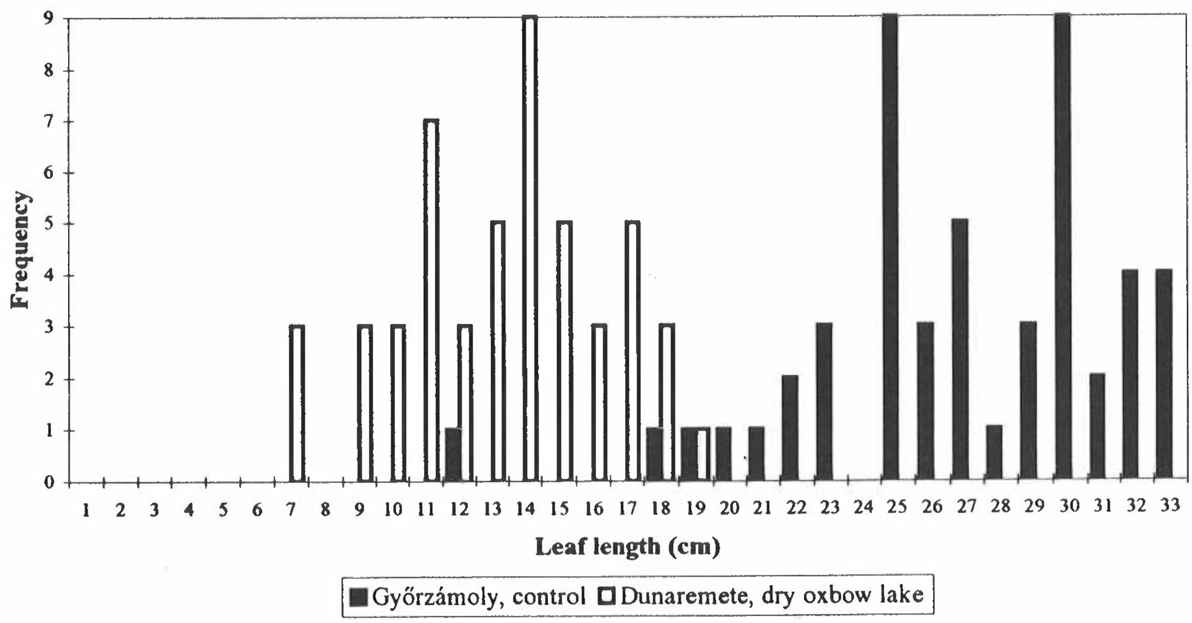


Figure 3

Leaf width and leaf length of *Nuphar lutea* in 1994

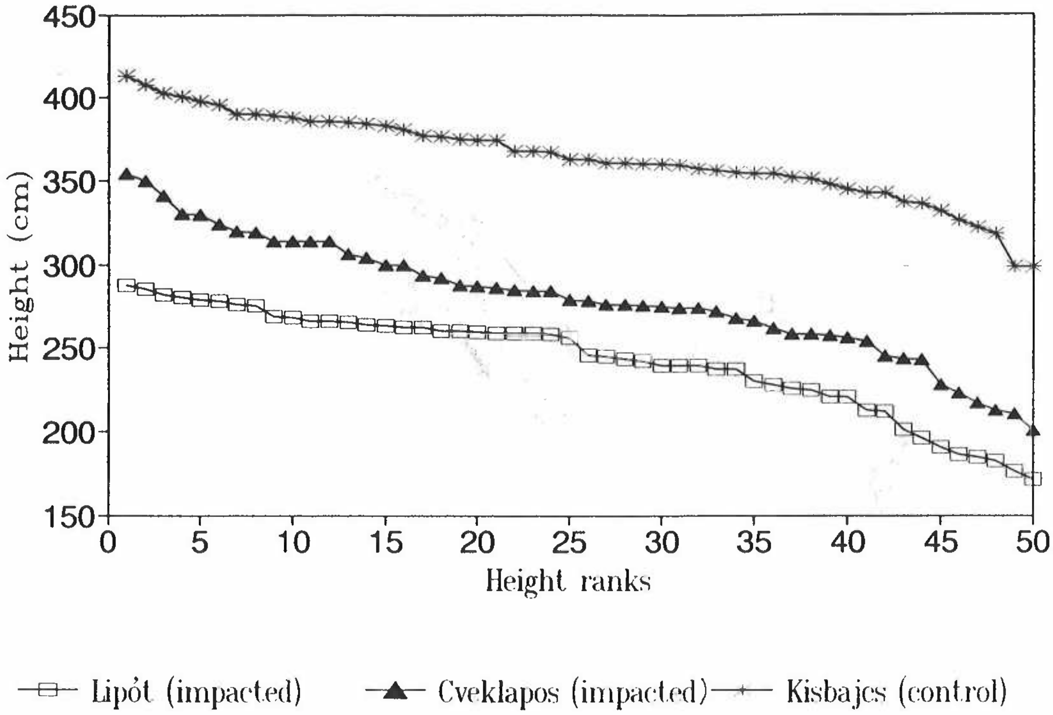


Figure 4

Height of reed individuals at the three study sites in 1993

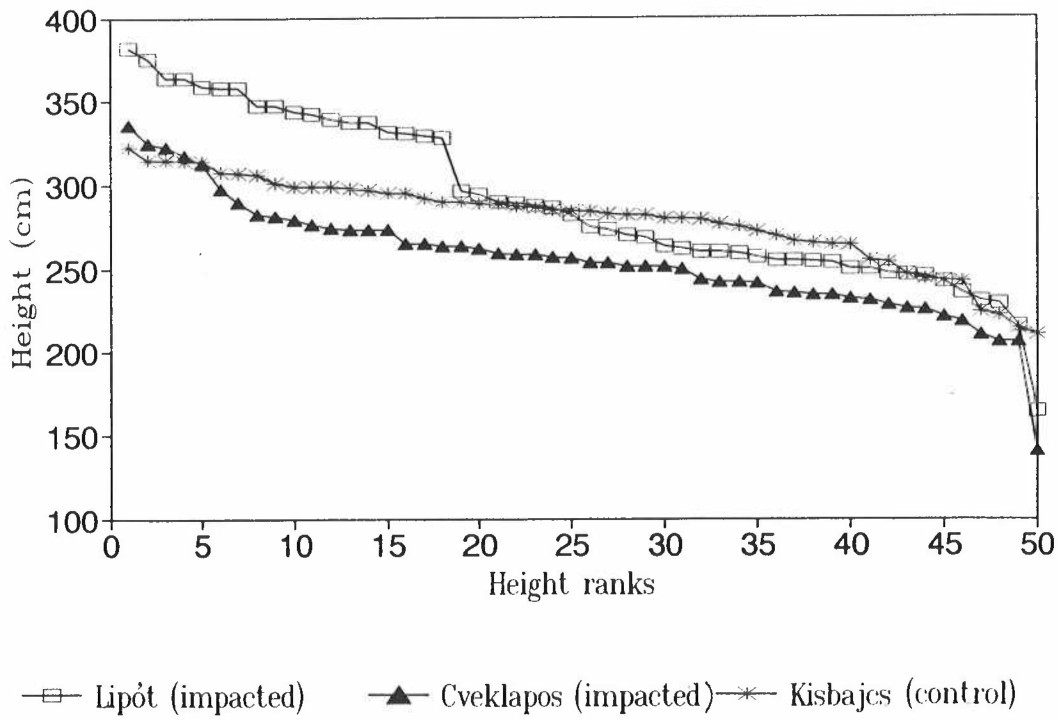
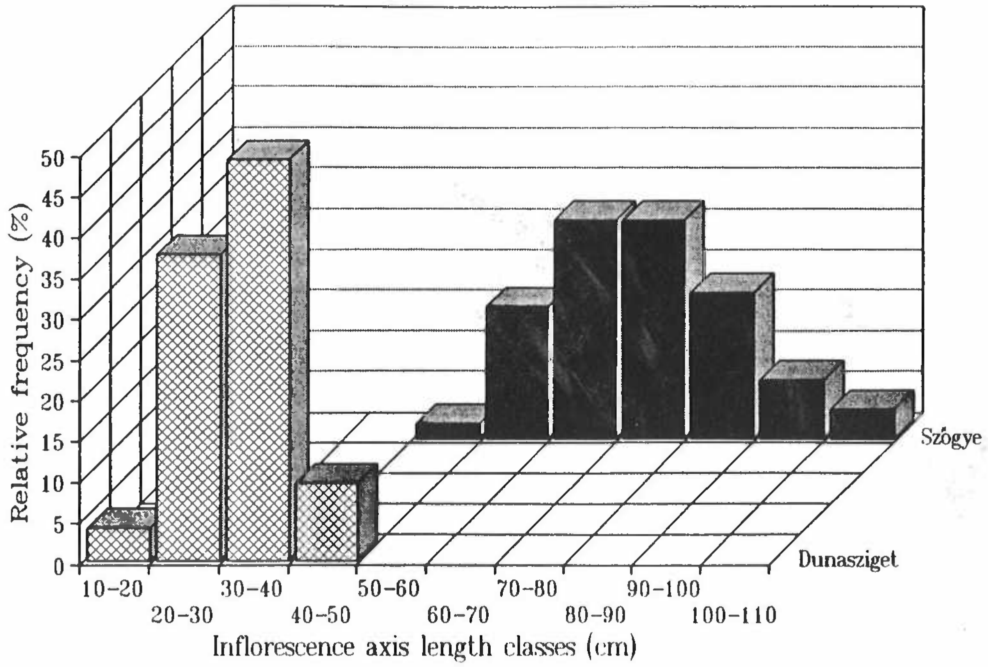


Figure 5

Height of reed individuals at the three study sites in 1994



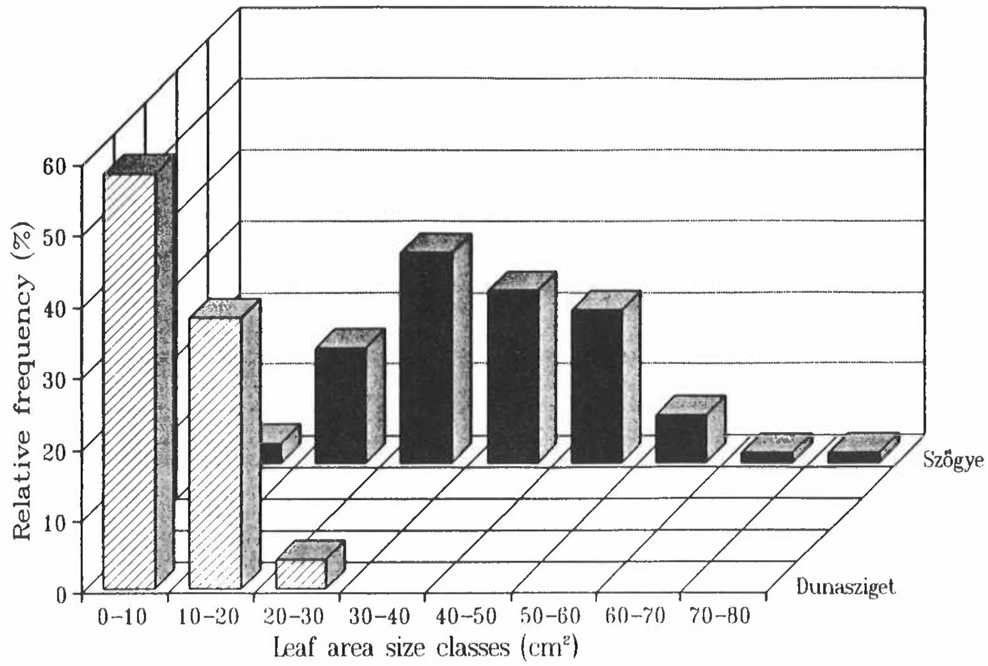


Figure 6

Distribution of leaf area sizes and inflorescence axis lengths at the two study sites

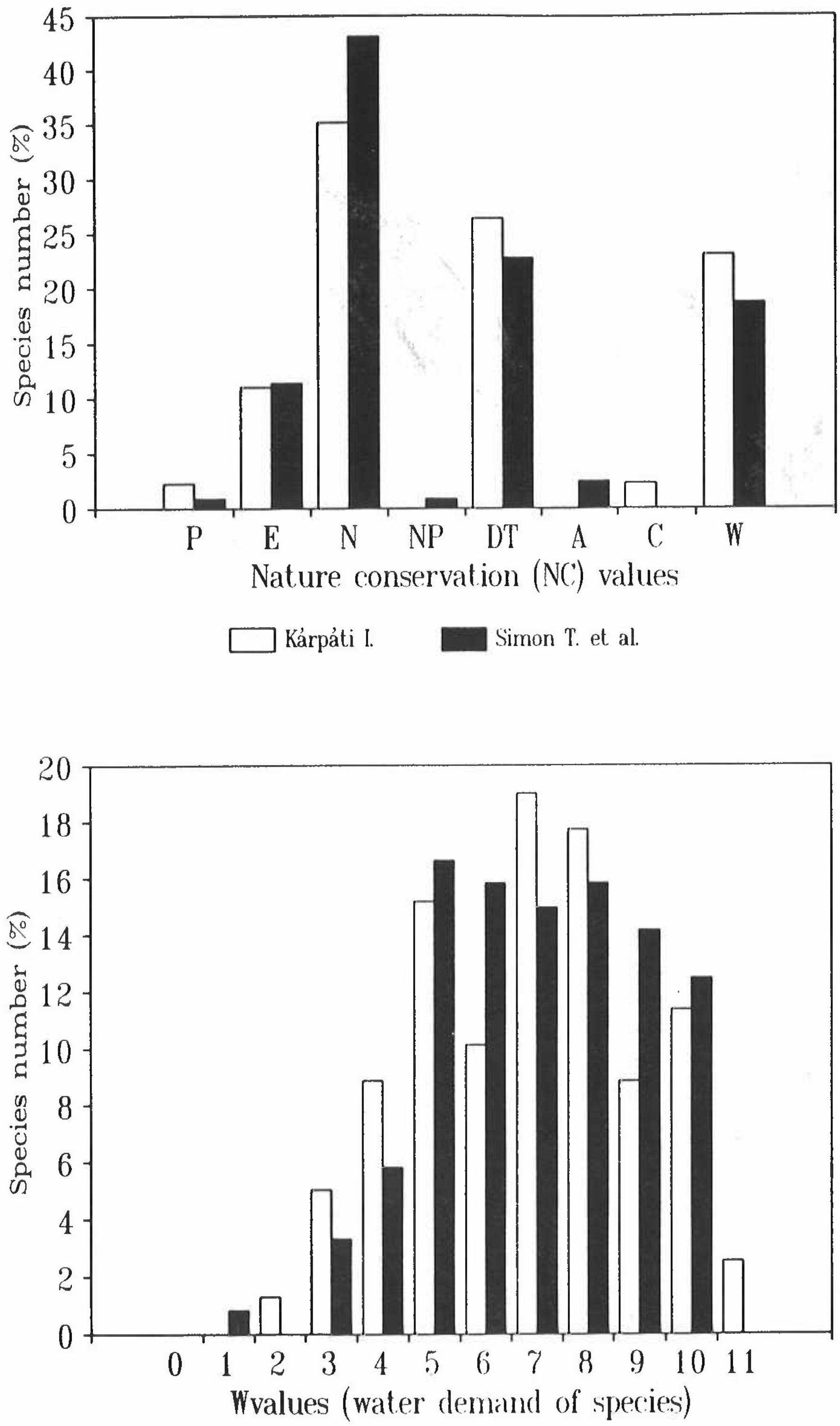
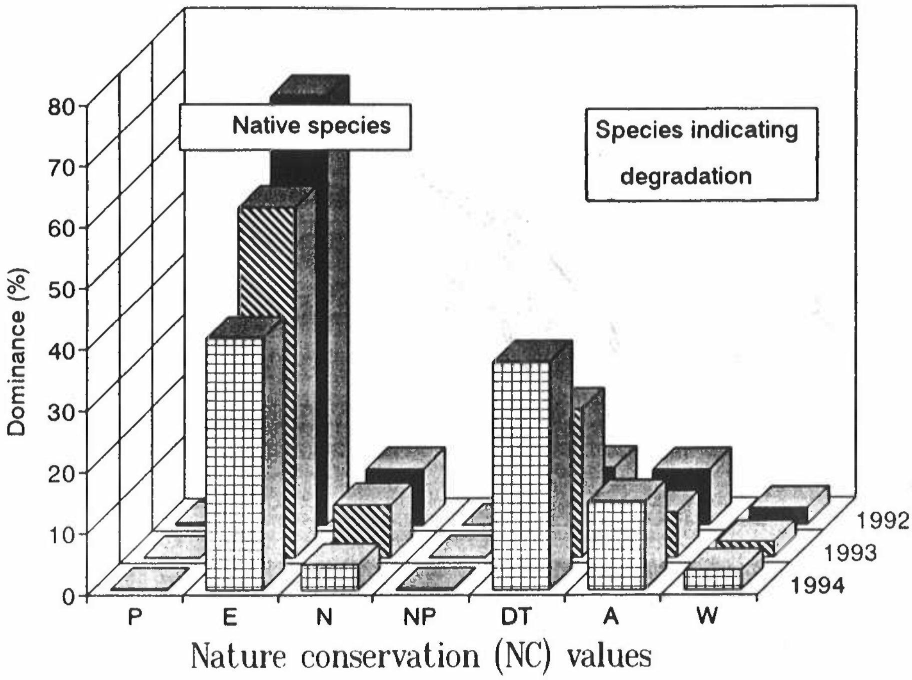


Figure 7

Standardised distribution of NC and W values for willow wood (*Salicetum albae fragilis*)

Nature Conservation (NC) values: P: protected species, E: natural species dominating in plant communities, N: natural species, NP: natural pioneers, DT: disturbance tolerant elements, A: adventives (introduced foreign species), W: weeds

W values: 2–5: drought-tolerant xerophilic species, 6–8: mesophilic species, 9–11: hydrophilic species (e.g. 11 = aquatic plants)



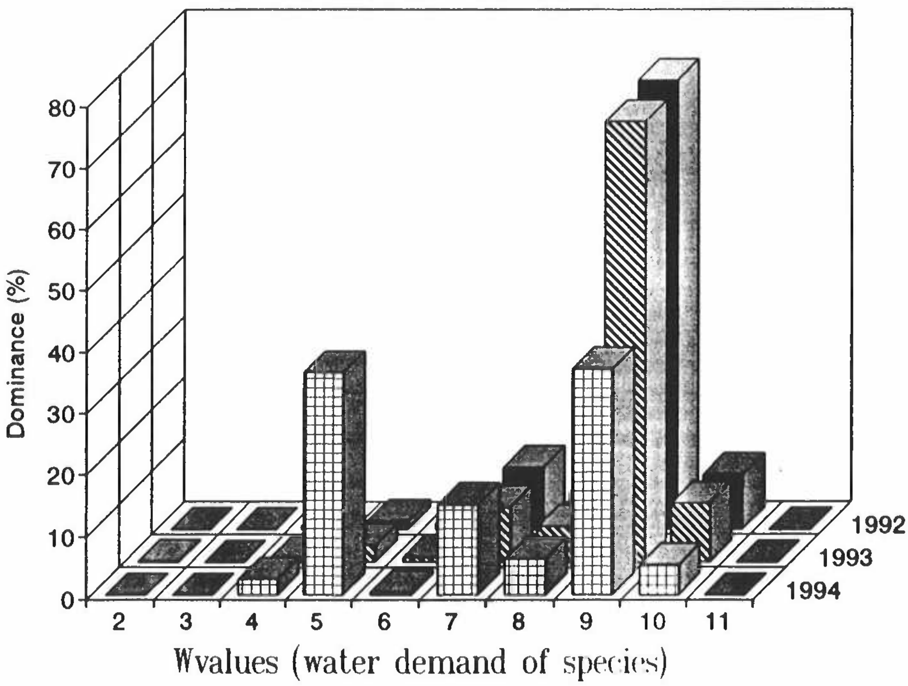


Figure 8

NC and W values for willow wood (*Salicetum albae fragilis*) at Dunaremete

VEGETATION SUCCESSION IN THE EXPOSED DANUBE BED

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Diverting the bulk of the Danube's water into the service canal in October 1992 caused a dramatic water level drop both in the main river bed and in its tributaries. The formerly permanently flooded Danube floor became exposed over large areas, where the colonisation of terrestrial plants started already in spring 1993. Although such extensive river bed drying rarely occurs in nature, the build-up of sandy or gravelly bars is quite common in the Hungarian part of the Danube. Lajos Tímár (1946–1947) studied the process of vegetation succession on a newly formed bar in the bed of the Tisza river near Szolnok. The phytocoenological description of semiruderal grasslands on the Danube flood plain was given by Kárpáti and Kárpáti (1963). István Bagi (1985, 1986, 1987a, 1987b) investigated the coenology of plant communities occurring on temporarily flooded areas along the Kőrös river.

The research group of the Department of Plant Taxonomy and Ecology at the Eötvös Loránd University has been participating in the botanical survey of the Szigetköz since 1986 (see Szabó et al., pp. 61–74 in the present volume). In 1993 our activities were further extended to the recently exposed river bed. In 1994 new sample sites were set up because the original plots were flooded again as a result of the water diversion. The new sites are located near to the Szigetköz reference point for water level fluctuation monitoring at the village of Dunaremete. Mostly weed-like herbaceous species appear in the exposed river beds, while willow and poplar seedlings are abundant in the new littoral zone. Although the main trends of vegetation changes are predictable, the exact sequence of transitions and their dynamics cannot be foreseen. This holds particularly true for the initial, perturbed stages of succession. In the Szigetköz this situation is further complicated by non-natural water level changes caused by human intervention. As a result of these irregular fluctuations, the vegetation may become flooded in periods to which plants are not adapted (e.g. when they are in the stage of flowering). All these phenomena explain the need for long-term field studies using permanent plots.

