The aquatic macrophyte vegetation in the Old Danube / Hungarian bank, and other water bodies of the Szigetköz wetlands

Borbála Ráth[1], Georg A. Janauer[2], Karin Pall[3] and Arpád Berczik[4]

With 3 figures and 3 tables in the text

Abstract: This is a descriptive account of the impact of the Gabcikovo hydro-electric-power (HEP) plant and other main-induced changes on the aquatic vegetation of the Szigetköz area. Today the environmental complex of water bodies in the Szigetköz supports 26 aquatic macrophyte species, which occur in the main river channel, and in different flood plain habitats. Prior to the construction of the Gabcikovo HEP almost no macrophytes existed in the main river channel. The HEP plant takes in most of the water today, reducing the discharge in the main river to a few hundred cubic-metres per second, compared with about 2000 $m^3.s^{-1}$ before. The water level has also decreased in the flood plain. Some parts of the channel and oxbow systems are irrigated through the complex "Active Floodplain Water-Supply System"(AFWSS), today. Several aquatic and amphiphytic species have invaded in the abandoned river bed and in shallow reaches with little flow or even stagnant character. Flood plain water bodies show a different successional development. In some side arm systems the lack of water has led to a near or full extinction of aquatic vegetation. Other parts, receiving compensation flow water by the AFWSS were transformed from marshlands to fully aquatic environments. Where algal production increased no macrophytes are present. Other water bodies have clear water, but only a few

[1] [4] Magyar Tudomanyos Akademia, Ökologia es Botanikai Kutatointezete, Göd (Hungary)
[2] Institute of Ecology and Conservation Biology, Section of Hydrobotany, University of Vienna, Vienna (Austria)
[3] Systema GmbH., Bensasteig 8, A-1140 Vienna (Austria)

eutrophic species remain there, and in many survey units rare species have disappeared. A striking feature of the aquatic vegetation is the clumped distribution of many species: they develop large stands in some habitats, but they are not widely distributed over the whole water body system. The whole system is still in a state of change and the decrease in species richness may continue.

Introduction

The main channel of the Danube river is the border between Hungary and Slovakia. Two large side arms create a northern and a southern island. The latter is called the Szigeköz. Various types of wetlands and flood plain water bodies are found there. Subsequent to starting operation of the hydro-electric power plant (HEP) in Gabcikovo (SK), much of the water of the Danube is diverted to the power plant retainment, which serves large ship navigation too. The remaining discharge to the former main stem – called the Old Danube – is much reduced. As a consequence general flow impact has been reduced too. Discharges larger than the intake capacity of the power plant enter the Old Danube via sluice gates, and water flow increases considerably during flood events. In late summer 1999 (in part 2000) a macrophyte survey was undertaken in the Old Danube, and in some of the flood plain waters to establish the impact of the water diversion to the HEP plant and the successive counter measures undertaken in the Hungarian part of the riparian corridor.

Site description

Survey unit (SU) 1 (river km 1845, Old-Danube) is a littoral region of the main Danube channel upriver from the large bottom sill. Successional colonisation by aquatic macrophytes occurred following the diversion of the Danube. SU 7 (river km 1839, Old-Danube) is characterised by spur-dike bays. Water depth and current velocity fluctuate with discharge. Aquatic macrophytes invaded this unit only after the diversion of the Danube.

SU 14 (Csákányi-Duna, active floodplain) is a deep (1.60–2.60 m) side arm with permanent water flow in the Cikola side arm system. Current velocity is high in the mid-stream, but moderate at the banks. The suspended matter content of the water is high. Aquatic macrophytes colonised the littoral zone and small bays in the area only after the diversion of the Danube. SU 15 (Schisler oxbow lake, active floodplain) is a larger disconnected oxbow in the active floodplain, surrounded by riparian forest. Prior to the diversion of the Danube SU 20 (Zátonyi-Duna, protected floodplain) was a ground water-supplied oxbow. Today it is part of the water supply canal system behind the flood protection levee.

SU 22 (river km 1828, Old-Danube) is a small pond, separated from the main arm (Old-Danube), but located in the abandoned river bed. It is surrounded by young Salix triandra and Phragmites australis stands. The pond receives water from the “Active Floodplain Water Supply System” (AFWSS), and from the Old -Danube during high discharge periods. Water depth increases gradually from the outer limit (0.6-1.4 m) towards the centre (2.5-3.0 m) and light conditions are favourable for macrophyte growth. SU 23 (river km 1828, Old-Danube) is a very shallow small pond near to SU 22., also receiving water from the AFWSS, and from the Old-Danube (water depth: 0.6-1.2 m). The third pond in this ensemble is SU 24 (river km 1828, Old-Danube), still directly connected to the main channel (Old-Danube). Water level and current velocity are very variable.