The purpose of our work is to study:

- the dynamics of abundant changes of species in the initial phase of succession,
- the speed of plant colonisation on the newly exposed substrate, and
- the changes in the substrate itself due to the vegetation cover.

To answer these and related – mostly syndynamical – questions, we designed a long-term study. During this, permanent sample plots were established in the main Danube bed and in those parts of the tributaries, where former channel floors had become exposed. Nomenclature of plant names follows Simon (1992).

Sites chosen for vegetation succession studies

The *exposed river bed sites* were set up on a gravelly terrace dried up as a result of the recent water level drop and in some parts of the Danube bed at the 1825 river km, about 1 km upstream of the water gauge at Dunaremete. Two parallel transects were established on 12 May 1994, running from the recent water edge to the original shoreline. In both transects, 25 adjacent quadrats of 2 m × 2 m size were set out. During the six weeks that elapsed between the pointing out and the field survey of these transects, the water level fell even further, thus enabling us to set up four additional quadrats at the lower end of the transects. The full length of transects became 58 m in this way. Coarse gravel dominates the substrate at the lower part of the transect, with increasing fine sand and silt deposition upwards. Finally, this is gradually replaced by a 3–5 mm thick silt layer that completely covers the sand and gravel beneath. The vegetation appearing on these sites is a mixture of the elements of river bed weed community (*Echinochloo polygonetum – lapathifolii*), bar vegetation (*Myricario – Epilobietum*), willow thickets (*Salicetum purpureae, Salicetum triandrae*) and white willow woods (*Salicetum albae – fragilis)*.

The *oxbow lake bottom sites* were established 1.5 km upstream of the water gauge at Dunaremete. Two transects were set out for phytocoenological studies also on 12 May 1994. Both transects cross the dry oxbow lake bottom and contain 18 quadrats of 2 m × 2 m size. The oxbow lake enjoyed a permanent water cover and supported lush aquatic macrophyte vegetation prior to the Danube's diversion. Yellow water lily (*Nuphar lutea*) was the dominant species there. On the shore of the oxbow lake – at the end of our transects – sedge species of aquatic habitats (*Carex gracilis, C. vesicaria, C. riparia, C. vulpina*), reed sweet-grass (*Glyceria maxima*) and reed (*Phragmites australis*) grow.

Field studies conducted in 1994

As a first step, the current coenostate of the vegetation was recorded along the transects in 1994. This included the estimation of the percentage cover of each species in each quadrat in the "river bed weed community" stand studied. Parallel with these, soil samples were collected for laboratory analysis at several depths along two transects on both sites. In the current study period, these substrates (soils or soil-like formations) are analysed for the ratio of gravel and fine sediments, the proportion of particles smaller than 2 mm (mud fraction) in the fine sediment, pH, carbonate content and total organic matter content.

Exposed river bed. A characteristic change was observed in the height of the vegetation along the transects running from the Danube floor up to the former river bank. Plant height and ground cover gradually increased in the first four quadrats, reaching the highest value (160 cm mean height) at a 10 m distance from the lower end of the transect, and then slowly decreased again further up on the bank. At 30 m from the water surface, vegetation height fell abruptly from 120 cm to 30–40 cm. Total plant cover followed a similar course along the transects (Figure 1). *Aster tradescantii* and *Matricaria maritima* were the most abundant species here. Ground cover of plant species with different water requirements was studied in detail. The abundance of water demanding species (W value = 8–10) showed two maxima along the transects: one close to the current river bank on substrates with favourable water supply and another one at the driest end of the transect. This latter spot was their original habitat before the river diversion, thus their seeds and rhizomes survive in the sediment for several years even under adverse conditions. The most important species are *Juncus articulatus, Galium palustre, Lythrum salicaria, Epilobium hirsutum, Polygonum lapathifolium, Echinochloa crus-galli, Veronica anagallis aquatica, Myosoton aquaticum* and *Ranunculus* *repens*. Although not present in the sample quadrats, the occurrence of large thalli of *Marschantia polymorpha* is quite characteristic on the wet ground surface. In the middle third of the transects, species with medium water demand (W = 5–7) are the most typical (e.g. *Rumex conglomeratus, R. crispus, R. obtusifolius, Agrostis stolonifera, Solidago gigantea* and *Urtica dioica*). In the upper third of the transects drought tolerant species and weeds appear (e.g. *Echium vulgare, Erysimum cheiranthoides, Lactuca viminea, Erigeron canadensis* and *Agropyron repens*), (Figure 2).

Coarse vegetation pattern (cover, height and spatial distribution of species with different water requirements) is determined by two main factors: the current water level of the Danube and – as the river and the groundwater systems are interconnected – the changes in the groundwater table and their influences on topsoil properties. The latter feature, most importantly the capillary water recharge, can be evaluated through monitoring changes in the temporarily outwashed or redeposited fine sediment fraction.

Abundance and cover of willow and poplar seedlings of particular importance in succession were also investigated along the transects. Willows – mostly *Salix purpurea* – dominated in spring, while young individuals of *Populus alba* appeared in large numbers in the lower quadrats by the end of summer (Figure 3). *Populus nigra* and *Alnus glutinosa* seedlings should also be mentioned here. The occurrence of these species indicates the imminent development of willow thickets, the next successional stage. All individuals were identified as seedlings, as we have seen no sign of sprouting. The highest abundance of tree seedlings was observed at a 15–20 m distance from the lower end of the transect, that indicates the position of the water edge at the time of seed dispersal. As the water level of the main Danube is influenced not only by the weather conditions, but also by the prevailing water regulation activities, the seeds of these trees are expected to be dispersed over a larger area and thus the willow belt will be wider in the coming years. We anticipate the development of willow thickets in the place of the present river bed weed communities. These secondary willow thickets are expected to be very similar to those found naturally on river banks.

During our studies, a plant species new in Hungary was discovered. *Mimulus guttatus* DC. is an adventive element of North American origin, which became naturalised along streams throughout Europe (Austria, Romania, Slovakia and Yugoslavia). Its occurrence at Dunaremete increases the diversity of the flora in the Szigetköz.

Oxbow lake. After the Danube diversion, the oxbow lake dried up and its bottom became exposed. In the following summer, the sediment was still wet, as the depth of the groundwater table was 15 cm. Elements of river bed weed communities (e.g. *Polygonum mite, P. lapathifolium, P. minus, Rumex obtusifolius*) have already appeared, and plant cover reached 20–40%. A peculiar terrestrial form of the aquatic macrophyte *Nuphar lutea* also occurred. By the time of setting out our sample quadrats in May 1994, the total plant cover increased to 60–90%, even reaching 100% in some plots by late June. The dominance of *Polygonum* species was conspicuous, their canopy completely shaded the stunted *Nuphar* individuals, which thus became limited by both water shortage and low light intensity. In spite of the adverse conditions, most *Nuphar* specimens brought flower. During the high water level in early summer 1994, the oxbow lake was filled with water again for about two weeks. This change was unfavourable for *Nuphar* as their leaves usually bear a long petiole and a lamina floating on the water surface. However, the stunted terrestrial forms have produced short petioles, thus leaf blades remained well below the water surface and were killed by anaerobic conditions. The short-term survival of this species in the dry oxbow lake bottom is made possible by nutrients stored in its thick rhizome. After the depletion of this reserve, the *Nuphar* population will disappear.

Most species inhabiting exposed river beds have a weed-like character. Their seeds have been transported from a long distance by the Danube. However, in the case of the dry oxbow lake bottom, the bordering reed stands serve as seed sources for plant colonisation. Most of the invading species are natural disturbance tolerant elements here (Figure 4, Simon 1988). Consequently, reed stands are expected to cover the former oxbow lake floor completely in the future. Compared to the exposed river bed, the substrate of the dry oxbow lake bottom has a more favourable water supply, that is also indicated by the higher number and dominance of water demanding species (W = 9–11). This is explained by a fine-grained, more than 80 cm thick sediment layer of good water regime covering the gravel basement.

Pedological evaluation of the sample sites

The marked environmental changes ensuing from the Danube diversion greatly altered the regular fluctuation pattern and chemical composition of surface and groundwaters, and also influenced the direction and intensity of soil formation processes. These changes have substantial effects on the region's natural vegetation and agricultural plant production as well.

The development and occurrence of corresponding "chrono-series" of alluvial soil types characterise both sample sites in our study.

The plant community type establishing at a certain locality is greatly influenced by soil hydrological properties, most importantly by the frequency of temporal inundation, the distance of current water and the extent of capillary rise from the groundwater table, which is directly interconnected with the river's current water. In a model developed for this situation, the most important input parameters include the ratio of gravel and fine sediment fractions, and the proportion of mud particles. Table 1 summarises the values of these soil parameters measured for the two sample sites.

At the time of sampling, the depth of groundwater table – that is practically belowground current water – was the following at the river bed site:

Quadrat No.	Depth (cm)
4	15
3	45
9	90
15	110

The surface height difference between the two ends of the 58-m-long transect was about 3 m.

From the analysis of the data in Table 1 it can be concluded that the proportion of fine sediment fraction gradually increases, while that of gravel decreases as one moves away from the recent open water surface towards the former river bank. Two abrupt changes can be observed along this trend (one at the deeper horizon of plot No. 3, the other at plot No. 15). It is also conspicuous that the proportion of fine sediment fraction taking part in future soil formation is only 2–4.3% in the currently exposed river bed. The river bed substrate cannot be considered as a soil, as it is only a gravelly skeleton mixed with mud, where the only obstacle for water movement is the prevailing water level of the Danube and the corresponding groundwater table depth. The floor of the former oxbow lake is filled with a substrate containing 2–3 times higher mud proportion compared to that of the river bed. The bulk density of this sediment also increases with depth. Depending on surface properties, the proportion of mud fraction varies between 40 and 70%. On this site, soil formation processes proceed toward the drying out of the alluvial soil, or that of the swamp soil developed in a closed bay.

Soils or soil-like formations have a high carbonate content, while their pH is in the neutral or slightly alkaline range. According to our preliminary studies, the organic matter content of the fine sediment fraction is not higher than 1%. This means that the main component of the puffer capacity of these soils is their high carbonate content.

Summary

The substantial water level drop in the Szigetköz created new habitats for terrestrial plants. Plant colonisation was very rapid in the exposed river bed and in the dry oxbow lake bottom studied, that resulted in a mean ground cover of 80% by the summer of 1994. The species composition is different at the two sites, as seed sources are also unlike. In the exposed river bed, the formation of a new willow thicket belt has already started.

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Table 1

The mechanical composition of soils at the two sample sites studied

Quadrat No.	Depth (cm)	Gravel/Fine fraction ratio (%)	Soil mud fraction (%)	Mud fraction in percentage of the original sample
Exposed river bed site				
4	0–20	92.1/7.9	22.7	1.79
3	0–20	90.9/9.1	17.2	1.57
	20–40	85.5/14.5	19.6	2.84
9	0–20	81.4/18.6	11.36	2.11
	20–40	84.7/15.3	15.92	2.44
15	0–20	56.0/44.0	8.58	3.78
	20–40	74.8/25.2	12.32	3.10
22	0–20	70.0/30.0	14.94	4.48
	20–40	70.4/29.6	14.38	4.26
Dry oxbow lake bottom size				
2	0–20		58.50	
	20–40		52.69	
	40–60		59.28	
	60–80		62.74	
9	0–20		53.72	
	20–40		52.84	
	40–60		55.84	
	60–80		65.56	
13	0–20		51.70	
	20–40		48.42	
	40–60		57.82	
	60–80		70.66	
14	0–20		51.08	
	20–40		55.10	
	40–60		50.80	
	60–80		51.30	

Time of sampling: 22 April 1994. Quadrat numbers refer to the corresponding phytocoenological sample plot numbers in the transect No. 1 at both study sites. Samples for soil analysis were taken in the upper right corner of each quadrat.

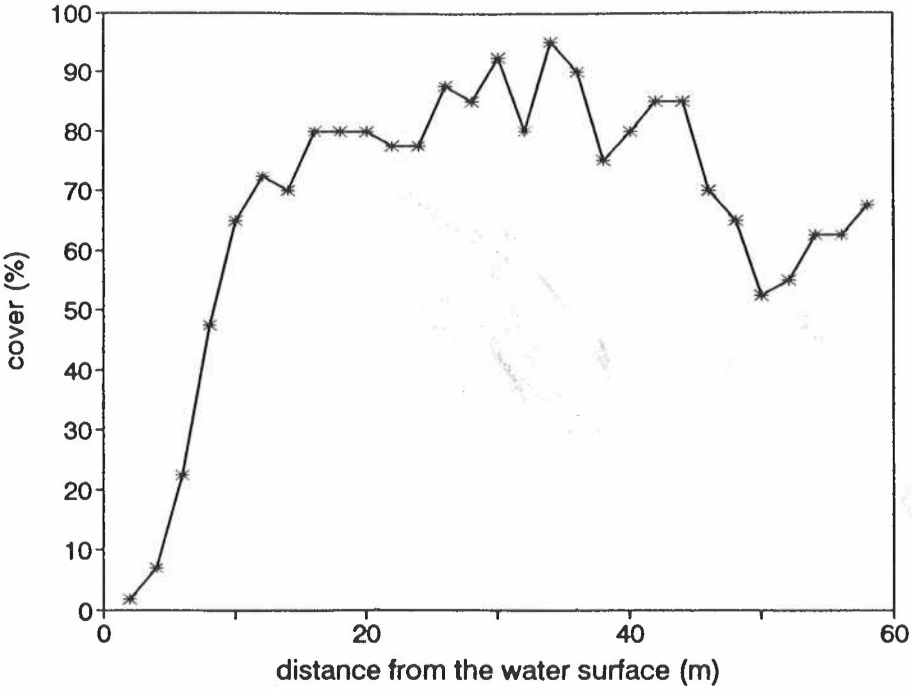

Figure 1

Mean plant cover in the exposed Danube bed at Dunaremete in 1994

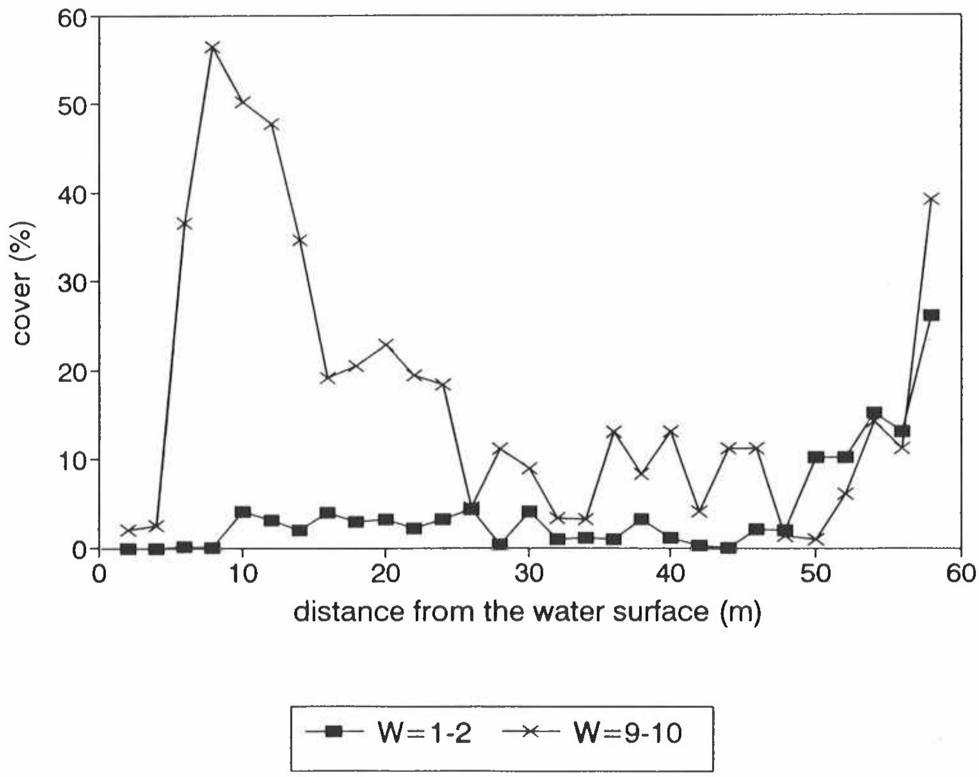

Figure 2

Spatial distribution of water demanding (W = 9–10) and drought resistant (W = 1–2) species in the exposed river bed

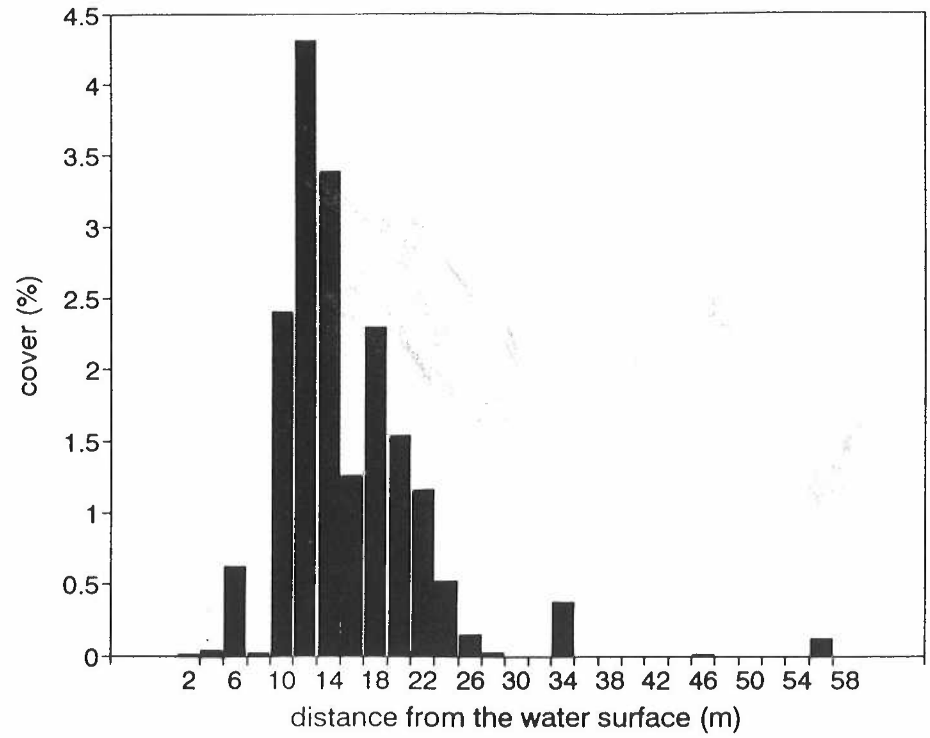

Figure 3

Occurrence of willow and poplar seedlings along a transect in the dry Danube bed at Dunaremete in 1994

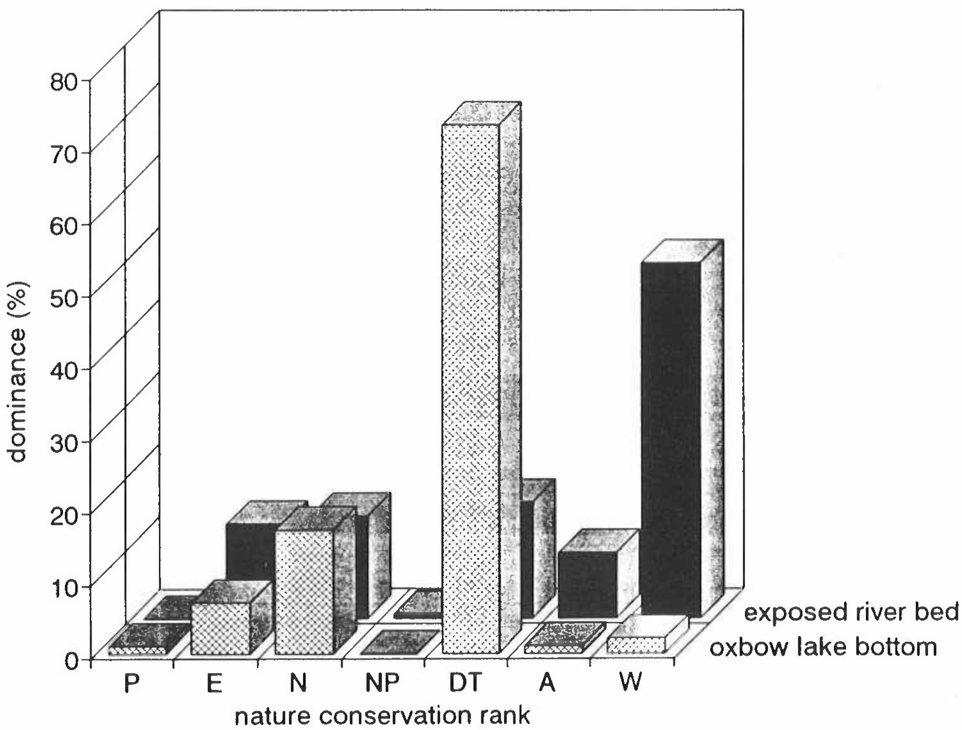

Figure 4

Nature conservation rank spectrum of the vegetation in 1994

(Nature conservation values: P: protected species, E: natural species dominating in plant communities, N: natural species, NP: natural pioneers, DT: A: disturbance tolerant elements, adventives, W: cosmopolitan weeds)

SIGNALS OF CRYPTOGAMS*

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Public awareness of the endangered flora of the Szigetköz region is usually concerned about forests and wild flowers. The higher plants, however, have better chances of surviving periods of scanty water supply. The small cryptogams are much more exposed to dramatical changes of living conditions, due to their small size and short lifetime, and they react faster to changes in their environment.

The aim of our monitoring studies performed in 1994 was to examine the effects of changes in water conditions, water level and even the changes of the river bed and the branches on non-vascular cryptogams. We studied the changes in the composition and quantity of aquatic and riparian bryophytic vegetation as well as periphytic algae.

Introduction

Role of algae and bryophytes in the monitoring of running waters

Monitoring changes in the water quality of rivers is a routine means of hydrobiology. The typical aim of monitoring is to detect the effects of human interferences, i.e. pollution in the widest sense. In hydrobiological practice, usually water chemical parameters are used, although the measurement of these parameters is expensive in terms of both labour and analytical facilities.

As a result, biomonitoring is getting more accepted as a means of testing water quality. All types of living organisms can be used for this purpose. The most typical applications are based on the recording of the abundance of bacteria, fish or invertebrates. Study of the autotrophic organisms has been less commonly practised as yet. Saprobity indices attached to individual species is frequently used, however, the reliability of this factor has been questioned.

Apart from the saprobity indices, a philamentous green algal species *(Cladophora glomerata)* as well as diatoms are usually used in biomonitoring studies. This can be explained by the most stable taxonomy of diatoms. Permanent slides of these taxa can be used for long-range comparisons. Diatoms react faster and "better" to organic pollution than the invertebrate fauna (Whitton 1991).

Data are much more scarce on the bioindication role of bryophytes in aquatic environment than on that of algae, though related studies were started in several countries in the mid-1970s. A considerable advantage of bryophytes compared to algae is their longer lifetime. Thus the sampling strategy is more simple. Bryophytes living in the waters represent the average water quality,

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moderately influenced by the effects of temporal waves of pollution and shorter periods of cleaner water.

Bryophytes are typically used to detect traces of heavy metals in running waters (Frahm 1975, Mouvet et al. 1986, Muhle 1984, Wehr et al. 1983). There are data on water quality (saprobity) indications of bryophytes (e.g. Frahm 1974, Empain 1973, 1978, Peñuelas – Sabater 1987, Sladeček 1973, Vrhovšek et al. 1984, 1985). There were certain efforts to standardise related values within the former COMECON countries (Sladeček et al. 1977). Monitoring in the strict sense has been seldom practised (Burton 1986, Frost 1990).

Research history

Periphytic algae

The study of the periphytic algae along the Hungarian reach of the river Danube was started already at the beginning of the 1900s due to the activity of Béla Cholnoky. Szemes (1960) summarised data on the cryptogams of the Danube till 1959, later prepared a taxonomical study on the flora of the river Danube (Szemes 1967a) and gave a detailed account of the periphytic algae (Szemes 1967b). Following a break of nearly twenty years, the study of the periphytic algae in the main branch of the Danube was continued (Ács 1988, Ács – Kiss 1991a,b, 1993a,b).

Investigation of the periphytic algal communities of the Szigetköz was started only in 1991 when the potential effects of the Gabčikovo–Nagymaros water plant system were brought into the centre of attention (Buczkó – Ács 1992, 1994a, Ács – Buczkó 1994).

Bryophytes

Bryophytes of the Szigetköz region and the relevant section of the Danube were hardly known from the point of view of bryology. Altogether four papers were found which included some data on the bryophytic flora of the region (Boros 1968, Boros – Vajda 1955, Boros–Zólyomi 1934, Polgár 1941). Consequently, the only way to reconstruct former conditions in the region was the investigation of unpublished evidence in the herbarium of the Hungarian Natural History Museum.

In general, the Szigetköz region and the relevant section of the Danube were fairly neglected. From the whole area, we could find specimens of altogether 3 hepatic and 23 moss species (collected by Ádám Boros, Sándor Polgár and Bálint Zólyomi, unpublished).

Bryological studies – as the algological ones – were started in 1991, in the frames of the above-mentioned project. The task was to record the actual state of the area. The geographical frames of the bryological project were extended over the Danubian branch systems of the Upper-Szigetköz region near Cikolasziget and Ásványráró. Collecting activity in 1991–92 resulted in 7 hepatic and 47 moss taxa in the two branch systems (Papp – Rajczy, in press). The bryophyte flora of the stones bordering the Danube was also studied in the area of the Upper-Szigetköz region. These studies yielded evidence on the presence of 29 moss species (Papp – Rajczy 1992).

Material and methods

Systematic observations (i.e. biomonitoring) was started in 1994, with the qualitative and quantitative investigation of the bryophytic vegetation as well as the periphytic algae living in the waters.

Periphytic algae

Experiences of former years indicated that during a longer period of low water level, the near-shore macrophyta serving as substrate for periphytic algae get dry, emerging from the water surface. As in 1994 a lasting lack of water was anticipated, we were afraid that during the vegetation period no suitable macrophyton communities will be available for sampling. Therefore, artificial "floating reed islands" were planted at three places in the branch which now acts as the actual water supply of the branch systems of the Upper-Szigetköz, instead of the Danube (Figure 1). Reed stems fastened to a metal frame were kept close to the surface by a buoy and fixed to the basement by weights. From the 12th of May 1994, samples were collected from the "islands" every week. The coating was elaborated by standard algological methods (Buczkó – Ács 1992). Control samples were collected from macrophyta immerged into water (e.g. *Najas, Potemogeton* spp.) and water plants (reed, rush) emerging from the water including the parts under the water level.

Bryophytes

Two habitats of aquatic–riparian bryophytes were studied: the near-water soil vegetation of the branch systems and the vegetation of the protective stones bordering the main branch (the so-called "Old Danube").

Based on the results of the investigations of 1991–92, permanent sampling sites were selected in the two branch systems studied as well as along the shore of the Old Danube. The sampling sites were planted at habitats with rich undisturbed bryophyte flora. Accordingly, in the Cikolasziget branch system, the former sections "L" and "N" were selected, while in the Ásványráró branch system the section formerly marked "m" was selected. Unfortunately, at the latter spot the bryophyte vegetation has been transformed essentially, and no adequate places could be selected for sampling. Thus a new site was selected at the fork of the Gombócos branch where a suitable moss cover was found. Along the Old Danube we could select a place where all three levels* were adequately developed and characteristic of the swift flowing section of the Danube. Unfortunately, at the section appointed first near Dunaremete (known as habitat for several rare species), invading weeds destroyed the moss vegetation. There the rare species disappeared, and the original levels were no longer separable.

At the top of the Nyáras island in the Cikolasziget phase, a transect was planted, i.e. a row of conjoining sampling quadrats from the blackberry bushes at the top of the dam to the current water level (Figure 2).

The bryophyte and flowering plant vegetation of the quadrats was studied using the classical Braun–Blanquet method. Sampling was performed three times per year, in late spring, middle of summer and in autumn. During springtime, the flowering plants were not registered, because they were not fully recordable as yet, only the estimated total cover was recorded.

* Level A: the zone of the low water level (generally under water).

Level B: the sprinkle zone of the average middle water level, generally directly affected by the water; this zone has the richest aquatic–riparian bryophyte vegetation.

Level C: this zone is flooded only by extremely high waters, rarely affected directly by the water.

Results and discussion

Periphytic algae

In 1994, over a hundred samples were analysed. Altogether 266 algal taxa were identified (Phycobacteria 15, Euglenozoa 4, Dinozoa 3, Chrysophyta 6, Xanthophyta 2, Bacillariophyta 167, Chlorophyta 69). The largest species number and abundance were found among the diatoms belonging to Pennales (Figures 3 and 4).

The quantity of algae living in the coating was multiplied and the species composition transformed compared to previous years. The most significant change observed in the 1994 samples from the "floating reed islands" was the striking abundance of diatoms belonging to Centrales (Figure 4). In some of the summer samples they were found in dominant quantities, comprising more than half of the total individual number. The phytoplankton of the Old Danube is typically dominated by Centrales; however, their ratio was very low in the coating samples collected in 1991 and 1992, usually under 5% (Buczkó – Ács 1994a).

New species typical of the main branch of the Danube appeared in the Szigetköz branches, which were formerly missing or present in very small quantities (e.g. *Cymbella sinuata*). The abundance of small forms of *Gomphonema parvulum* and *G. olivaceum* also increased essentially. Compared to former observations, *Gyrosigma acuminatum* was found in very large quantities. *Skeletonema potamos*, a fragile form belonging to Centrales, appeared in increased quantities within the coating and there were several delicate forms that were not found formerly (e.g. *Polyedropsis spinulosa*). These features are related to the fact that the sediment content of the Danube decreased, there are less sand- and silt particles transported by the water, thus more delicate forms of algae can find suitable conditions of living as well.

The study of algae living on the "floating reed islands" resulted in surprising observations. Instead of the predicted planktonic eutrophication (a poly-hypertrophic transformation of the open water surface), i.e. the mass multiplication of floating plant organisms, the benthonic plants became dominant – reed-grass and flowering plants emerging from the water. Parallel to this, the quantity of periphytic algae has multiplied as well. The changes are observable in several orders of magnitude, though unfortunately we have no exact data for this. (To estimate this, we should know the total surface of plants, animals and artefacts in the water.) It is clear, however, that the surface serving as substrate for coating increased dramatically. Also, the individual number per surface unit increased essentially compared to the results of 1991 and 1992. The former mosaic-like character of the habitats is disappearing, there is no essential floristical difference between the coatings collected at different sampling sites. This means a growing uniformity of the periphytic flora (Buczkó – Ács 1994b).

The ratio of open water surfaces decreased essentially. Wide algal patches (composed mainly of Lyngbya and Cladophora) are uniformly spread, same as reed-grass and plants emerging from the water (reed, rush). Their spreading is promoted by the constant (low) water level, as well as by the lack of shading, which is a consequence of the former felling of the riparian forests. The disappearance of these forests meant a dramatic change for the limited light algal communities of the Danube. All these changes transformed the running water character of the river branches.

In the course of the natural aging processes in natural succession the bed of lakes and mortuaries is gradually filled with sediments. The water level decreases continuously, and, in the end, the former lake or mortuary is completely filled up. Among natural conditions, this process usually lasts for centuries or longer. In the Szigetköz region, the situation is similar due to the loss of water. The water level decreased essentially during one year. According to Felföldy (1981), by a considerable increase of the water plants emerging from the water, the aging process (i.e. filling up) is getting faster. The great benthonic eutrophication witnessed in 1994 clearly indicates that premature aging processes have started in the Szigetköz. If we are not able to find suitable means and sources for water supply, this trend will continue and completely destroy the remaining natural habitats.

Bryophytes

Changes in the branch systems

It was apparent already during the planting of our sampling sites that the richness of the bryophyte flora encountered two years before had decreased essentially. Several of the rare species disappeared completely as a consequence of longer lack of water supply. The following taxa were no longer present: *Cratoneuron filicinum, Didymodon luridus, Hygroamblystegium fluviatile* and *Rhynchostegium murale*. There was only one habitat from the collecting spots of 1991–92 (the richest one) which could preserve part of the original richness of the bryophyte flora. Though a number of rare species have disappeared, fortunately *Lunularia cruciata*, which can be found in Hungary only here, has survived as yet. We can observe the advance of forestal species at the expense of the definitely aquatic taxa into the former riparian areas. In the place of the former river beds which have got dry, mainly flowering plants and colonist bryophyte taxa have settled.

The disappearance of rare aquatic and riparian species as well as their replacement by forestal species can be regarded as disadvantageous from the point of view of nature conservation, because these processes indicate the loss of the specific habitats of the Szigetköz region.

From spring till summer, the moss cover was stable or increasing in the study area, decreasing essentially by autumn at most places. Only one sampling site was different in the Cikolasziget branch system: here the minimal bryophyte cover was observed in summer and the quantity of mosses increased by autumn. This phenomenon can be probably explained by the extra water supply. Namely, this branch was almost completely dry after the diversion of the water, with the exception of a very small lake. The deterioration of the original flora was most apparent here. As a result of additional water supply, almost the total branch was flooded and this was very advantageous for the microenvironment. The "blossoming" of the bryophyte vegetation could be observed at first sight. This change was not observed at the other sampling sites and the quantitative data on coverage do not indicate similar changes at other places.

Changes in the bryophyte vegetation living on the protective stone border of the Danube

The changes of the bryophyte vegetation were most dramatic here, as the lack of shading trees does not moderate the complete lack of water. On this habitat, which is rather unique in Hungary, probably a number of rare species have died out. One species (*Cinclidotus danubicus*) has probably finally disappeared from Hungary because its habitat, the fast Danube water, is not existing any more. The presence of species which are rare or very rare in Hungary like *Didymodon luridus, Fontinalis antipyretica, Hygrohypnum luridum* and *Pohlia bulbifera* is also questionable in the Szigetköz section of the Danube.

Formerly, the bryophyte vegetation of the watering zone of medium water level was the most abundant. In the transect studied, this zone has gradually deteriorated, though to superficial observation it seems intact. In the new stripe between the former low water level and the current water surface, colonist mosses typical of wet soil have appeared in great masses. This is the reason for the second maximum (Figure 5). Apart from the advance of colonist species, these quadrats have been occupied by flowering plants because the factors which were unfavourable for them (wave movement, strong drift) have ceased (Figure 6). Bryophyte diversity shows similar values along the transect to those of coverage. The second maximum here, which is fairly flat in the case of coverage values, is dominant here (Figure 5). This is clearly the consequence of the large number of colonist species. An interesting feature was observed in sampling quadrat No. 5, where a major increase in diversity values could be observed in the autumn samples. This can be explained by the spreading of the species present in the neighbouring (lower) section into the quadrat, which was planted, roughly, at the lower border of the medial level. This phenomenon is similar to the spreading of the species typical of the upper level in quadrat No. 2. Thus the habitat of the former medium water level is threatened by the invasion of species more resistant to dry environment from both directions.

Summary

Biomonitoring of cryptogamic plants was started in the Szigetköz region in 1994. In the first year, the occurrence of 266 periphytic algal and 49 bryophyte taxa was recorded at the sampling points. Measurements were made concerning their weekly (algae) as well as seasonal (bryophytes) distribution. The resulting data serve as an adequate comparative basis for tracing the future changes. A short review of the phytoindication of algae and bryophytes has been given as well.

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List of algal taxa found in the course of the investigations

Phycobacterium

Anabaena catenulata (Kütz.) Born. & Flah.
Aphanisomenon flos-aquae (L.) Ralfs
Aphanochaete sp.
Chroococcus minutus (Kütz.) Näg.
Lyngbya hyeronymusii Lemm.
Lyngbya limnetica Lemm.
Merismopedia glauca (Ehr.) Näg.
Merismopedia tenuissima Lemm.
Nostoc sp.
Oscillatoria amphibia Ag.
Oscillatoria curviceps Ag.
Oscillatoria irrigua ? (Kütz.) Gom.
Oscillatoria nigra ? Vauch.
Oscillatoria sp.
Snowella lacustris Chod.

Euglenozoa

Euglena sp.
Phacus dangeardii Lemm. ?
Phacus sp.
Trachelomonas sp.

Dinozoa

Peridinium sp. 1
Peridinium sp. 2
Peridinium sp. 3

Cryptophyta

Cryptomonas ovata Ehr.

Chrysophyta

Dinobryon sertularia Ehr.
Dinobryon sociale Ehr.
Kephyrion ovale ? (Lackey) Huber-Pest.
Synura petersenii Kors.

Xanthophyta

Centritractus belenophorus Lemm.
Goniochloris mutica (A. Braun) Fott

Bacillariophyta

Achnanthes clevei Grun.
Achnanthes delicatula (Kütz.) Grun.
Achnanthes kolbei Hust.
Achnanthes lanceolata (Bréb.) Grun.
A. lanceolata var. *minor* (Straub) Lange-Bert.
Achnanthes minutissima Kütz.
Achnanthes plönensis Hustedt
Achnanthes sp.
Amphora commutata Grun.
Amphora lybica E.
Amphora ovalis (Kütz.) Kütz.
Amphora pediculus (Kütz.) Grun.
Amphora thumensis (Mayer) Cleve-Euler
Anomoeoneis sphaerophora (Ehr.) Pfitz
Asterionella formosa Hassall
Asterionella ralfsii W. Smith
Aulacoseira distans
Aulacoseira granulata (Ehr.) Sim.
A. granulata var. *angustissima*
A. granulata var. *curvata*
Aulacoseira italica
Bacillaria paradoxa Gmelin
Caloneis amphisbaena (Bory) Cleve
Caloneis bacillum (Grun.) Cl.
Caloneis schumanniana (Grun.) Cl.
Caloneis silicula (E.) Cl.
Campylodiscus clypeus E.
Campylodiscus sp.
Cocconeis pediculus Ehr.
Cocconeis placentula Ehr.
Cymatopleura elliptica (Bréb.) W. Smith
Cymatopleura solea (Bréb.) W. Smith
Cymbella affinis Kütz.
Cymbella aspera (Ehr.) Cl.
Cymbella austriaca Grun.
Cymbella caespitosa (Kütz.) Brun.
Cymbella cistula (Ehr.) Kirchner
Cymbella cuspidata Kütz.
Cymbella ehrenbergii Kütz.
Cymbella helvetica Kütz.
Cymbella microcephala Grun.
Cymbella minuta Hilse
Cymbella naviculiformis Auerswald
Cymbella prostrata (Berkeley) Cl.
Cymbella silesiaca Bleisch
Cymbella sinuata Gregory
Cymbella turgidula Grun.
Denticula kützingii ? Grun.
Diatoma hyemale (Roth) Heiberg
Diatoma mesodon (Ehr.) Grun.
Diatoma tenuis Agardh
Diatoma vulgaris Bory
D. vulgaris var. *ovalis* (Fricke) Hust.
Diploneis elliptica (Kütz.) Cl.
Diploneis modica Hust.
Diploneis oblongella (Naegeli) Cleve-Euler
Diploneis ovalis (Hilse) Cl.
Epithemia sorex Kütz.
Epithemia sp.
Eunotia bilunaris (Ehr.) Mills
E. bilunaris var. *linearis* (Okuno) Lange-Bert.

Fragilaria brevistriata Grun.
Fragilaria capucina Desm.
F. capucina var. *gracilis* (Oestrup) Hust.
F. capucina var. *mesolepta* (Rabenh.) Rabenh.
F. capucina var. *vaucheriae* (Kütz.) L.-B.
Fragilaria construens (E.) Grun.
F. construens var. *binodis* (E.) Grun.
Fragilaria crotonensis Kitton
Fragilaria fasciculata (Agardh) Lange-Bert.
Fragilaria pinnata Ehr.
Fragilaria pulchella (Ralfs) Lange-Bert.
Fragilaria tenera (W. Smith) Lange-Bert.
Fragilaria ulna (Nitzsch) Ehr.
F. ulna var. *acus* (Kütz.) Lange-Bert.
Fragilaria sp. 1
Fragilaria sp. 2
Frustulia vulgaris (Thwaites) De Toni
Frustulia sp.
Gomphonema acuminatum Ehr.
Gomphonema angustatum (Kütz.) Rabh.
Gomphonema angustum Agardh
Gomphonema augur Ehr.
G. augur Ehr. var. *sphaerophorum* (Ehr.) L.-B.
Gomphonema clavatum Ehr.
Gomphonema minutum Agardh
Gomphonema olivaceum (Hornemann) Bréb.
G. olivaceum var. *calcareum* (Cl.) Cl.
Gomphonema parvulum Kütz.
Gomphonema truncatum Ehr.
Gyrosigma acuminatum (Kütz.) Rabh.
Gyrosigma attenuatum (Kütz.) Rabh.
Gyrosigma spencerii (W. Smith) Cl.
Gyrosigma sp.
Hantzschia amphioxys (E.) Grun.
Melosira varians Ag.
Meridion circulare (Greville) Ag.
Navicula bacillum E.
Navicula capitata Ehr.
N. capitata Ehr. var. *hungarica* (Grun.) Ross
Navicula capitatoradiata Germain
Navicula clementis Grun.
Navicula costulata Grun.
Navicula cryptocephala Kütz.
Navicula cuspidata Kütz.
Navicula digitoradiata (Gregory) Ralfs
Navicula gastrum (Ehr.) Kütz.
N. gastrum var. *signata* Hust.
Navicula gottlandica Grun.
Navicula gregaria Donkin
Navicula halophilioides Hust.
Navicula lanceolata (Agardh) Kütz.
Navicula laterostrata Hust.
Navicula lenzii Hust.
Navicula margalithii Lange-Bert.
Navicula menisculus Schumann
Navicula minuscula ? Grun.
Navicula oblonga Kütz.
Navicula pseudotuscula Hust.
Navicula pupula Kütz.
Navicula pygmeae Kütz.
Navicula radiosa Kütz.
Navicula reinhardtii Grun.
Navicula rhynchocephala Kütz.
Navicula veneta Kütz.
Navicula viridula (Kütz.) Ehr.
N. viridula var. *linearis* Hust.
Navicula sp.
Neidium affine (E.) Pfitzer
Neidium ampliatum (Ehr.) Krammer
Nitzschia acicularis (Kütz.) W. Smith
Nitzschia angustata (W. Smith) Grun.
Nitzschia angustatula Lange-Bert.
Nitzschia brevissima Grun.
Nitzschia capitellata Hust.
Nitzschia compressa (Bailey) Boyer
Nitzschia dissipata Grun.
Nitzschia filiformis (W. Smith) Van Heurck
Nitzschia flexa Schumann
Nitzschia frustulum (Kütz.) Grun.
Nitzschia fruticosa Hust.
Nitzschia linearis (Agardh) W. Smith
Nitzschia nana Grun.
Nitzschia palea (Kütz.) W. Smith
Nitzschia recta Hantzsch
Nitzschia sigma (Kütz.) W. Smith
Nitzschia sigmoidea (Nitzsch) W. Smith
Nitzschia sinuata (Thwaites?) Grun.
N. sinuata var. *delognei* (Grun.) Lange-Bert.
N. sinuata var. *tabellaria* (Grun.) Grun.
Nitzschia tryblionella Hantzsch
Nitzschia vermicularis (Kütz.) Hantzsch
Nitzschia sp.
Pinnularia divergens W. Smith
Pinnularia gibba Ehr.
Pinnularia maior (Kütz.) Rabenh.
Pinnularia microstauron (E.) Cl.
P. microstauron var. *brébissonii* (Kütz.) Mayer
Pinnularia viridis (Nitzsch) Ehr.
Pleurosigma elongatum W. Smith
Pleurosigma sp.
Rhoicosphaenia abbreviata (Agardh) L.-B.
Skeletonema potamos (Weber) Hasle
Skeletonema subsalsa
Stauroneis anceps E.
Surirella angusta Kütz.
Surirella biseriata Brébisson
Surirella ovalis Bréb.
Tabellaria fenestrata (Lyngb.) Kütz.
Thalassiosira guillardii Hasle