The Lipót flood plain lake consists of survey units 28 to 32, all situated behind the protective levee. In the past water was supplied by ground water connection. Lentic conditions and significant water level fluctuations were characteristic. In autumn 1993 the Lipót lake was connected to the AFWSS at Dunaremete, a small town close by. In 1996 the channel was also connected to the water supply system of the protected floodplain and the channel part (SUs 28 and 29) was dredged. Since then the water is deep (1.8-2.5 m), current velocities are moderate, and slight water level fluctuations are minimal. SU 30, a large still water body, is situated downriver of survey units 28 and 29. Earlier the hydrological conditions were similar in all the three sampling sites. After drying up in summer 1993 the system got supplied through the AFWSS, too. Water level fluctuations (water depth: 0.8-1.2 m) and current are negligible. In SU 31 only a dense *Phragmites australis* zone was found to spread in the water. In SU 32 the original lentic conditions of the Lipót lake still prevail. Water supply occurs via SU 31, water depth is between 0.6 and 1.0 m. Water level is almost constant, transparency is high, and organic detritus is found on the bed near the banks.

Methods

The survey team used a boat in all survey units. The methodology followed a standard approach, which is based on the field survey described in KOHLER et al. (1971), KOHLER (1978) and KOHLER & JANAUER (1995). It is the same which was used in earlier assessments of the aquatic macrophyte vegetation in the Danube river and in flood plain water bodies in the Szigetköz area before (RATH 1994, RATH 1998, PALL et al. 1996). Much earlier studies were based on different methods and the results cannot be compared directly (RATH 1978, RATH 1987). For further details see the "Methods" section in this volume.

Results

Species richness

In Table 1 the species occurring in the Szigetköz are listed. In this study only the macrophytes are presented in detail. Filamentous algae are reported in the field sheets, but they are not differentiated in this presentation, especially as they only occurred in a few small spots. In the survey units in the main channel (Old Danube) and in the flood plain waters 26 species were present, which include pleustophytic forms (e.g. *Lemna* and *Salvinia*), floating leaf plants like *Nuphar*, submerged forms like the pondweeds (*Potamogeton spp*.), and even *Saggittaria saggittifolia*, which occurred as a submerged plant.

When differentiating between the main river, the active flood plain (this is the one between river and levee), and the protected flood plain (behind the levee), the highest number of species is found in water bodies which belong to the last category. As the bed of the Old Danube is abandoned in part, due to the reduced water discharge most of the year, in a few cases ponds are left behind, which contribute much to the reported species richness in the channel. Water bodies in the active flood plain are poor in species (n=7).

Species richness in the Szigetköz can be compared with some parts of the Danube river corridor in Austria (Tab.2). Results show also a decrease in species number between 1992/93 and 1999, this is prior to, and after the, diversion of the water. This is true for the main channel as well as for the flood plain waters.

Habitat parameters

The diversity of habitat conditions is described in Table 3. The bank was reinforced with rip-rap in most cases. Fine inorganic material was present either on gentle slopes or sometimes on a steep bank. Banks composed of gravel banks rarely exist in the part of river corridor investigated in this study. The pre-dominant material on which the plants grew was gravel and sand. In survey units located in the main channel medium flow velocities were predominant, but slower flow was also detected. The spectrum of water bodies encompassed the main channel, oxbows, a flood plain lake, and water bodies outside the flood protection levee. The dominant land use in the adjacent land is riparian scrub. In a few cases villages are situated close by.

Distribution Diagram

The diagram (Fig. 1) indicates clearly the general scarcity of aquatic vegetation in the main river channel (the survey units are marked by the river-km). Species richness is higher in ponds situated in the abandoned part of the river channel, and in the flood plain waters, respectively.

Relative Plant Mass (RPM)

The dominant species is *Nuphar lutea*, but it reaches only 16% RPM (Fig. 2). This is a small value in comparison to other reaches of the river (see other contributions in this volume). About 10 sub-dominants follow the leading macrophyte and form a large block of species with RPM-values between 10 and 5%. This situation is much like that in the Giessgang water body system in Greifenstein in 1997 (JANAUER & PALL 1999).