Chlorophyta

Actinastrum hantzschii Lagerh.
Ankistrodesmus falcatus (Corda) Ralfs
Characium ensiforme Herm.
Chlamydomonas reinhardtii Dang.
Chlamydomonas sp. 1
Chlamydomonas sp. 2

Cladophora glomerata (L.) Kütz.
Closterium leibleinii Kg.
Closterium moniliferum (Bory) Ehr.
Coelastrum microporum Näg.
Coelastrum sphaericum Näg.
Cosmarium granatum Bréb.
Cosmarium meneghinii Bréb.
Cosmarium obtusatum Schmidle
Cosmarium ocellatum Eichl. & Gutw.
Cosmarium punctulatum Bréb.
Cosmarium reniforme Ralfs (Arch.)
Cosmarium subtumidum ? Nordst.
Cosmarium turpinii Bréb.
Cosmarium undulatum var. *minutum* Wit.
Crucigenia quadrata Morr.
Crucigenia tetrapedia (Kirchn.) W. & G.S. West
Crucigeniella apiculata (Lemm.) Kom.
Dictyosphaerium pulchellum Wood.
Didymocystis planktonica Kors.
Kirchneriella obesa (W. West) Schmidle
Lagerheimia genevensis Chod.
Monoraphidium arcuatum (Kors.) Hind.
Monoraphidium contortum (Thur.) Kom.-Legn.
Monoraphidium minutum (Näg.) Kom.-Legn.
Monoraphidium mirabile (W. & G.S. West) Kom.-Legn.
Monoraphidium tortile (W. & G.S. West) Kom.-Legn.
Neodesmus danubialis Hind.
Oedogonium sp. 1
Oedogonium sp. 2
Oocystis borgei Snow
Pandorina morum (Müll.) Bory
Pediastrum biradiatum Meyen
Pediastrum boryanum (Turp.) Menegh.
Pediastrum duplex Meyen
Pediastrum tetras (Ehr.) Ralfs
Polyedropsis spinulosa Schmidle
Scenedesmus acuminatus (Lagerh.) Chod.
Scenedesmus acutus Meyen
Scenedesmus apiculatus (W. & G.S. West) Chod.
Scenedesmus armatus Chod.
Scenedesmus bicaudatus Dedus.
Scenedesmus denticulatus Lagerh.
Scenedesmus disciformis (Chod.) Fott & Kom.
Scenedesmus ecornis (Ehr.) Chod.
Scenedesmus intermedius Chod.
Scenedesmus opoliensis P. Richt.
Scenedesmus quadricauda (Turp.) Bréb.
Scenedesmus spinosus Chod.
Schroederia nitzschioides (G.S. West) Kors.
Schroederia setigera (Schröd.) Lemm.
Schroederia spiralis (Printz) Kors.
Staurastrum polymorphum Bréb.
Staurastrum sp.
Stigeoclonium fasciculare Kg.
Stigeoclonium tenue Kütz.
Tetraedron caudatum (Corda) Hansg.
Tetraedron incus (Teil.) G.M. Smith
Tetraedron minimum var. *tetralobulatum*
Tetrastrum elegans Playf.
Tetrastrum glabrum (Roll) Ahlstr. & Tiff.
Ulothricales sp.
Ulothrix zonata Kütz. phylamentous *Chlorophyta* sp.

List of bryophyte species recorded in the study quadrats

Hepaticae

Conocephalum conicum (L.) Lindb.
Lophocolea bidentata (Schrad.) Dum.
Lunularia cruciata (L.) Lindb.
Marchantia polymorpha L.
Pellia endiviifolia (Dicks.) Dum.

Musci

Amblystegium riparium (Hedw.) B., S. & G.
Amblystegium serpens (Hedw.) B., S. & G. var. *serpens*
Amblystegium serpens (Hedw.) B., S. & G. var. *juratzkanum*
Amblystegium varium (Hedw.) Lindb.
Anisothecium sp. 1
Anisothecium sp. 2
Anisothecium varium (Hedw.) Mitt.
Barbula unguiculata Hedw.
Brachythecium populeum (Hedw.) B., S. & G.
Brachythecium rutabulum (Hedw.) B., S. & G.
Brachythecium salebrosum (Web. & Mohr) B., S. & G.
Bryum argenteum Hedw.
Bryum barnesii Wood.
Bryum cf. *capillare* Hedw.
Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer & Scherb.
Bryum sp. 1
Bryum sp. 2
Bryum sp. 3
Calliergonella cuspidata (Hedw.) Loeske
Ceratodon purpureus (Hedw.) Brid.
Cinclidotus fontinaloides (Hedw.) P. Beauv.
Cinclidotus riparius (Brid.) Arnott
Cratoneuron filicinum (Hedw.) Spruce
Didymodon fallax (Hedw.) Zander
Didymodon luridus Hornsch.
Didymodon cf. *vinealis* (Brid.) Zand.
Drepanocladus aduncus (Hedw.) Warnst.
Eurhynchium hians (Hedw.) Sande Lac.
Fissidens sp. 1
Fissidens taxifolius Hedw.
Funaria hygrometrica Hedw.
Hygroamblystegium fluviatile (Hedw.) Loeske
Leptobryum pyriforme (Hedw.) Wils.
Leskea polycarpa Hedw.
Minium ambiguum H. Müll.
Minium marginatum (With.) Brid. ex P. Beauv.
Minium stellare Hedw.
Physcomitrium pyriforme (Hedw.) Brid.
Plagiomnium cf. *affine* (Funck) T. Kop.
Plagiomnium rostratum (Schrad.) T. Kop.
Plagiomnium undulatum (Hedw.) T. Kop.
Pohlia melanodon (Brid.) J. Shaw
Pohlia wahlenbergii (Web. & Mohr) Andr.
Rhynchostegium riparioides (Hedw.) Card.

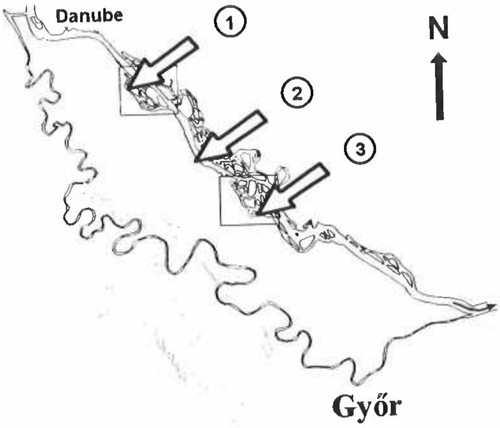

Figure 1

Algological sampling sites ("floating reed islands") in the Szigetköz region
(1 – Cikolasziget, 2 – Kisbodak, 3 – Ásványráró)

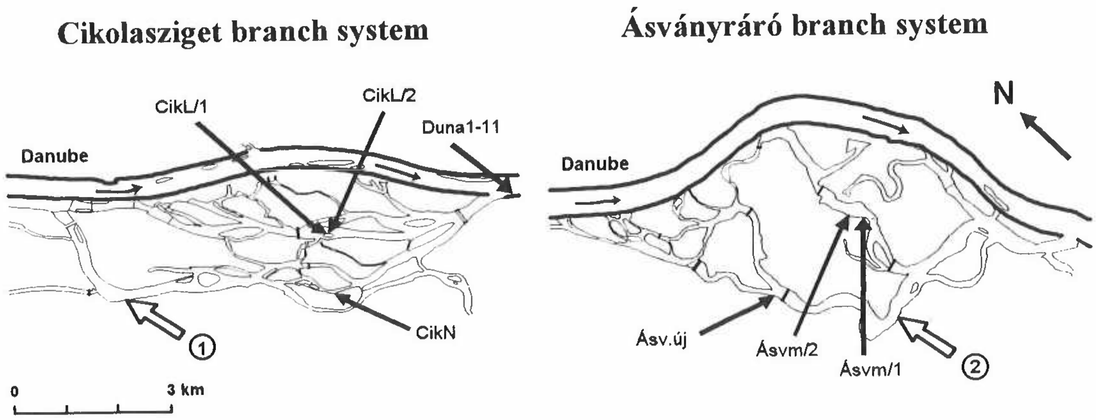

Figure 2

Bryological sampling sites in the branch systems (1, 2 – algological sampling sites, see Figure 1)

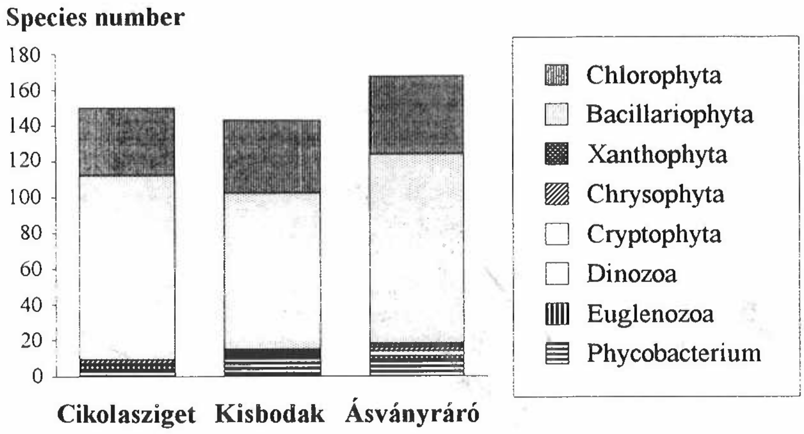

Figure 3

Taxonomical distribution of algae collected from the "floating reed islands"

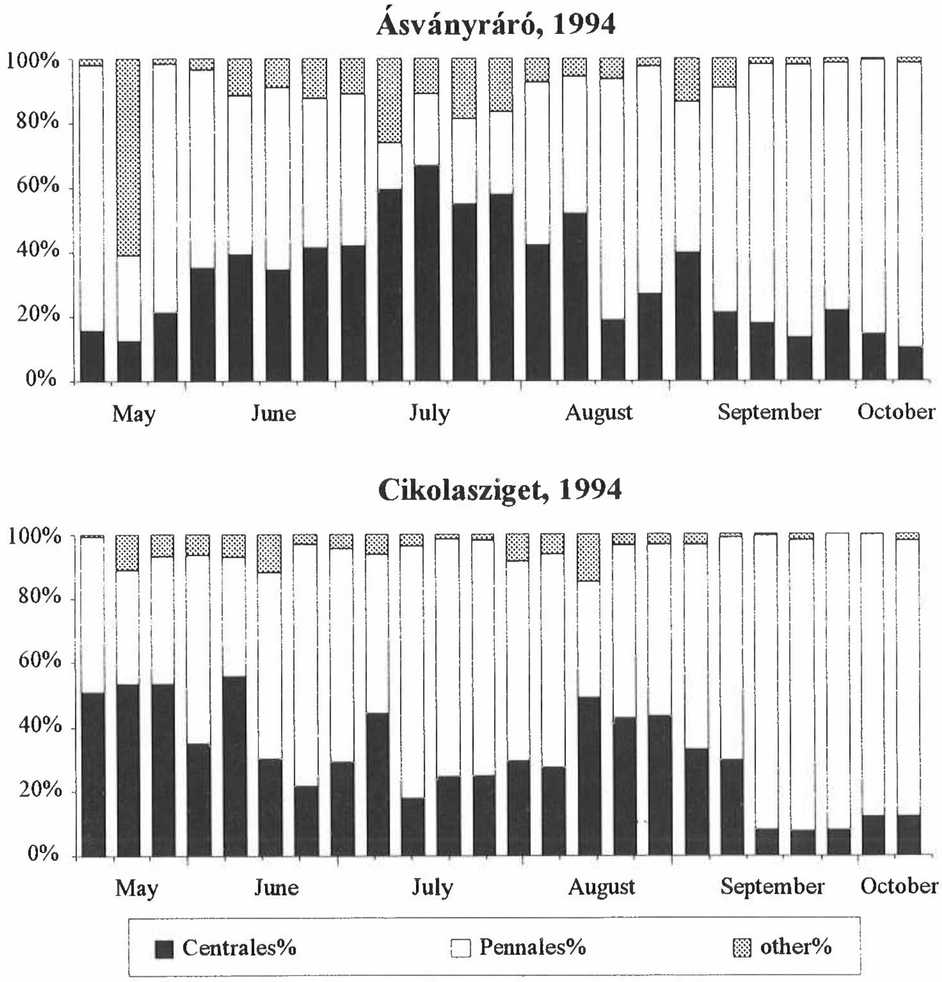

Figure 4

Relative abundance of the periphytic algae on the "floating reed islands", based on individual numbers. Within the diatoms, the orders Centrales and Pennales were distinguished

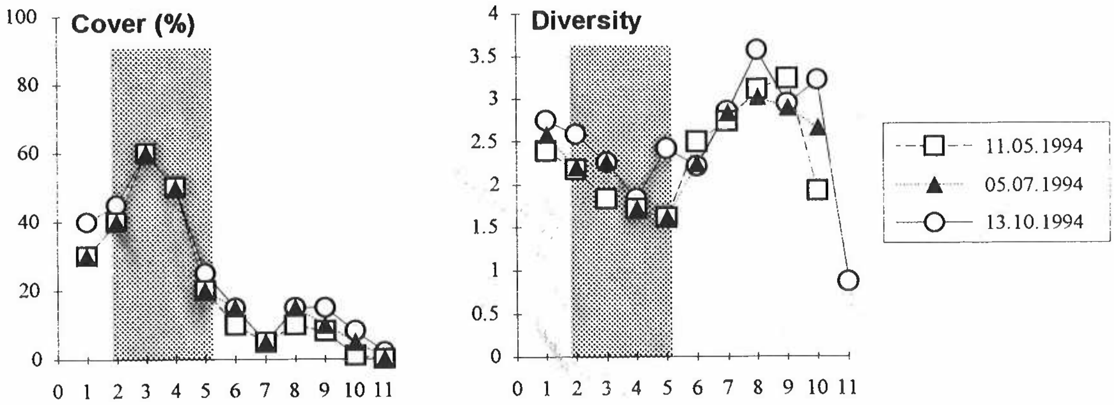

Figure 5

Total bryophyte cover and bryophyte species/cover diversity of the study quadrats along the transect on the protective stone border of the "Old Danube"
(11 = actual water level)

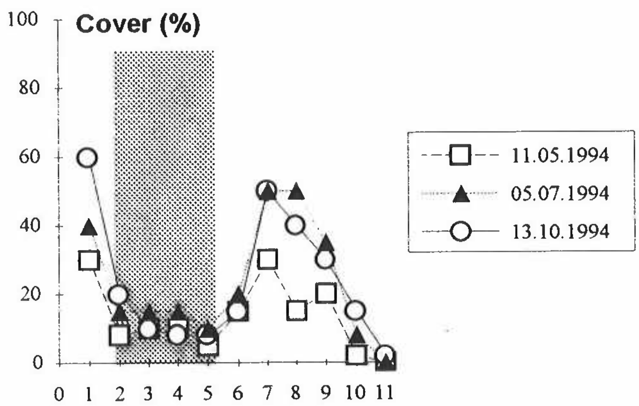

Figure 6

Total cover of flowering plants of the study quadrats along the transect on the protective stone border of the "Old Danube"

STUDY OF TREE GROWTH IN FORESTRY MONITORING

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Introduction

To investigate the impacts of the Gabčikovo–Nagymaros Project (referred to later as the Project) on the environment, a monitoring system, including several scientific fields, was established in 1986. The Forest Research Institute has been conducting observations within the framework of this system since the beginning of this monitoring. The growth, structure, site and health of the riparian forests have been observed (Halupa 1985, Halupa et al. 1994). The main objectives of forestry monitoring are as follows:

– To identify the main abiotic site factors and to observe their changes.
– To study how the abiotic environmental factors – or at least those that can be measured – affect the growth and development of the trees and stands.
– To study, in an indirect way, how tree growth reflects the changes in the environment, both those observed and those not accounted for in the monitoring. The basis of these studies is that tree growth is strongly determined by the environment, and it indicates, to a certain degree, the environmental conditions and their changes.
– To observe the health condition of trees and stands.
– To make economic predictions for the forestry enterprise. By investigating the trends of the environmental changes, the future of the stands can be forecasted, which enables us to assess the necessary measures to be taken. This is of utmost importance for the enterprise, because the hybrid poplar stands in the flood plain of the Szigetköz produce timber at a rate several times higher than the national average. A substantial reduction of this growth or a necessary change of species due to the deterioration of the hydrological conditions may cause damage to the enterprise, for which it should be prepared.
– To study the forests as essential biological entities from a natural protection point of view. Parts of the Szigetköz are protected, and the conservation of many habitats is important in a European perspective, too.

In this paper, some results of forestry monitoring since the diversion of the Danube (October 1992) are summarised. First, we give a short description of the ecological conditions of tree growth in the Szigetköz. Then, the methods and results of annual stand growth, weekly girth growth and forest health observations are discussed.

Site conditions and their changes in the flood plain of the Szigetköz

The spatial distribution and cultivability, as well as the development and productivity of terrestrial plants are determined by their genetic endowments and the environmental conditions. All these conditions are referred to as site. The most important groups of site factors are the climate, the soil and the hydrological conditions. The main site factors of the Szigetköz can be characterised as follows (Halupa 1988, Halupa – Csókáné 1994).

Climate. The macroclimate of the Szigetköz can be classified as forest steppe climate. This is unfavourable for the forests, and stands of higher than marginal productivity can only exist where sources of water other than precipitation, such as groundwater or inundations, are at the trees' disposal. In the flood plain, evaporation is high due to the large open water surface of the river and its side branches. This results in a mesoclimate slightly more favourable for trees: climate of the flood plain can be classified as sessile oak – Turkey oak climate type.

Soils. The soils of the flood plain have developed from pure alluvial soils. They are azonal formations, because soil development was hampered by the repeated deposition from the river. The physical structure of the soils is typically sand and muddy sand. In sites of higher elevation, humic alluvial soil types and their combinations can be found. Before the implementation of Variant C of the Project, the frequent inundations deposited layers of some 2 cm a year, ensuring a regular supply of nutrients for the trees. Below this fine-textured deposit, the soils of the Szigetköz are characterised by a thick gravel layer, sometimes mixed with coarse sand. The depth of the soil varies in a mosaic-like fashion, and the gravel is typically found close to the surface, within 100–150 cm, sometimes even as close as 50 cm.

Under the original water regime, the existence of this gravel mattered on small areas only. However, in the absence of inundations, due to the diversion of the Danube, and with the lack of any recharge system currently, the thin soil layer can be regarded as a soil deficiency. There is no more capillary contact between the fertile soil and the groundwater, thus trees have no access to water pools, and this limits tree growth.

The calcium content of the soil varies depending on the mud content. The usually high amount of calcium does not decrease soil fertility as long as the floods regularly occur and the soil is moist. The absence of the floods increases drought, causing physiological drought for the trees.

Hydrological conditions. The hydrological conditions of most sites in the Szigetköz used to be determined by the water regime of the Danube and the elevation. The elevation is defined as the height of the soil surface above the (average) water level in the river, upon which the depth of the water table level and the frequency and duration of the inundations depend.

Before the diversion, all sites were classified into the elevation categories defined below. The same categories are used for the sites after the diversion, too, even if conditions have changed substantially, and the sites could be categorised differently.

The extremely high and the high elevations represent 2% of the flood plain, and are flooded rarely and for a short time. The occurrence of middle high and middle low elevations is 20% and 71%, respectively. These are sites under constant effect of water, where the inundations last for up to 1 and 2 months, respectively. The stands of highest productivity grow on these sites. The deep seated and very deep seated areas occupy 7% of the flood plain. These are wet and extremely wet sites, offering favourable conditions for the willows.

Annual stand growth investigations

Methods. To measure stand productivity, 30 plots of 0.1–0.25 ha were marked out (Halupa et al. 1993). The species of the stands is mainly hybrid poplar. That the species in 80% of the plots is hybrid poplar, as opposed to the 64% ratio in the flood plain forests, is explained by the characteristics of these poplars to sensitively and quickly, thus measurably react to the environmental changes.

In assessing stand volume and increment, the breast height diameter and the height of each tree in the plots are measured each year after the termination of the vegetation season. Volume is estimated from these measurements by using standard volume functions. The annual changes of all these measures, i.e. the increments, are also derived.

Results and discussion. In analysing the measured and estimated data, several factors have to be considered that affect tree growth independently of the effects of Variant C of the Project (Somogyi et al. 1995). A few of these – sometimes hardly measurable – factors are the following:

– Tree species: the reaction of fast growing species to the changes in the environment is more rapid and expressed, and their water requirement is greater than that of the slow growing ones.

– Age: it is a common biological phenomenon that the activity (e.g. the growth) of the living beings significantly changes with age.

– Silvicultural treatments (thinnings): the growth of tree individuals temporarily increases after thinnings, and decreases later with the advancing competition (cf. the growth of white poplar trees in 1994 in Figure 3).

– Weather: this is such a complex system that the impacts of its various factors can hardly be considered separately.

For the two vegetation seasons having passed since the diversion of the Danube, our experiences by species are as follows.

Hybrid poplars

In at least one of the two years, a decrease of tree growth was observed. This can easily be explained for the old stands of more than 20 years of age, as opposed to the 8–15-year-old stands that are in their most intensive period of growth.

The measured volume increments in the young and medium-aged, as well as in the older stands are shown in Figure 1 and Figure 2, respectively. As a reference, the increments of the yield Classes I to III of the so-called yield tables for 'I-214' poplar (Halupa – Kiss 1978) are also shown in these figures. (These tables contain average growth data for this species in 6 different site classes; Class I refers to the best, Class VI to the least productive site.) The figures show that the majority of the investigated stands (like many of the stands in the Szigetköz) grow on sites of Class I or II, i.e., on the best sites.

In 1993 the growth of the stands was good where the gravel lies deep, the site is of medium low or lower elevation, and where the trees are young or of middle age. The decrease of the growth was considerable in sites of medium high and high elevation, i.e., that used to be inundated only in the case of big floods and where the groundwater table lies deep in the gravel now (e.g. forest compartment Dunakiliti 14E, Dunasziget 15A, 34A, 11D). The growth also decreased in 3 of 8 plots in compartment Lipót 4A.

In 1994, *in young and medium-aged stands* (up to 15 years of age, see Figure 1): the growth dropped in 5 of 8 plots in compartment Lipót 4A only in 1994. In the plot at Dunasziget 15A, situated on the main river bed, a considerable decrease of growth occurred due to the diversion of the river. *In the old stands* (above 15 years, see Figure 2), growth varies greatly in the plots, and the causes of changes are difficult to establish. In the plot in compartment Lipót 27C, where the water supply is favourable, the stand showed good growth in 1993, which dropped by 50% in 1994. An abrupt decrease was observed in Dunasziget 4A. In compartments Dunakiliti 14A, 14E and Dunasziget 34A, the growth due to age is low, and annual growth changes irregularly. The growth in Dunasziget 7K did not change. Site and water availability is rather unfavourable here because of the shallow soil. The production capacity of this site was and is small, and because the Danube had little bearing on site productivity, the diversion, too, had little effect on the growth of this stand. In Ásványráró 6G, which is a deep-seated site, no decrease in growth was observed.

Willows

The most extensive damage in the forests happened in the pioneer willow stands that are the most water-dependent of all. The lack of inundations showed almost instantaneously in adverse effects.

There are only two monitoring plots in willow stands, but we also observed other willow stands and consulted local foresters, too. Based on all these experiences, it can be stated that, although the growth of willow stands was still rather good in 1993, it dropped dramatically in 1994.

Hardwoods

These stands grow relatively slowly, and depend less on excess water. Therefore, they react in a less detectable way, and more slowly to the decrease of the amount of water. In addition, our limited database does not allow us to detect any reliable change in tree growth. In Hédervár 11B and Ásványráró 26A the growth did not change much, and in Dunasziget 22B growth decreased slightly.

Weekly girth growth of individual trees

The annual growth of the trees (within the vegetation period) can also indicate changes in the environment. Therefore, the monitoring programme also includes measuring girth growth of single trees.

Methods. Girth growth of 117 trees at breast height is measured weekly from 1–2 weeks before, until 1–2 weeks after the vegetation period. The measured trees are situated in 10 of the 30 plots mentioned above. The change in the distance between the two tips of a band embracing the bole at breast height is measured to the nearest one tenth of a millimetre. Weekly data for these trees have been collected in the last 7 years.

The factors affecting growth. In addition to weekly growth, the annual girth growth, growth rhythm, points of local maximum, and the length of the vegetation period are also worth investigating. These growth phenomena may depend on the species and the site factors, such as temperature, the amount of precipitation, the depth of groundwater table, etc. The impacts of the various factors are difficult to study separately, because all factors act at the same time. It is often effective to investigate which factors were at minimum (i.e. limiting) at the local positive or negative peaks of the growth curve.

The beginning of the vegetation season depends mainly on the temperature. Growth starts only at a daily average temperature of +10 °C. The maximum growth in the main growing period in summer is only reached when all factors are at optimum. In the Szigetköz, where temperature is favourable most of the time, the amount of water and nutrients can be limiting. The termination of the growth – and the vegetation season – is determined by the temperature and the amount of available water in the soil.

During the whole vegetation season, but first of all in the main growing period, abrupt "ups" and "downs" can be observed in the pattern of girth growth even under normal conditions. The peaks occur when both temperature and water are optimal, whereas drops happen when it is either cold or dry or both.

Detailed information on the hydrological and meteorological conditions of the period investigated is necessary to explain the measured growth data, especially when the effects of the diversion of the Danube are to be evaluated. Abundant precipitation shortly after the diversion, for instance, may alleviate its negative impacts, as opposed to a dry period that may increase them. Therefore, before analysing the measured growth data, these conditions must be characterised for 1993–1994.

The hydrological conditions and precipitation in 1993–1994. As it was mentioned, the rapid growth of the trees was supported by the regular floods before the diversion of the Danube. In early 1993 this situation changed. Except for the small and short-lasting floods in July 1993 and May 1994, there were no floods – not even in the vegetation period – that could have filled up the water and nutrient pools of the soil and the trees. Along with this, the water table level sunk already in 1993, and it went further down in 1994. As a consequence, the relative importance of the precipitation, the only remaining source of water, increased.

The amount of precipitation in 1994 was much more favourable than in the previous years. The largest precipitation in the Győr meteorological station between 1987 and 1994 (673 mm) was measured in 1994, and was by 64 mm more than the long-term average.

In addition to the amount of the precipitation, its distribution also matters. Special attention should be paid to the precipitation in the vegetation period, which usually lasts from April till September. 1994 was exceptionally favourable in this respect, too.

Since the importance of the same amount of precipitation is different in the various months, it was proposed to use weighted sums of precipitation (Pálfai 1991). According to this method, different weights are given to the precipitation of the months of the year that reflect the importance of the water for the plants. In the autumn–winter–early spring period, water is stored in the soil and plants, in spring and summer it is used for actual life activity. The greatest importance of all is attributed to the July precipitation, because plants require much water in this month, and, unfortunately, July is the most drought-prone period of the year in Hungary. The monthly weights are the following: October: 0.1, November: 0.4, December–April: 0.5, May: 0.8, June: 1.2, July: 1.6, August: 0.9 (Pálfai 1991). Using the weighted sum of precipitation, 1994 was the best year around Győr, and the second best around Mosonmagyaróvár since 1987.

Results and discussion. With the above in mind, the following can be stated concerning girth growth:

Total annual growth (Figures 3 and 4): it increased in Lipót and Ásványráró in 1993 compared to the previous year. This can be attributed to the flood in July. In addition, the soil and the trees may still have had enough reserve, which can be explained by the thick soil, the thinning and the young age of the stands.

As opposed to this, an overall decrease ensued in 1994: growth dropped by 61–88% in the hybrid poplar stands. The only exception is the white poplar stand in Dunasziget 15B, where the thinning in the previous year temporarily accelerated the growth of the remaining trees.

Growth pattern of the vegetation season (Figure 5): its characteristics changed after the diversion. The change depends on site, but it usually became asymmetric: a greater portion of the total growth was produced early in the vegetation season (until around the end of May), then the growth slowed down considerably. The peaks in the growth caused by the inundations in the earlier years disappeared, the number of peaks decreased.

Health conditions

With respect to the health condition of the forests, our observations cannot be regarded as representative. Yet, considering all our experiences in the field, it can be stated that the trees started to shed their leaves already in July–August in the last two years. This could be observed especially in the higher elevations. This shedding, occurring abnormally early, was brought about by the dry conditions, and is a reaction of the trees to avoid damage.

Conclusions

The two years that have elapsed since the diversion of the Danube are not long enough to make highly reliable statements about the impacts of the diversion. What seems to be sure, however, is that the growth of trees slowed in a measurable way, and their health started to deteriorate. In order to stop this degradation and to reconstruct the original growing conditions, a steady level of the water in the main river bed and/or the side branches does not seem to be enough. The uneven temporal occurrence of wet conditions, required by the riparian forests, can only be guaranteed by regular natural or artificial inundations.

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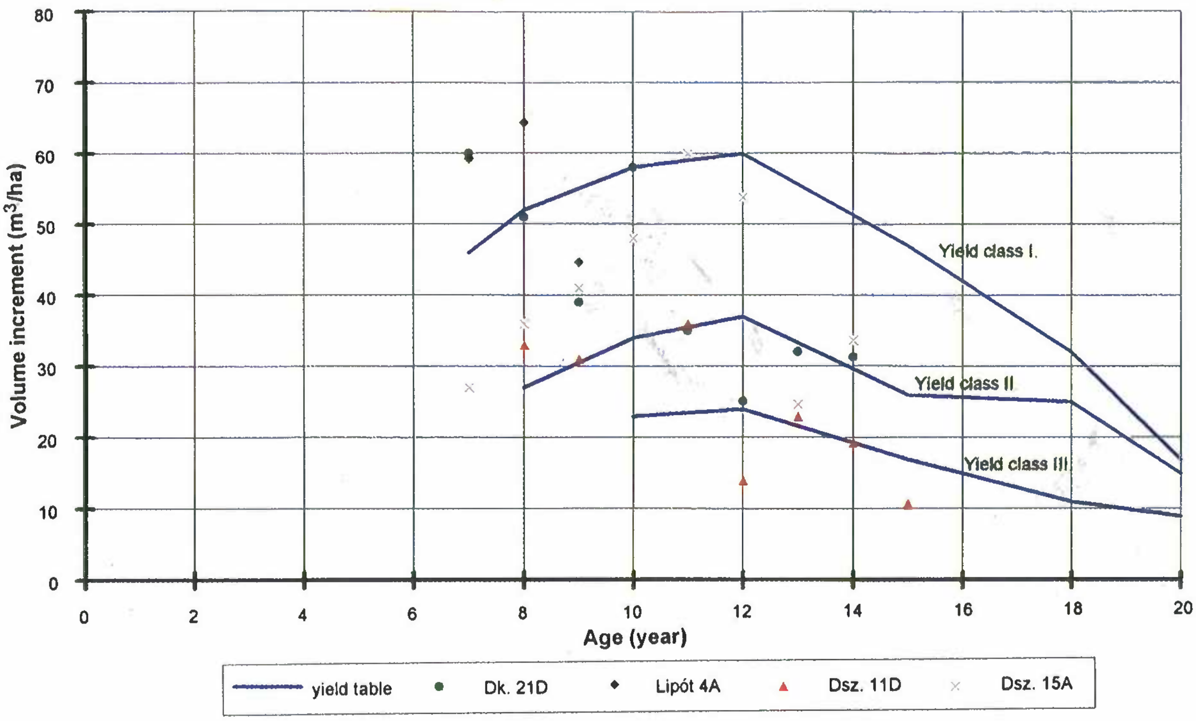

Figure 1

Volume increment of 'I-214' hybrid poplar for young and medium-aged stands, and the increment given in the yield table by age

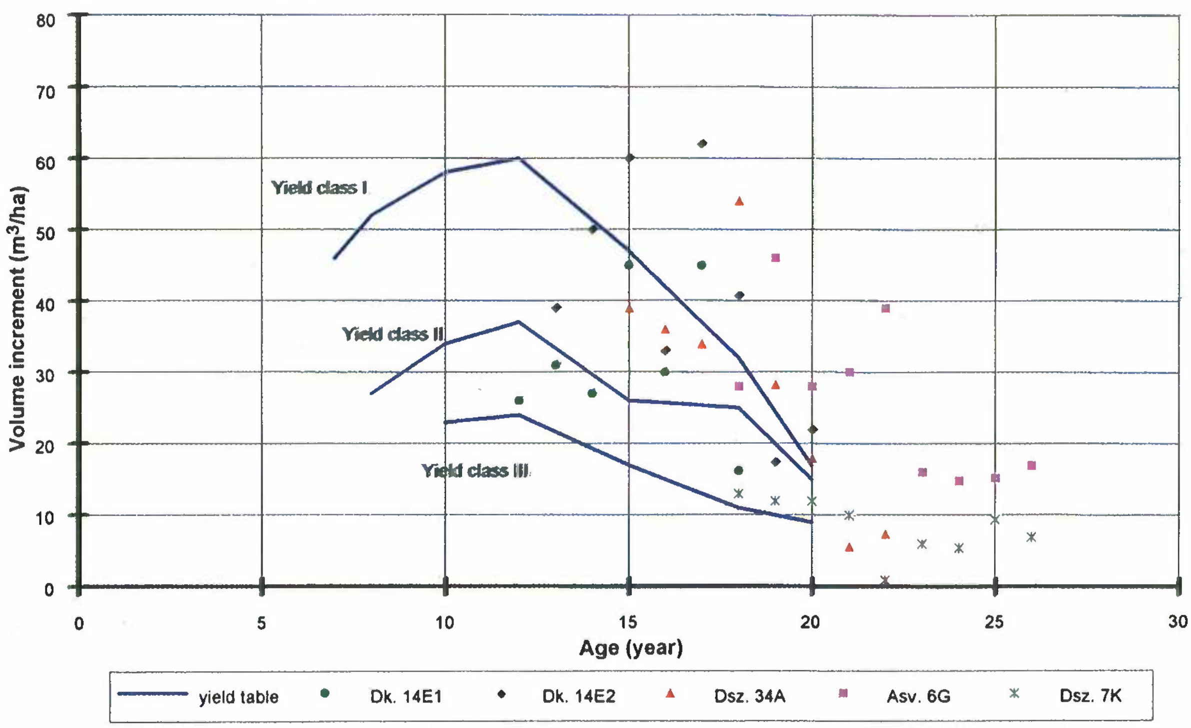

Figure 2

Volume increment of 'I-214' hybrid poplar for old stands, and the increment given in the yield table by age

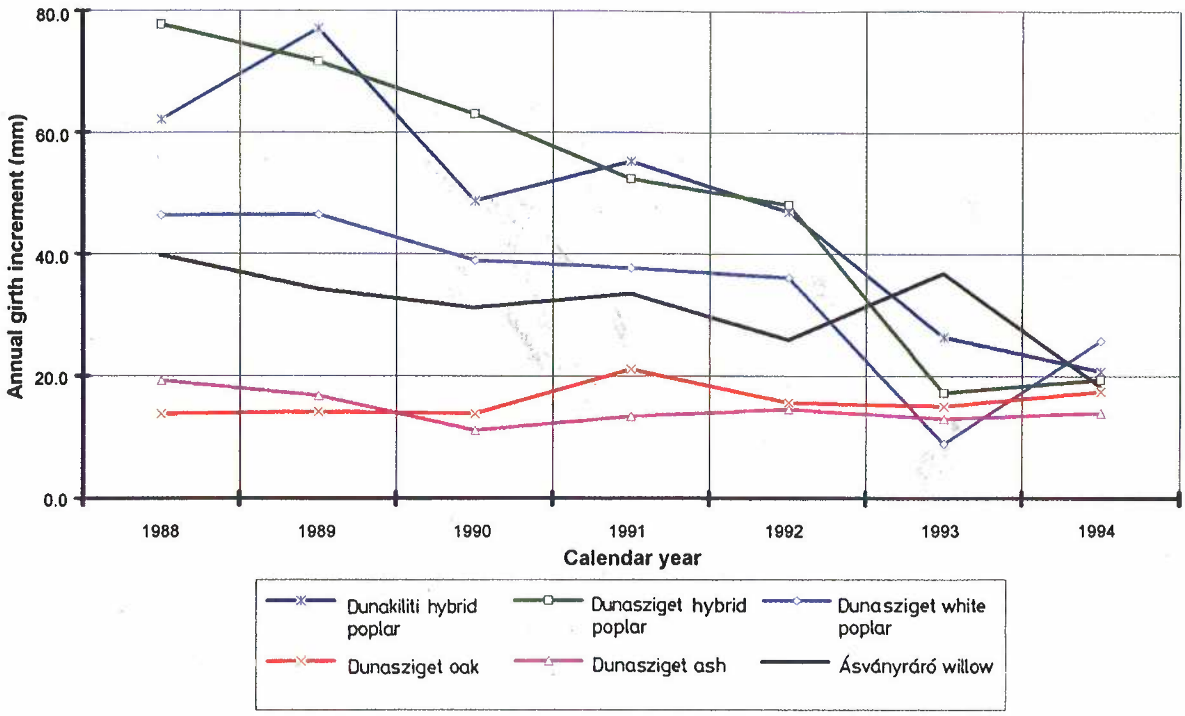

Figure 3

Girth increment of trees in various plots

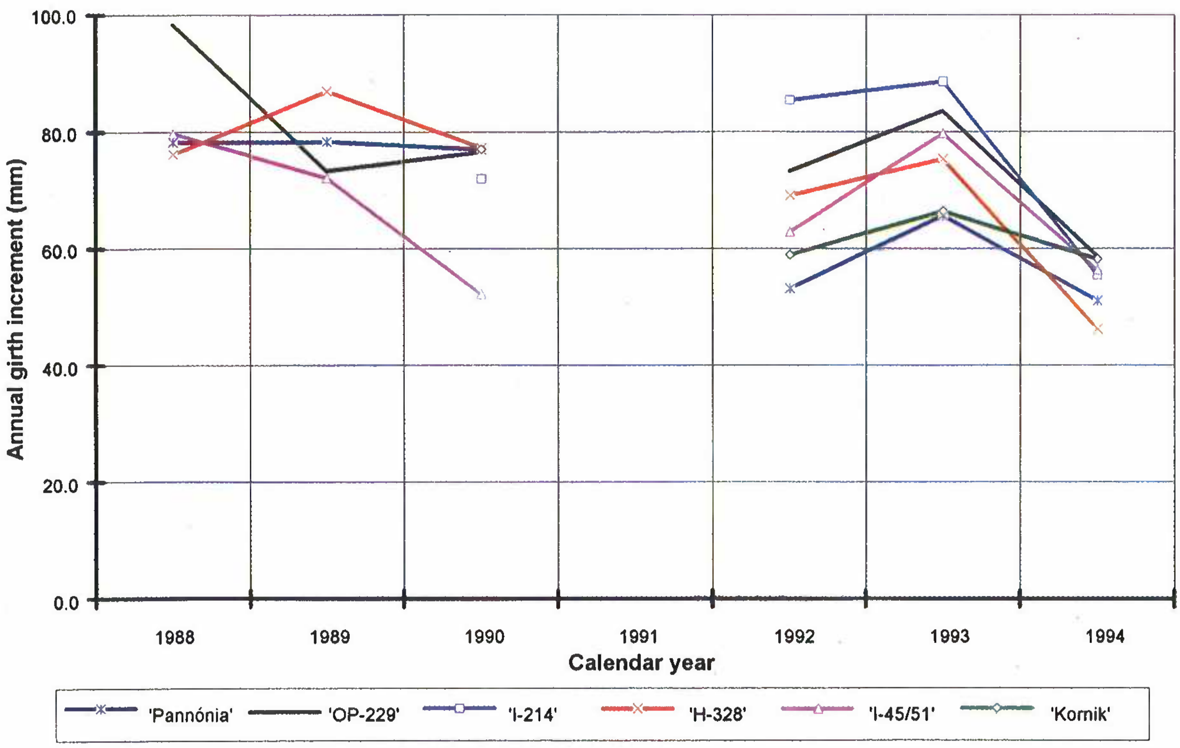

Figure 4

Girth increment of 6 hybrid poplar clones in Lipót 4A

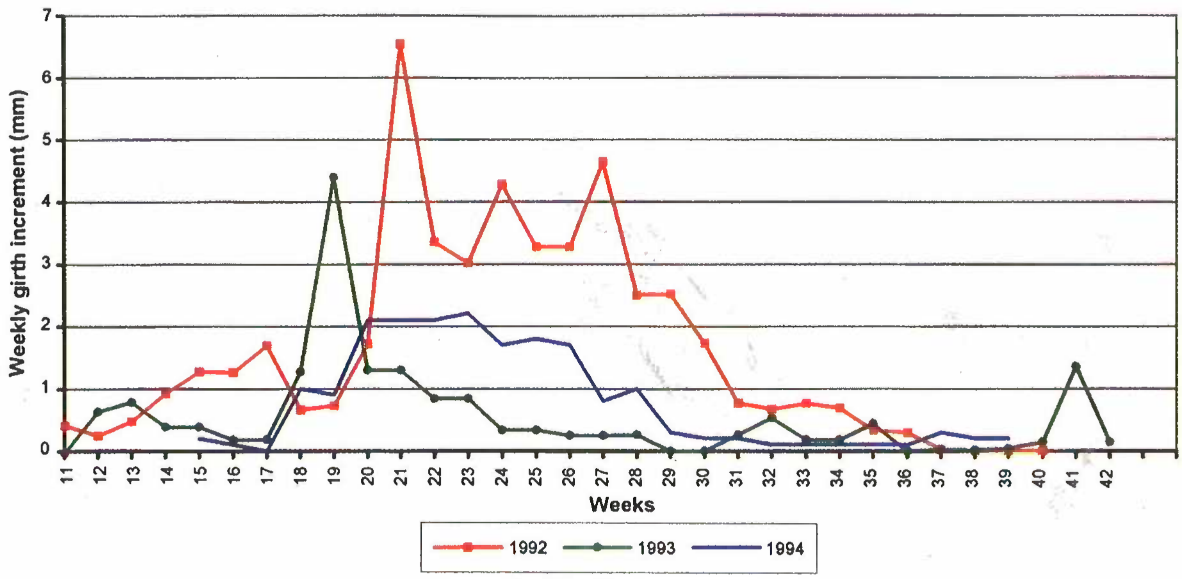

Figure 5

Growth pattern of hybrid poplar trees right on the bank of the Danube changed substantially after the diversion

HEALTH CONDITION OF FORESTS IN THE SZIGETKÖZ

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The Szigetköz is an area lying at the upper part of the river Danube in Hungary, and is exceptionally rich in natural beauty and wealth. It is a valuable area from the point of view of forest management, too; in addition to the original forest communities of the flood area, there are extended poplar-hybrid plantations of high productivity on the alluvial soil over a thick gravel cover.