Mean Mass Index (MMO/T) and Distribution Ratio (d)

The diagram (Fig. 3) reveals how "clumped" the distribution of species is in this 20 km long stretch of the Danube. All the species have a much higher mean plant mass estimate based on their survey units of occurrence (white bars) than on the total length of the reach (black bars). Yet, some reach a high plant mass where they occur (MMO, white bar > 2), e.g. floating leaf species and duckweed, but the distribution of other species is extremely constrained with regard to the whole length of the study area.

Discussion

This descriptive study illustrates the situation of the aquatic vegetation in the Danube river bed and in active (between river and levee) and protected (behind levee) flood plain water bodies in 1999. The main channel of the Danube was free of vegetation prior to 1994, when the Gabcikovo hydro-electric power plant had been put into action and most of the water in the river had been diverted to the retainment of the power house. In 1994 a first growth of macrophytes was reported (RATH 1997) and aquatic plants had spread to seven locations by 1996, in succession to the great decrease in hydrological dynamics. The construction of the bottom sill at river-km 1843 is a remediation in part to the extreme reduction of water supply to the flood plain.

Species list and Distribution Diagram

The Kohler method was not used in any of the previous aquatic plant surveys, so the only possible level of comparison is the number of macrophytic species. Filamentous and all microscopic algae are reached from this, although they are listed in the field report. In this study 26 species were found in the main channel, and in the active and in the protected flood plain water bodies. The comparison with older reports will be based on that parameter, therefore. Species numbers of older references are listed in Table 1. Prior to the diversion of the water practically no aquatic plant growth was reported for the Szigetköz, and due to the dynamic run-off regime where the river spilled into the wide flood plain behind the constriction at Devin (SK) and Hainburg (A) the overall situation was even less favourable than in the river stretch at Vac (RATH 1994), where six species were found. In 1997 the Old Danube (former main channel) housed 15 species already (RATH 1997), but none reached high estimates of plant mass. There were considerably less species than in the Austrian reach, but information on the bottom does not describe the main channel only, but mouth sections of tributaries, harbours and other habitats with little flow dynamics are included, too. In 1999 the Szigetköz sheltered 13 species in the main channel, 7 species in the active flood plain, and 16 species in the parts of the flood plain protected by the levee (Table 1).

The distribution diagram (Figure 1) reveals the highly dispersed character of the aquatic vegetation in the main channel. Survey unit (SU) 1 (1845 river km, Old-Danube) is a littoral region of the Danube, upriver from the bottom sill. Necessary conditions for colonisation of the aquatic macrophytes developed only after the diversion of the Danube. Common submerged species (*Potamogeton pectinatus*, *Potamogeton perfoliatus*), adventive species (*Elodea canadensis*, *Elodea nuttallii*), and *Butomus umbellatus* were detected in this habitat of low flow, but plant mass estimates (PMEs) were very low. SU 7 (1839 river km, Old-Danube) consists of spur-dyke bays in the abandoned part of the main channel. Aquatic plant growth appeared after the diversion of the Danube, as water depth and flow vary to a great extent in connection with the highly variable discharge. Only small amounts of *Potamogeton pectinatus* and *Zannichellia palustris* were found there.

The rather high species richness in the main channel is due to the existence of small ponds, which have formed in the abandoned part of the river bed. SUs 22 is the largest, SU 23 is smaller and SU 24 is still connected to the main channel (Fig.1). Most of the year flow velocities are small, supporting species like *Ceratophyllum demersum*, *Lemna minor* and *Najas marina*, which show little adaptation to fast water flow. However, they survive the occasional flooding of the whole river bed.

The situation in the flood plain water bodies is different. In the Cikola side arm system the species number was about three times higher in the past (Table 2. For details refer to PALL et al. 1996: report on the conditions prior to the activation of the Gabcikovo power plant, surveys 1992 and 1993). SU 14 (Csákányi-Duna in the Cikola system) is characterised by a decline in species richness and abundance of macrophytes after the bottom sill was put into operation in 1995. The change in water supply (Active Flood plain Water Supply system, AFWSS) showed a direct response in the aquatic vegetation. SU 15, the Schisler oxbow lake, is also part of the active flood plain. Prior to the diversion of the Danube large areas were covered by marsh vegetation (*Phragmites australis*, *Typha angustifolia*, *Typha latifolia*) on its northern and southern end. Large stands of submerged species (*Ceratophyllum demersum*, *Myriophyllum spicatum*, *Potamogeton perfoliatus*, *Ranunculus circinatus* etc.) used to be present in the open water. Today Schisler lake is saved from drying up by the operation of the AFWSS. In 1997 it was connected to the Csákányi-Danube. Water depth and water flow increased. The marsh zone disappeared at the southern end and declined at the northern end. The aquatic macrophyte stands considerably declined, became species-poor and scarce. In 1999 the water was of strikingly green colour due to increased algae production. No aquatic macrophytes occurred in the open water any more, but some species survived at the northern end of the dead arm in the die back zone of *Phragmites australis*.