Silviculture is based in the Szigetköz on a continuous optimum water supply due to the high water conductivity of its soil. Yearly one or two total inundations ensured water and nutrient supply for the forests, and by it, the survival and functioning of the ecosystem of the flood area forest. The regularly appearing inundation advantageously prevented the rapid growth of animal organisms (insects and vertebrates) which would damage the forest. All these factors were effective in the pristine state of the Szigetköz. The first human intervention was the regulation, the construction of dams compelling the river to flow in the area between them. This change could be at least partially overcome by the forest. Areas outside the dams got drier and this fact led to the necessity of artificial afforestation. That is how poplar-hybrids were introduced. The hydrological intervention did not basically change the natural conditions of the area to a degree which would endanger silviculture. This situation was due to the fact that in the gravel beds constituting the subsoil, the groundwater (water of the Danube) always reached the roots of the trees according to the law of communicating vessels.

In consequence of the diversion of the Danube in October 1992, this factor which gave life to the forests there ceased abruptly and to a decisive degree. This new situation has resulted in severe changes of forest life. Great forest areas which had been regularly inundated by Danube floods have remained dry.

The change in the environmental conditions has been well reflected in the state of health of the forests. Used to the original optimum water supply, communities developed which got weaker in the new hydrological conditions and this is reflected by the health of the forests.

If data about the state of health of trees are recorded for many years using the same parameters, the results will clearly indicate the process and the level of the changes.

Ecological changes in forests can be best monitored by recording their condition of health; this method is superior to all others, as forests occupy the same site for decades and they conserve the past.

In order to study the health of the Szigetköz forests, ten sample plots have been selected by us in co-operation with the Scientific Institute of Forestry at locations differing from a hydrological point of view. They are partly in natural forest communities, partly in artificially planted forests. Each plot contains 100 numbered trees, thus the plants studied can also later be identified unambiguously. Data have been and will be collected twice a year, using the same parameters.

The sample plots are indicated on the enclosed map.
The main recorded and measured parameters are the following:

- measure and cause of foliage lack,
- quantity of dry branches in the crown,
- phenomenon and measure of top dryness,
- quality and measure of trunk damage,
- quality and measure of stump and root decay.

These data well characterise the state of health of trees and its changes.

Changes of the complete community are recorded by insect light traps which will be operated for several years, moreover, phytocoenological measurements are also planned to be carried out every year.

As soil conditions have a decisive role in the life of flood area forests, the present soil quality is recorded on the basis of soil profiles in the sample plots, and the soil samples are also analysed in a laboratory.

The selection of plots and the recording of data in 1993 and 1994 are to be considered as the basic records. Nevertheless, data recorded during these years have already been influenced by the changed conditions, but the data concerning the pristine situation are unfortunately lacking.

The summarised results of the records made in 1994 are presented in Table 1. Detailed data can be found in the yearly reports. Data collected hitherto do not allow general conclusions. It is, however, evident that in areas where the previous regular flooding ceased, top dryness has started. Top dryness indicates a significant decrease in the groundwater level which is to be reached by the roots of the trees. Such areas with top dryness are found in the area of Rajka–Dunakiliti.

Recordings in the future will enable us to make unambiguous conclusions about the interrelations which can be generalised for the whole area.

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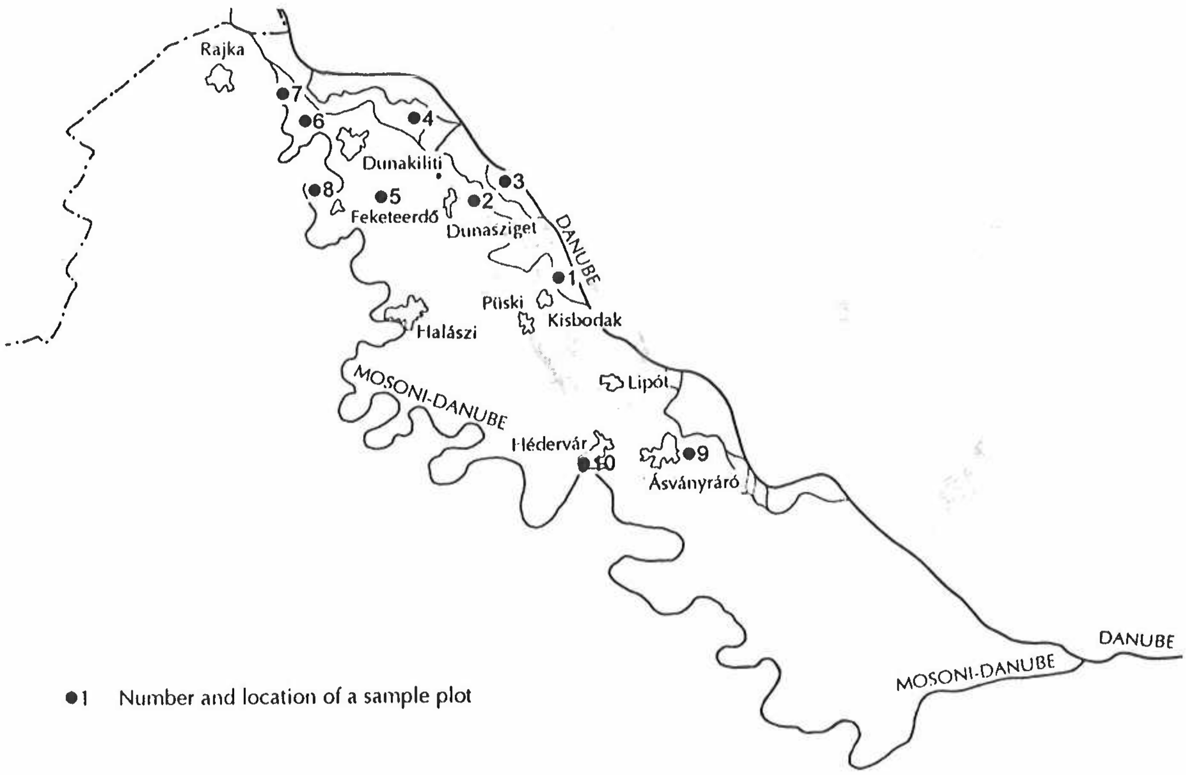
Table 1

Sample plots

Number	Location*	Stand	Evaluation of the health condition
1	Kisbodak 16I	Willow plantation	Very good
2	Dunasziget $22B_1$	Oak – ash – alder	Good, but oaks with starting crow dryness
3	Dunasziget 1A	White poplar – grey poplar	Starting top dryness and crow death
4	Dunakiliti 26A	Poplar-hybrid	Crown dryness and strong insec damage on wood
5	Feketeerdő 2A	Hornbeam – oak	Start of crown dryness
6	Dunakiliti 1A	Oak – ash – elm – white poplar	Start of crown dryness, 46% o trees with top dryness, the crow of 65% is damaged
7	Rajka 14H	Oak – ash – white poplar – robinia	23% of trees with top dryness, th crown of 58% is damaged
8	Feketeerdő 1H	Ash	Good, without significant damage
9	Ásványráró 2C	Poplar-hybrid	Good, without significant damage
10	Hédervár 4E	Ash – walnut – elm	Good, without significant damage

* The numbers and capital letters following the name of the location refer to the examined part of the forest.



Sampling plots of forest protection monitoring in the Szigetköz

AGRICULTURAL SURVEYS AND THEIR RESULTS

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The Mosonmagyaróvár Department of Production-Development of the Pannon University of Agricultural Sciences is measuring the water content of soils at 48 agricultural and 6 forestry observation points that were selected and continuously observed earlier. Measuring, adjusted to the weather conditions and the various development phases of the plants, was carried out on 12–13 occasions between the end of March and the beginning of November every year from 1989 onwards.

Phenological surveys are carried out on 47 agricultural fields. The growth, development and health of stands are examined in the main development phases of the plants, in farm production conditions. The number of observations considered are between 4 and 6, together with the last estimate for production.

The effects of the methods of production (i.e. natural and agrotechnical factors) on the size of the yield are examined in the agricultural utility survey and evaluation (by computerised processing). The field-level data of 17 agricultural units are processed and analysed for 11 species which constitute 90% of the arable land of the region.

The efficiency of agricultural production – as a biological production – is influenced by numerous interrelated factors.

Let us have a brief look at how the main groups of factors influencing production changed in 1993 and 1994.

Weather

1993 was a drought-ridden year. Precipitation was very low in the first half of the year (minimal in April and May). There was more in the following months, and the last months of the year were quite rainy. During the growth period, with great variation at certain observation points, 153–286 mm rain fell (more in the Middle-Szigetköz). Spring came late, but at the beginning of the growth period temperatures were higher than usual. From 22nd April, warm weather, more typical of summer, and occasionally with a heat wave, was experienced, lasting until mid-July.

1994 was a year with more precipitation. The amount of precipitation outside the growth period was 17–39 mm more in the Upper-Szigetköz, and 68–94 mm more at other places, than in the first period of the previous year. Much rain fell (between 181 and 249 mm) in the first three months of the growth period. Until the farming period in June, precipitation with a 127–253 mm variation at survey locations was higher than in the previous year, temperatures also being favourable. Between 26th June and 15th August there was a heat wave with little rain (local showers resulted in regional differences) and with a daily average temperature between 21 and 28 °C. In the second half of the growth period, precipitation was generally low, its regional distribution rather whimsical and timing unfavourable. During the growth season, a total of 300–400 mm was measured.

Groundwater

The amount of groundwater in half of the Szigetköz area was such that it could influence the water content of the soil. Following the diversion of the Danube, the groundwater situation in the Lower-Szigetköz remained unchanged. In the middle area of the Szigetköz (from Dunasziget to Ásvány-ráró), in a 4200 ha area (19%), the level of groundwater dropped so low that it disappeared from the cover layer. In other areas of the Szigetköz, the drop was less than 50 cm, but these were places less affected as regards fresh groundwater supply.

In 1994 the growth season's average depths of groundwater, compared to the situation in 1993, changed only to a small degree.

Agrotechnology

Due to the slow and uncertain transformation of agriculture, the inadequacy and faults of the applied technology have further reduced the chances of production. The majority of the farms do not have the working capital that would guarantee the production level created previously. Therefore, only the basic technological elements of several species can be implemented.

Main faults

Insufficiency of resupply of nutrients: in 1989, on 1 ha utilised arable land, an average of 333 kg; in 1992 45.6 kg; in 1993 82.4 kg; and in 1994 128.5 kg mixed nutrient was supplied.

The biological background had worsened, only home-grown seed was used for several species.

The farmers are trying to save on soil works.

Although demand for irrigation had grown, only 9% of the utilised area was irrigated.

Research results

At the end of March 1993, soils indicated a still acceptable (55–65%) degree of saturation. In the area affected by the diversion, the supporting impact of groundwater was missed. The water content of the soil was gradually decreasing from the end of April and, where there was no groundwater by mid-June, there was hardly any or no water at all to feed the plants. In the second half of July, the upper layers were recharged, but the water content of the soil grew significantly only from October.

Measures taken at the end of March 1994 show that the available water content of the soil was between 60 and 75%. Conditions were near optimal in April; at certain areas with high groundwater, saturation level was reached. In spite of the more intensive use of water, the quantity of water that could be used by plants was at its highest in May. The water content of the soil had been adequate until mid-June; until then the recharging role of the groundwater was not missed. Water content had gradually reduced from the beginning of July (before the harvest to only 40–50 cm depth of the root layer). Surveys at the end of August showed that the water content was just as low as at the beginning and in the middle of July of the previous year.

Figure 1 shows the water content curves of the soil section fed from precipitation, comparing two years using survey periods that were not far apart. In April of both years, there was available water In 1994 there was significantly more in the root layer. The first measurement in June 1993 showed that there was hardly any water left in the section, and in 1994 it was well supplied.

Figures 2, 3 and 4 show the recharging effect of the groundwater.

Figure 2 shows the situation at forestry observation point No. 9990 in the Upper-Szigetköz. April 1992: groundwater reached the top layer; November: 150 cm groundwater level dropped, dried out soil (down to bound water level). April 1994: The flood wave of the Danube raised groundwater which approached the top layer and wet the lower layers.

Figure 3 gives the situation at the agricultural observation point No. 2630 in the Middle-Szigetköz. April 1992: in soil with a thin top layer, groundwater moved in and wet the top layer; November: following the diversion, the groundwater sank deep; April 1994: even the biggest flood wave of the Danube did not raise the groundwater into the top layer; optimal precipitation conditions, adequately full wetness curve.

Figure 4 illustrates the situation at the agricultural observation point No. 2676 in the Lower-Szigetköz. November 1992, on high water area, independently of the diversion, groundwater dropped deep; April 1994: during a flood wave, groundwater was near the surface, soil saturated.

Phenological observations in 1993 indicated more variation in the plant stands of fields than earlier. In a large proportion of the cases, as the water content condition of the soil worsened, so did the characteristics of the plant stands. The plants indicated the lack of water as early as in June in nearly all the surveyed fields.

In 1994, as a result of favourable water conditions, all species produced good or very good stands until mid-June. The atmospheric drought lasting 50 days worsened the growing prospects of all species with the exception of dry peas. According to surveys carried out in mid-July, the plant stands in areas of thin top layer already showed signs of suffering from lack of water. In sample areas that were also supplied from groundwater, the colour of maize remained deep green even in August. Maize and sugar-beet showed the worst effects of the lack of water. Sugar-beet was helped through the critical period by irrigation (64% of the sowing area had been irrigated).

Figures 5, 6 and 7 show the available water in the soil in the same periods of each year.

Figure 5 shows the situation at observation point No. 2630 (near the Dunaremete pier). 1992: adequate moisture (also supplied from groundwater). The grass growth in the fields was 24 t/ha. 15 June 1993: very little available water, groundwater was low. The first yield of grass was a minimal 11 t/ha, second yield was burnt out. 1994: good moisture from precipitation, groundwater did not reach top layer even during flood wave. The first yield was high (21.5 t/ha), second yield due to the drought was poor (4.5 t/ha).

Figure 6 gives the situation at observation point No. 1011 (Middle-Szigetköz, the effect of driving water back was felt). 1992: the indirect effect of groundwater was felt, good moisture. Wheat yield was high (7.8 t/ha). Spring 1993: adequate moisture; beginning of summer: hardly any moisture in the soil, wheat yield 5.1 t/ha. Spring 1994: the indirect effect of groundwater was felt, good moisture; beginning of summer: soil was not fed by groundwater any longer, moisture was reduced in the top layers of soil. By July the surface of leaves was reduced to minimum size, the yield of sugar-beet (on private land) was 34 t/ha. On the mass-production area of the same field, 53 t/ha yield was achieved by using 171 mm water for irrigation.

Figure 7 illustrates the situation at observation point No. 2676 (Lower-Szigetköz, near the flood plain, high water area). 1992: fed straight from groundwater, good moisture. The sugar-beet yield of the field was high even without irrigation (48 t/ha). Beginning of summer 1993: only deeper layers were fed from the groundwater, there was little available moisture in the root layer. The spring barley yield in the field was 4.4 t/ha – good value for this year. June 1994: still good moisture, the yield of the silage maize was high (36 t/ha).

Table 1 gives the averages of yield. In 1993, due to the drought, the deficient agrotechnology and the loss of groundwater, the crop yield was very low. Compared to the average yield of the previous 13 years, summer-harvest crop was 27–48% lower; there was less loss in the autumn-harvest yield, with the exception of certain species. 11 species produced an average of 20.5% less than the average of many years.

In 1994, the yield of promising plant stands was ruined by the 50-day-long drought from the 26th June. Wide straw crop (cereals) was 11–22% less, silage maize was 25% less. Growing conditions were favourable for dry peas (14.9% excess yield), and was only affected by drought a few days before harvest. Regional average yield of the silage maize showed a great variation. Excess yield was achieved in areas where the crop was grown together with the drought-tolerant Sudan-grass (23%). Excess yield of sugar-beet was 12%. The spread of the average yield of the fields was great. The yield of irrigated fields was high (64% of the sowing area), but the volume of all fields was increased by the autumn rain. The loss of crop in the average of 11 species was 10.8%.

Table 2 gives the average yields in the Middle-Szigetköz. In this area which was suffering from the loss of groundwater, the loss of crop in the average of 11 species was greater in 1993 (23.3%), while it was nearly identical (10%) in 1994 with the Szigetköz average. The latter value was due to the fact that 92% of the sowing areas of sugar-beet was irrigated, and its yield (48.4 t/ha) was 16% more than the many years' average of that small region.

Table 3 shows the relation between the groundwater level and the average yield. On the average of the 13 years between 1980 and 1992, groundwater was higher than 200 cm on 23.1% of the cultivated arable land, it was between 200 and 300 cm on 30.2% of the land. In these categories, groundwater directly and indirectly influenced/increased the moisture content of the soil. This effect was demonstrated by the growth of crop. Due to the diversion of the Danube, the area affected was changed and in the past two years the recharging effect of groundwater was not felt on 18.5% of the arable land. In the drought-ridden year of 1993, the role of groundwater was demonstrated by the higher than average crop. 1994 was a year with good precipitation (300–400 mm in growth season, an annual 600 mm), but with inadequate distribution and atmospheric drought. The species distribution of average yield achieved in certain categories of groundwater levels was just as varied as in the years 1982, 1985 and 1987, when precipitation was high. In the weighted average of the categories, the calculable result is the following: in the area of directly and indirectly effective groundwater (34.8%), the rate of yield was 7.4% higher than the regional average, whereas in areas of deep groundwater (65.2%) it was 4.0% lower than the regional average. The crop average of sugar-beet was influenced by irrigation.

Summary

The results of plant production are greatly influenced by the water supply of the soil. The distribution of precipitation and its sum for a year and for the growing season are important as well.

The Szigetköz is a particular place from this respect, because of the temporal or constant presence of groundwater in the cover layer, resulting in soil moisture content independent from the extremities of the weather. The wetting effects of precipitation and groundwater are demonstrated by sample figures.

Under bad natural conditions the plants give low yield. The year of 1993 was droughty, had precipitation only at the end. In 1994 the start was good, but a 50-day-long atmospheric drought

greatly decreased the chance of good yield. The yield was lower than usual in both years. Groundwater wetting increased the yield to a greater extent in a dry year.

As a consequence of the closing of the dam on the Danube, wetting from groundwater ceased to exist on 19% of the agricultural land in the Middle-Szigetköz region.

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Table 1

Yield of the crop species studied in the Szigetköz area in the average of the years 1980–1992 and in 1993 and 1994

Crop	Yield (t/ha)		Difference of the 1993 yield from the 13 years' average (%)	Yield (t/ha) 1994	Difference of the 1994 yield from the 13 years' average (%)
	average of 13 years	1993			
Wheat	5.50	3.98	–27.6	4.90	–10.9
Winter barley	4.84	3.21	–33.7	3.92	–19.0
Spring barley	5.06	3.25	–35.8	3.92	–22.5
Dry peas	2.76	1.69	–38.8	3.17	+14.9
Green peas	3.49	1.80	–48.4	2.10	–39.8
Sunflower	2.30	3.02	+31.3	2.08	–9.6
Potato	28.06	23.75	–15.4	22.77	–18.9
Maize	6.75	5.24	–22.4	5.03	–25.5
Silage maize	26.72	26.72	0.0	27.27	+2.1
Sugar-beet	40.68	37.82	–7.0	45.55	+12.0
Alfalfa	32.49	28.82	–11.3	29.56	–9.0
Weighted average of the difference (%)			–20.5		–10.8

Table 2

Yield of the crop species studied in the Middle-Szigetköz in the average of the years 1980–1992 and in 1993 and 1994

Crop	Yield (t/ha)		Difference of the 1993 yield from the 13 years' average (%)	Yield (t/ha) 1994	Difference of the 1994 yield from the 13 years' average (%)
	average of 13 years	1993			
Wheat	5.45	3.81	–30.1	4.65	–14.7
Winter barley	4.64	3.96	–14.7	3.72	–19.8
Spring barley	5.03	3.04	–39.6	4.40	–12.5
Dry peas	2.61	1.70	–34.9	2.67	+2.3
Green peas	–	–	–	–	–
Sunflower	2.42	3.30	+36.4	2.33	–3.7
Potato	26.15	23.75	–9.2	22.77	–12.9
Maize	6.40	5.06	–21.0	5.24	–18.1
Silage maize	27.88	25.73	–7.7	25.28	–9.3
Sugar-beet	41.70	38.80	–7.0	48.43	+16.1
Alfalfa	39.72	32.06	–19.3	29.65	–25.3
Weighted average of the difference (%)			–23.3		–10.0

Table 3

Relative yield of the crop species studied depending on the water table depth (from April to September)

Crop	Water table depth (cm)				
	< 150	151–200	201–300	301–500	> 500
	Average of 13 years (1980–1992)				
Wheat	105.8	106.7	102.1	94.9	91.9
Spring barley	101.5	103.6	101.4	96.8	95.8
Maize	109.9	113.8	104.1	92.4	79.4
Silage maize	104.8	104.3	106.8	95.4	73.7
Sugar-beet	101.3	100.8	101.5	98.1	96.8
Average of all the crop species	106.2	106.6	103.2	95.8	87.5
Total area of land (%)	9.9	13.2	30.2	40.7	6.0
	in 1993				
Wheat	158.7	120.0	125.8	87.8	60.6
Spring barley	144.0	115.5	104.5	84.2	71.5
Maize	158.6	119.1	122.6	86.8	72.1
Silage maize	112.7	127.2	120.5	94.9	80.8
Sugar-beet	118.2	101.4	97.7	101.5	77.0
Average of all the crop species	144.9	113.0	115.4	92.1	66.6
Total area of land (%)	5.3	9.2	20.3	59.0	6.2
	in 1994				
Wheat	126.6	93.1	114.8	94.7	74.6
Spring barley	111.1	117.1	112.6	92.6	73.0
Maize	122.7	97.5	101.1	102.5	70.2
Silage maize	116.3	101.2	103.7	98.2	55.7
Sugar-beet	85.3	96.3	107.3	96.0	–
Average of all the crop species	115.5	99.4	108.5	97.6	78.4
Total area of land (%)	8.3	10.3	16.2	59.7	5.5

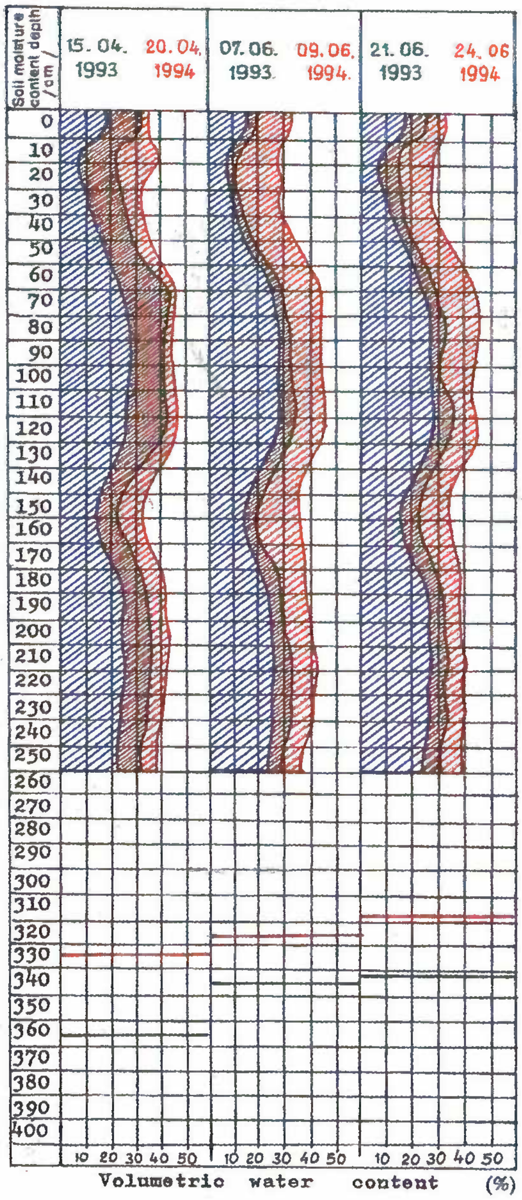

Figure 1

Relative moisture content of soils (well No. 9418)

Blue lines = hygroscopic water, Green lines = available water content in 1993, Green and red lines together = available water content in 1994, Horizontal green lines = water table depth in 1993, Horizontal red lines = water table depth in 1994

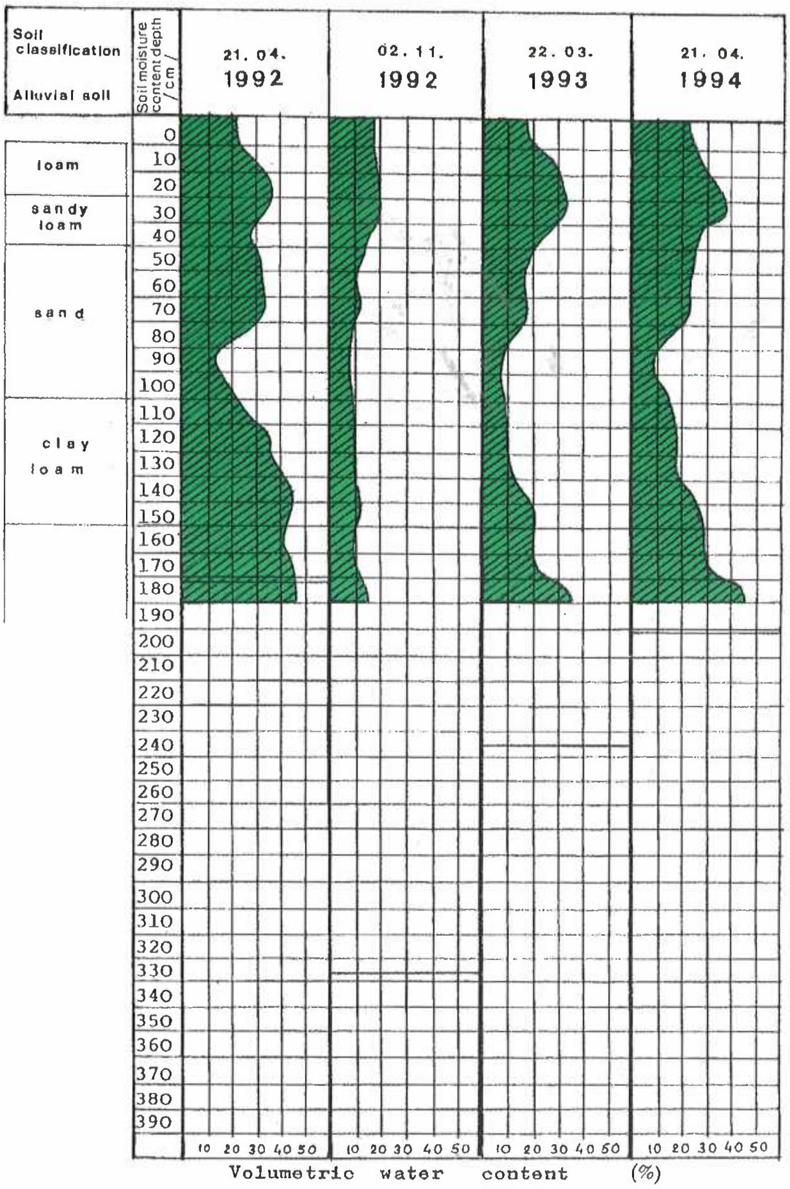

Figure 2

Relative moisture content of soils (well No. 9990)

The green crosshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned

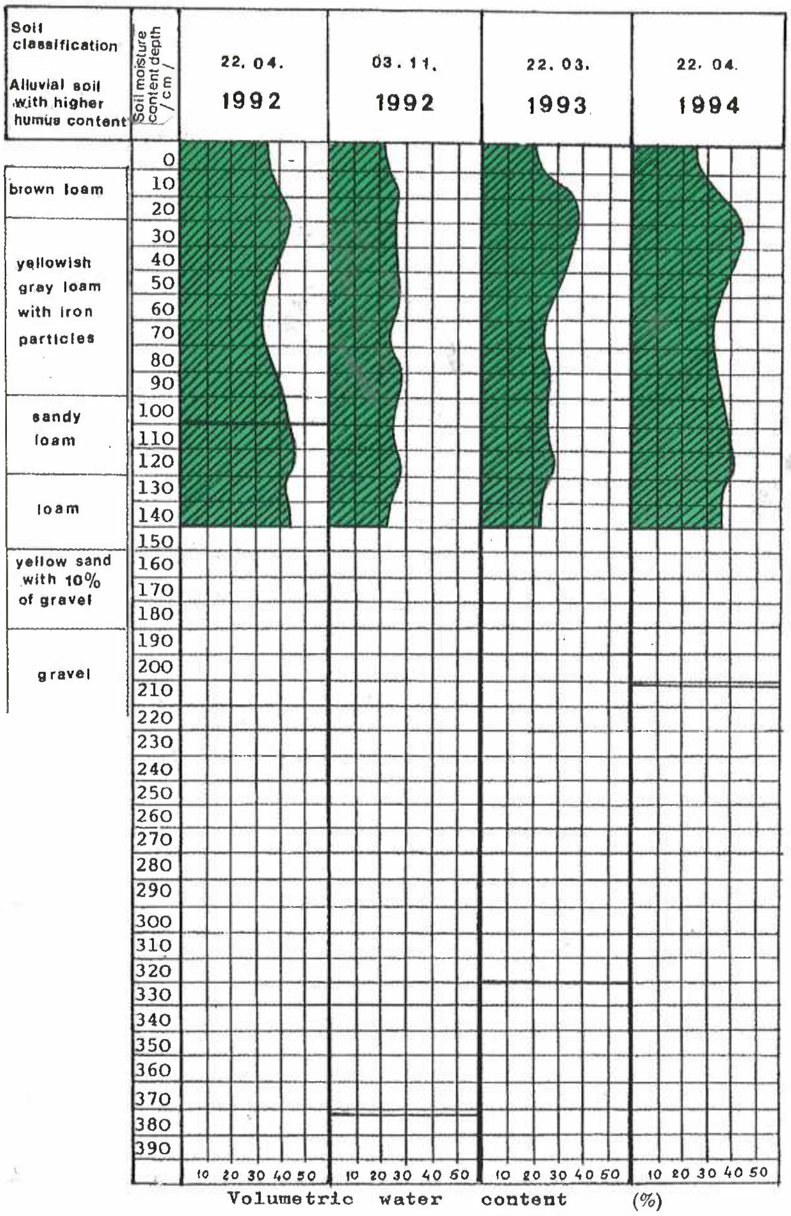

Figure 3

Relative moisture content of soils (well No. 2630)

The green crosshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned

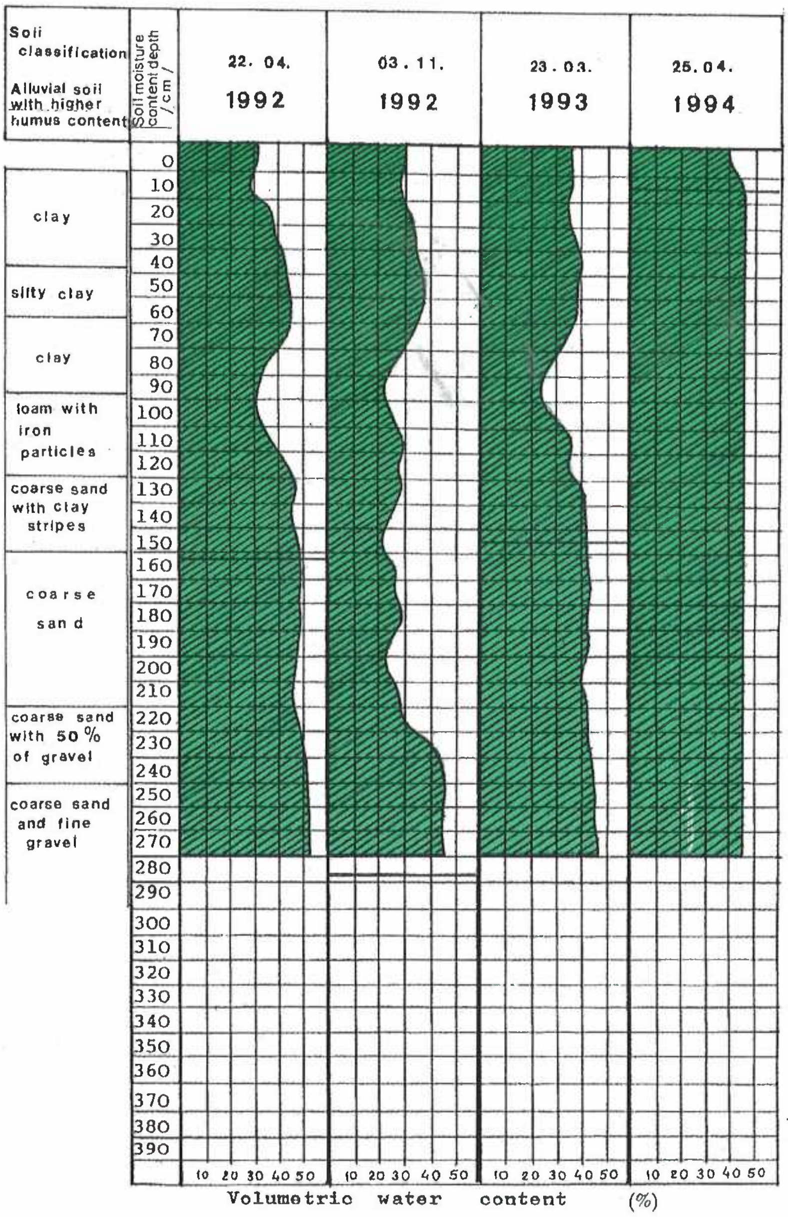

Figure 4

Relative moisture content of soils (well No. 2676)

The green corsshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned

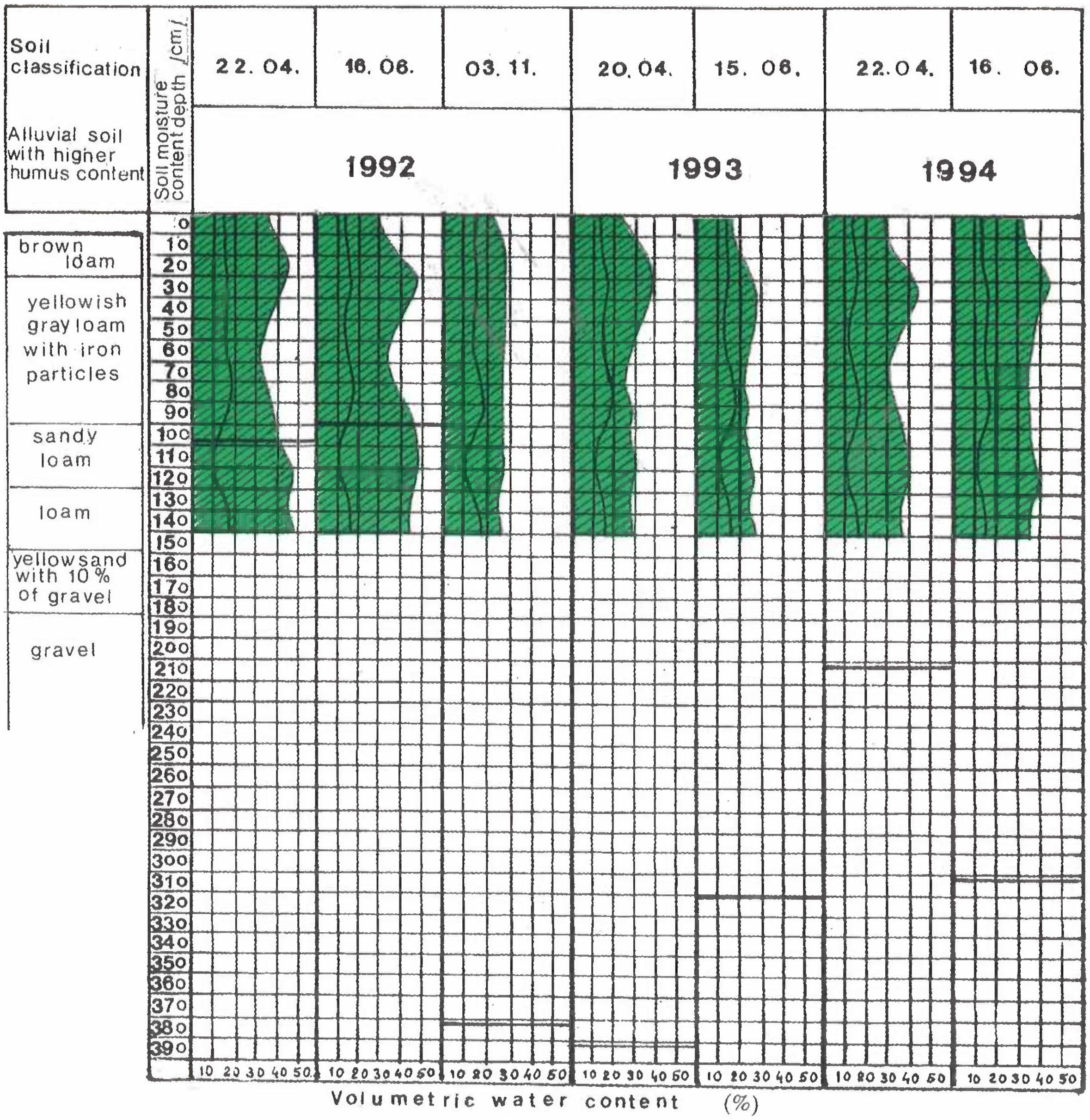

Figure 5

Relative moisture content of soils (well No. 2630)

The green crosshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned. The blue vertical lines display the wilting point water content of the soil profile in the different layers

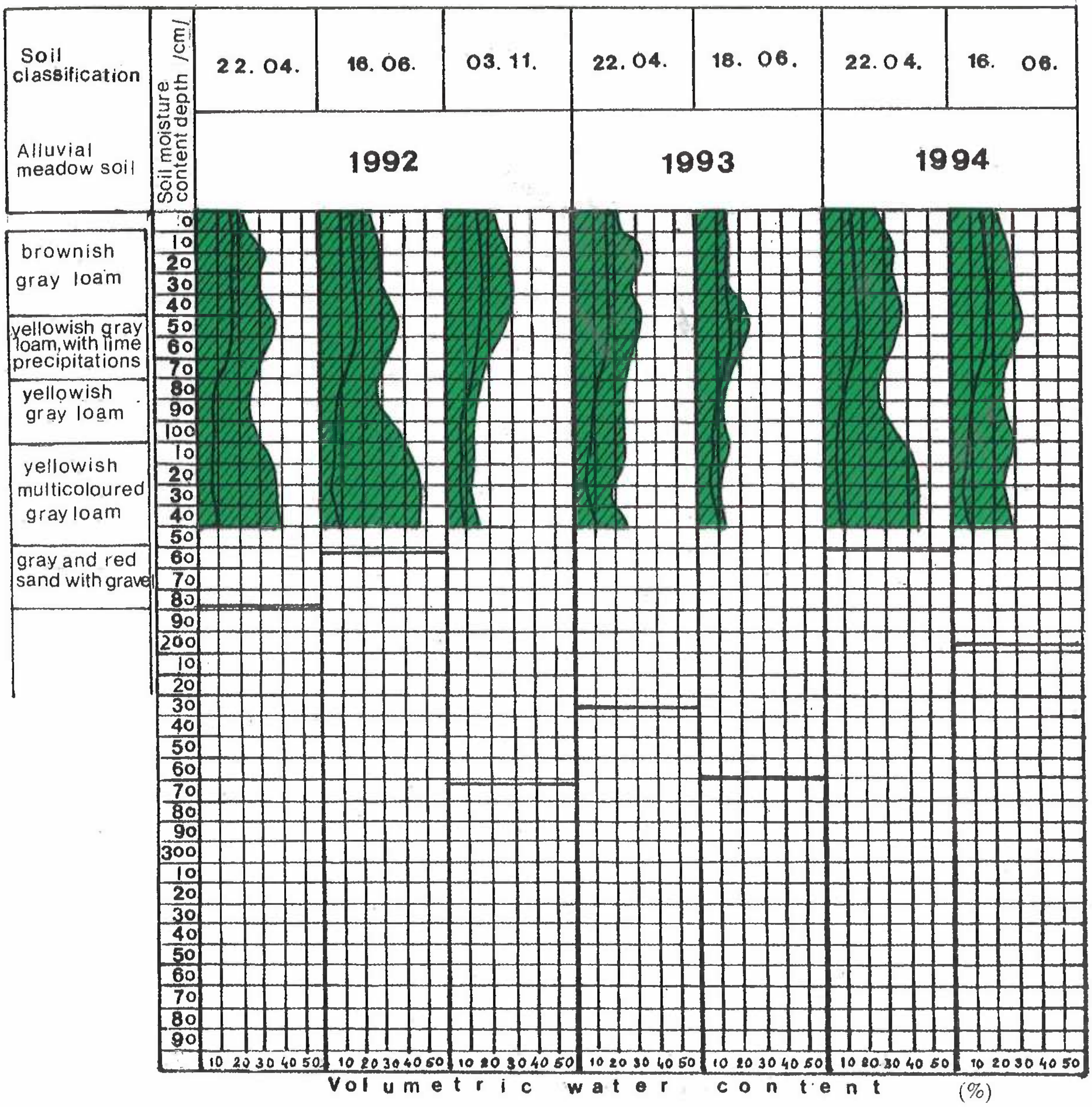

Figure 6

Relative moisture content of soils (well No. 1011)

The green crosshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned. The blue vertical lines display the wilting point water content of the soil profile in the different layers

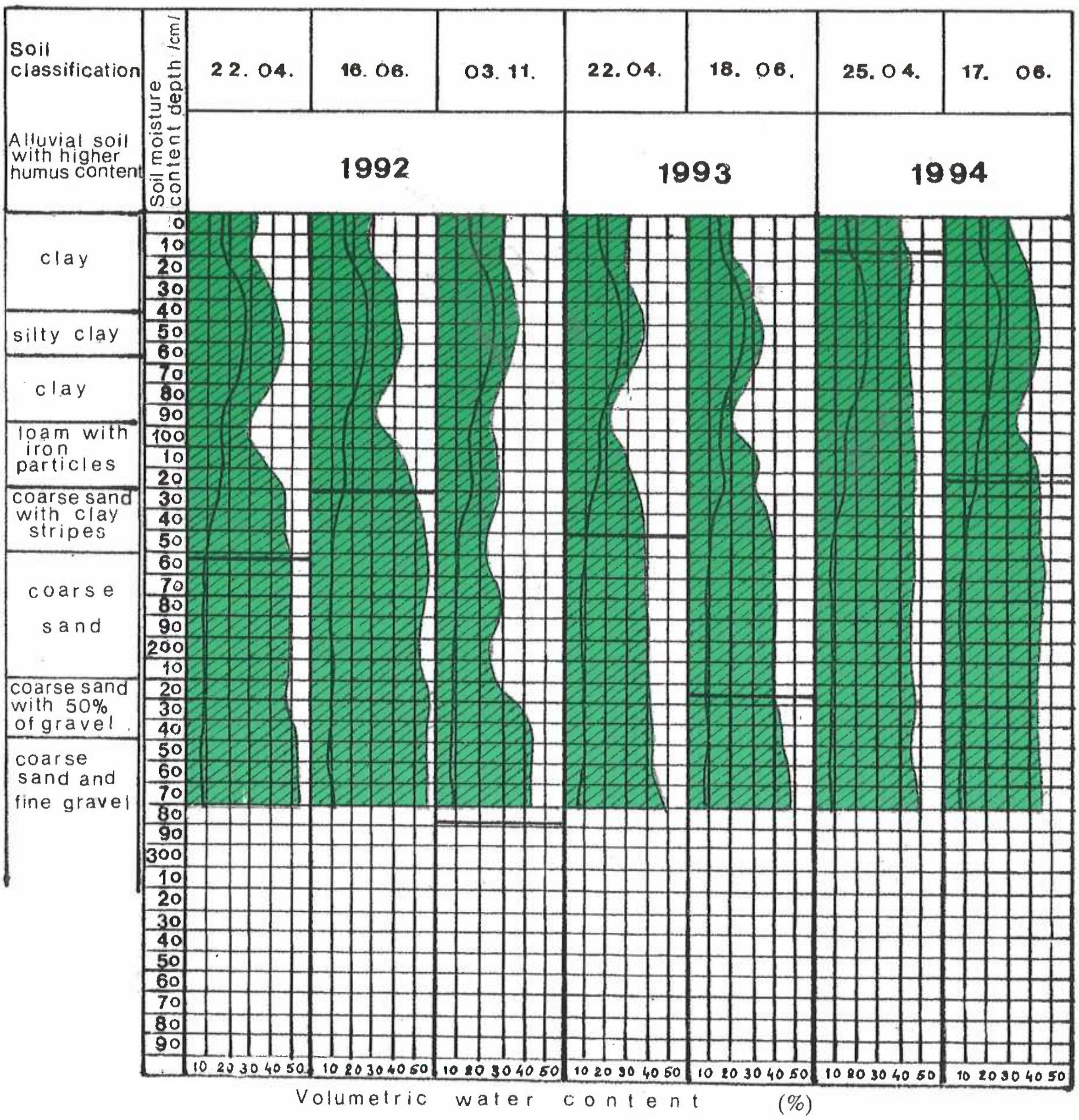

Figure 7

Relative moisture content of soils (well No. 2676)

The green crosshatched area displays the moisture content of the soil measured in 10 cm thick layers, expressed as the volumetric water content in the periods compared. The blue horizontal lines display the water table depth in the periods mentioned. The blue vertical lines display the wilting point water content of the soil profile in the different layers

From Figure 2 to Figure 7 there are black lines printed instead of the blue ones.

"It is not hard to formulate the alarm calls, but to make the public recognise them ..."

(Juhász-Nagy – Zsolnai 1991)

ZOOLOGICAL MONITORING IN THE SZIGETKÖZ (1994)

FERENC MÉSZÁROS and OTTÓ BERTALAN

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Introduction

Ideas of natural values

In a certain sense the key words of the biosphere crisis, i.e. the conflict between mankind and nature, are: value, damage, gain, efficiency and the conflict of interests. We believe that the effects exerted on the fauna of the Szigetköz by the diversion of the Danube can be categorised as damage.

According to the Concise Oxford Dictionary "damage is harm or injury that causes loss of value". To judge the loss of values as a consequence of a certain measure, in this case that of the diversion of the Danube on the fauna of the Szigetköz, it might be worthwhile investigating some details of this loss more thoroughly. What we are dealing with here are the natural (zoological) values, and their loss. When we talk about natural values, we cannot skip the discussion of two questions:

- Why the biota (flora, fauna) is considered to be a value?
- If it is a value, why is it so difficult to recognise it?

Perhaps the greatest problem of mankind now is the biosphere crisis, the most apparent symptoms of which are the fast decay of the biota of our planet, the decrease of biodiversity, and the drastic degradation of our ecological environment. These threatening signs make it inevitable to recognise that nature in general is valuable. It is usually not recognised that it is a value category of paramount importance. Despite all this, in actual individual cases, under given circumstances, the recognition of the value of nature is not so obvious. Especially not so, when – here we might recall the ideas of Juhász-Nagy (1993) – the value of nature stands against the momentary economic interests. As biodiversity is a characteristic parameter of nature, the maintenance of life is dependent on the sustainment of biodiversity. Any decrease in diversity means that the chance to recover after perturbations also declines. Consequently, each and every specimen, species, population, association, etc. of the biota of our planet is valuable.

If the above is true, it is very difficult to understand why it is so hopeless sometimes to make the political and economic decision-making bodies accept the values of the biota. In a monetary value-system it seems impossible to make the value of nature, or its components, recognised.

The value of the fauna of the Szigetköz

According to the faunistic research carried out in the past years (Mészáros – Báldi 1992), the most characteristic values of the fauna of the Szigetköz are:

1. high species richness,
2. special associations of species,
3. high degree of special mosaicity.

The effects the diversion of the Danube exerted on the biota can only be detected by long-term ecological research (Kovácsné Láng – Fekete 1995). Consequently, the evaluation of changes in the fauna – in the short term – is fairly uncertain. This uncertainty is further increased by the following:

– the zoological evaluation of the Szigetköz was completed in 1992; hence we already know which species occur in the region from among those presumed to be important on the basis of certain considerations;

– quantitative studies have not been carried out, and quantitative estimations are also missing;

– the animal population – with the exception of disastrous events – usually reacts to even drastic environmental effects not with extinction, but with the gradual change of population parameters (e.g. abundance, reproduction rate, migration).

Under the present controversial circumstances it must be accepted that

– any kind of natural diversity is valuable,

– every kind of human action threatening or decreasing the diversity is harmful, and hence, the emanating degradation must be taken as a damage.

Changes in the fauna after the diversion of the Danube

The effects exerted on the fauna since the diversion of the Danube at the end of October 1992 can be divided into two periods.

Prompt and drastic effects directly after the diversion (from the end of October 1992 till the beginning of the reproductive season of 1993)

It was the aquatic fauna which suffered most. The details, at least in the case of the fish fauna, are well known. As a consequence of the diversion, the habitat of fishes was reduced by approximately 50%. The direct loss of fish is estimated to be 200 tons. This figure does not contain the loss in reproductive output, neither other biological damages. Some additional data: according to our estimation 50% of the bigger mussels completely vanished (*Unio* spp., *Anodonta* spp.). Probably 70–80% of the so-called small mussels (*Pisidium* spp., *Dreissena* spp.) perished. The effect on the terrestrial fauna could not be appreciated owing to the timing of the diversion (the end of October). This effect is indirect anyway, and hence can only be detected over a longer period of time.

Changes detected after a longer period of time

The fauna of the Szigetköz will mainly be affected by the long-term effects, which process must be monitored. The already completed research is suitable only for a momentary description of the present status which is a transitional phase of a protracted – maybe several decades long – biological process. If we exclude the theoretically possible anthropogenic effects, the main limiting factor of the aquatic organisms is the surface water with its physical parameters, while the same of the terrestrial organisms is the groundwater. These limiting factors are closely interrelated (e.g. floods).

We forecasted two basic changes in the fauna of the Szigetköz (Mészáros – Ronkay – Vojnits 1994):

– an increase in species diversity as a consequence of the invasion of mezophil fauna, followed by a decrease issuing from emigration and the extinction of special fauna elements,

– unpredictable fauna migration will begin among the Upper- and the Lower-Szigetköz and the neighbouring areas.

From the results of the 1994 zoological monitoring, the above-mentioned trends are more than apparent (Mészáros 1994).

Extinction and disappearance of species

From the animal taxa involved in our research, probably very few species became extinct in the Szigetköz, but some new species appeared, which were not recorded before.

It is a very difficult question to judge whether the disappearance of a species by its habitat is a reversible or an irreversible process, and also whether the detection of new species could be attributed to the deficiencies of earlier research. It is very probable that the number of species have not yet changed considerably since the diversion, the number of registered species may even have increased. It must be borne in mind that if we cannot observe or find a given animal species or taxa at a given time, it can be attributed to different reasons (so it is not sure that the given taxon has become extinct). There is no doubt that the molluscan species of the temporary ponds, channels and ditches became extinct where the water disappeared completely since the diversion. All the aquatic molluscan species have become extinct, which were formerly living in the Kálnoki-channel, in the side branches of the Zsejke-channel, in the smaller channels between Dunaremete and Lipót, in the ditches of the islands of the flood plain above Dunaremete. Between Ásványráró and Dunaremete the meadow and willow bog mosaics dried out, and also the shallow lake near the gravel-pit lake between Lipót and Dunaremete. On the stretch between the 1850–1848 river km of the main Danube, not a single living molluscan specimen was found. From the Old Danube, no living or lately perished specimen of *Theodoxus* (Th.) *danubialis, Fagotia acicularis* or *Unio crassus* was recovered. The former two species were inhabiting the bank barrier basalt fillings and the not rolled, stable bottom stones. Between the points where the Danube crosses the border of Hungary and Ásványráró, their habitat completely disappeared. The abundance of *Unio crassus* was very low even before the diversion, and the mitigation of its habitat might have decreased its number under the critical minimum viable population size.

With the disappearance of *Stratiotes aloides* from the Lipót dead arm, two *Odonata* species: *Aeshna viridis* and *Leucorrhinia pectoralis*, listed in the Bern Convention, also became extinct. Another *Odonata* species: *Coenagrion ornatum* disappeared from the region of Lipót and from the

Zsejke-channel. At the same time, in the channels presently filled with water, for example in Zsejke-channel, Gazfő-Danube, Novák-channel, almost all those species were recorded which were formerly living in the area covered with water.

Fauna changes in the flood plain and at certain points outside the dikes (reedbeds)

Species number and abundance decrease and/or increase. Between the 1840 and 1801 river km, 21 molluscan species were found. This is approximately half of the riverine fauna. The average species number per kilometre value decreases upstream:

River km	Species No.	Item/collection
1801–1810	7.9	127.9
1811–1820	6.4	79.0
1821–1830	4.0	80.1
1831–1840	3.1	49.1

Due to encountered sampling difficulties, the number of collected specimens (items per collection) is not easy to analyse, since the data were very scattered. Nevertheless, its trend correlates with that of the species number decline given above. In the Upper- and Middle-Szigetköz, we did not find Dobsonfly species (*Megaloptera*). At least 4–5 *Ephemeroptera* species disappeared from most of the side branches having connection with the main channel. From the riverine forest preferring, but not aquatic *Neuropterans*, willow stands have disappeared from the majority of the flood plain since 1993. The decrease in water level in the side branches causes an increase in the number of *Sisyridae*. The *Trichoptera* assemblages, rich in species, of the Mosoni Danube are still present, but *Hydropsyche angustipennis*, a characteristic euryotopic species of moderately polluted waters, appeared at several sampling sites, where it was not recorded formerly. The abundance and the species number of the reed-associated *Lepidopterans* were considerably lower, compared to former inventories. In the Lower-Szigetköz several characteristic species of the sand-steppe associations were found in high numbers. The abundance and the species number of the reed-associated *Lepidopterans* usually do not decline even in severe drought, provided the water supply of the area is appropriate. In the desiccated former river bed, the proportion of xerophilous, or drought tolerating beetle species was 38%, while none of these species occurs in the samples collected at the sample sites located in the wet willow stands, where the proportion of the hygrophilous species was 68% (see Figures 1 and 2).

Changes in the species composition. Drought tolerating or xerophilous species appeared in higher number and abundance, while the abundance and number of aquatic and semiaquatic species decrease. Warmth preferring and xerophilous *Neuropterans* appeared in the flood plain habitats (*Hypochrysa elegans, Myrmeleon inconspicuus*). Characteristic hard-wood riparian forest *Neuropterans* (*Xanthostigma xanthostigma, Hemerobius micans*) were also collected in the flood plain. Several faunistically important and valuable species were recorded in the *Scirpo–Phragmitetum austro-orientale* and *Calamagrostis – Salicetum cinereae* complex outside the dikes (e.g. *Eulithis testata, Graphipora augur, Xestia sexistrigata, Diachrysia zosimi*). Several of these are Palaearctic species of wide distribution, closely associated with plant communities of the intermediate zone of continental broad-leaved forests and steppes, rich in herbaceous layer. In Hungary these species occur in very few localities, while in North–Northwestern Europe and in the Eastern part of the Palaearctic they are found in higher numbers. Their appearance and discovery within a year cannot be accidental. The profound change in the water regime could be detected through the population structure change of water frogs. In 1993 and 1994 the ratio of *Rana lessonae* and *R. esculenta* was approximately equal. If we compare it to the state recorded in 1989–1991, we can see that the ratio of *R. esculenta* significantly increased. The spring water regime is a very influential factor in sustaining the L–E (*R. lessonae – R. esculenta*) population systems. The lack of spring (April–May) floods and the continuous low water level during this period will cause in the long run the decrease of water frogs, and the increase of the ratio of *R. esculenta* (Figure 3).

Increase of internal migration

The specimens of some *Lepidoptera* species – mainly the members of the least mobile characteristic wetland-meadow species, which are usually restricted to their habitats – were detected far from their characteristic habitats in the middle of summer. This local migration might signal the change of the habitats of the Szigetköz. Such extraordinary migration patterns are the signs of environmental disturbances, aimed at discovering new, potentially suitable habitats.

Changes in the fish fauna

Nearly 50% of the so-called Szigetköz fish nursery that played an important role in the reproduction of the fish fauna, has partly been damaged or disappeared (Bertalan 1994). Fishery experts found 53 such nurseries in the whole of the Szigetköz. In 1993 and 1994 we found 16 inappropriate spawning sites. The former spawning sites, situated in the big branches near the main branch in the Upper- and Middle-Szigetköz, are at present either absolutely dry, or their water regime is uncertain, and hence their fish production is weak. Neither is the spawning of fish undisturbed in the Lower-Szigetköz. The water fed into the main channel causes unpredictable water level changes over a considerably large area. As the fish turn back and forth several times, they reach their spawning sites too late. In the Mosoni Danube more successful spawnings were observed than in former times. The artificial water recharge brought about new spawning sites. Any amount of extra water recharge fed into the main channel, and hence also into the Szigetköz, gives the fish fauna of the region a better chance of survival. The quantitative analyses of the 1994 fish harvest are not yet available. But it is a well-known fact that 20% less fish were caught in 1993 from the remaining water bodies of the Szigetköz than in 1992. According to preliminary results, the loss of the fish harvest was less than it was expected on the basis of the loss of fish caused by the diversion.

Places where no detectable faunal change was recorded

Partly as a consequence of the artificial water recharge, there was no detectable aquatic or semi-aquatic faunal change at the following places: the Mosoni Danube, the channels outside the dikes, and the water bodies affected by them. At some places, the population even became stronger.

The effects of artificial water recharge on the fauna of the flood plains

The zoological evaluation of the effects of the water recharge system in 1994 is hopeless, especially owing to its late installation. It is highly probable that the previous ecological parameters of the flood plain cannot be restored with water recharge alone. Its function can only be the reduction of the damage caused in the case of some taxa. Its effectiveness is only of local importance, and is also highly dependent on the given taxa (its lifestyle, ecological requirements and development form). We would like to draw attention to the fact that the hygrophilous *Oribatid* species were either not found (*Hydrozetes parisiensis, Heterozetes palustris*), or their abundance was lower in the soil samples collected along the shoreline in the vicinity of the water recharge system operated at Kisbodak. The water movement in the soil from the open water of the channels towards their surroundings is probably very limited.

Summary

The main findings of the 1994 zoological monitoring can be summarised in the following points: (1) some kind of change was detected in all the studied zootaxa; (2) the nature of these changes is different from any former ones; (3) the trends of biodiversity changes are negative compared to the state prior to the diversion of the Danube. It is justified to ask, how much the fauna of the Szigetköz is threatened in its present state, whether we should expect an ecological disaster? The word "disaster" reminds us of the well-known natural disasters. As – except for a short period of time, right after the diversion – we have not experienced anything of that kind, no disaster is apparently threatening. It would be a disaster if a new fauna were formed with different characteristics, namely, where the formerly present flora and fauna elements and associations are missing, of which the Szigetköz owed its biological uniqueness.

*

The data presented in this study are the results of the zoological monitoring of the Szigetköz. The participants of the research were: Dr. A. Ambrus, Dr. A. Bankovics, Dr. A. Báldi, K. Bánkuti, Dr. L. Forró, T. Fuisz, A. Gubányi, Gy. J. Horváth, T. Kisbenedek, T. Kovács, Dr. S. Mahunka, Dr. G. Majoros, Dr. O. Merkl, Dr. F. Mészáros, Dr. Cs. Moskát, L. Peregovits, Dr. L. Ronkay, Dr. Gy. Szél, Dr. Gy. Sziráki, Dr. Á. Uherkovich, A. Vida, A. Zágon.

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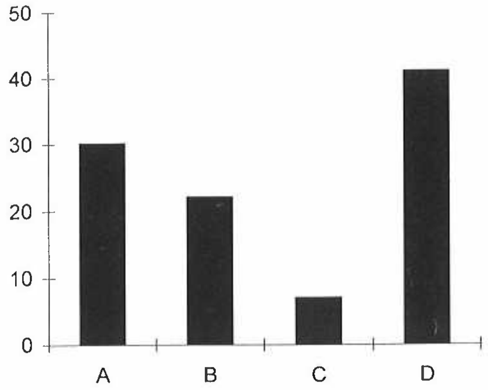

Figure 1

Proportion of Carabid beetles in the dry bed of the main channel according to their drought tolerance (at Dunakiliti)

(A = drought tolerating and xerophilous species, B = neutral species, C = sylvicolous and hygrophilous species, D = littoral and hygrophilous species)

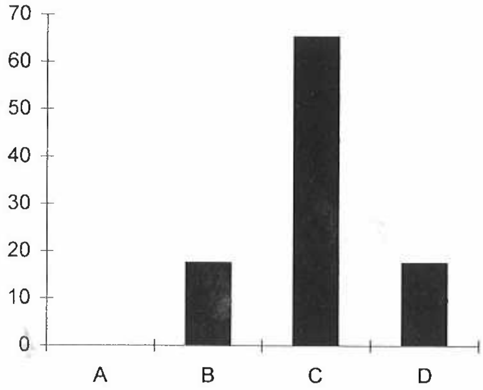

Figure 2

Proportion of Carabid beetles in the willow forests according to their drought tolerance (at Ásványráró and Kisbodak)

(A = drought tolerating and xerophilous species, B = neutral species, C = sylvicolous and hygrophilous species, D = littoral and hygrophilous species)

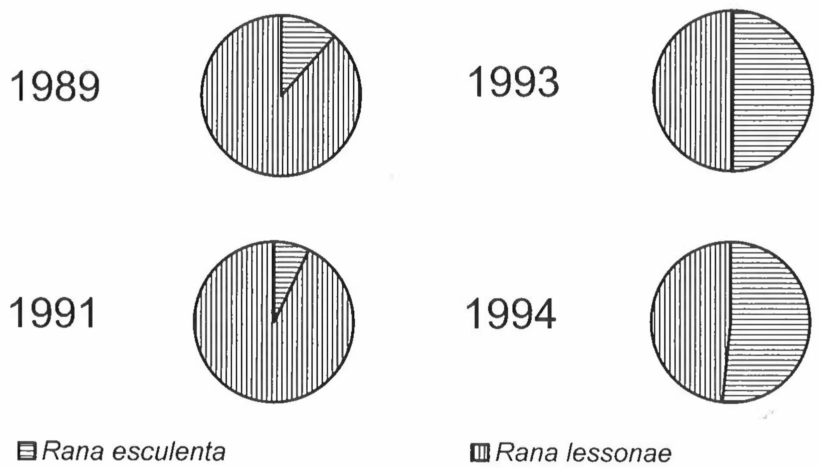

Figure 3

Change of the population structure of water frogs (*Rana esculenta* complex) through the years with different water supply