Another system behind the protective levee is SU 20, the Zátonyi-Duna. It was a dead arm prior to the diversion of the Danube. Today, moderate current velocity and great depth (1.8-2.5 m) are constant features there, as water is supplied through the AFWSS. Transparency is high and light conditions are favourable for macrophyte growth. The original littoral zone got submerged and *Typha angustifolia* stands are decaying in the deep water. Erosion developed on the western shore, and nearly all trees (*Populus canadensis*) collapsed into the water. The number of aquatic species has dropped from 25 (status of 1992/93, Pall et al. 1996) to 8 species (Table 2) and rare species like *Hippuris vulgaris*, *Nymphoides peltata,* and *Utricularia vulgaris* (PALL et al. 1996) became extinct . Still water conditions are indicated today by high plant mass of *Hydrocharis morsus-ranae*, *Nymphaea alba*, *Potamogeton lucens*, and the submersed form of *Sagittaria sagittifolia*, which grows as a helophytic species usually, and *Spirodela polyrhiza* invaded the littoral zone.

In the Lipót oxbow system two distinctive parts are present. The upper stretch is canal-like, the lower part is more like a lake. In the upper section aquatic species nearly disappeared, or declined to a great extent, some protected and rare species (e.g. *Hippuris vulgaris*, *Hydrocharis morsus-ranae*, *Nymphoides peltata*, *Salvinia natans*, see PALL et al. 1996) became extinct. This is due to the connection with the AFWSS near the town of Dunaremete in 1993, and the dredging of the canal when connecting it to the supply system of the protected flood plain in 1996. Now deep water (1.80-2.5 cm), moderate current velocity and slight water level fluctuations are characteristic. A large still water body follows downriver (SU 30), which is the beginning of the lake-like section in the Lipót system. Hydrological conditions were similar to SUs 28 and 29, but after drying out in summer 1993 water was allocated there through the AFWSS. *Nuphar lutea* is still the typical local macrophyte species., but other species disappeared or declined. Inundated *Phragmites australis* is thinned out and *Typha angustifolia* stands decay. *Najas marina* is a new species to this site. In the next SU (No. 31) *Phragmites australis* is so dense that no aquatic species occur. In the last part of the Lipót system, SU 32, the original lentic conditions prevailed. Due to the constant water level and high transparency *Nuphar lutea* and *Hippuris vulgaris* are present, but protected and rare species like *Hydrocharis morsus-ranae*, *Lemna trisulca*, *Nymphoides peltata*, *Salvinia natans*, and *Utricularia vulgaris* were also found.

Relative Plant Mass (RPM)

In the whole Szigetköz system *Nuphar lutea*, was the dominant macrophyte. The dominance of a floating leaf species indicates the general lack of high flow dynamics, which are due to the diversion of a great part of the discharge of the Danube to the Gabcikovo power plant. Sub-dominants are *Ceratophyllum demersum* and *Potamogeton lucens*, also adapted to not too high flow dynamics. Only in fourth place the rheophilic *Potamogeton pectinatus* is found. However, this species develops large plant mass in still water reaches just as well. Regarding Relative Plant Mass 18 species reach values above 1%, which is rather unusual for habitats which may still be influenced by direct flood flows. But with respect to that general opinion on the susceptibility of some aquatic species to high flow dynamics, the occurrence of e.g. *Ceratophyllum demersum* in a pond in the abandoned river bed, should initiate more detailed studies on habitat hydraulics in ponds below the bank-full line.

Mean Mass Index and Distribution Ratio

The striking – and only – feature of the diagram is the extremely "clumped" dispersion of the species in the Szigetköz. Not a single species has reached a Distribution Ratio even close to 0,5, which would be the threshold for a moderately even dispersion of a species in the whole survey area. So far as is known no other stretch of the Danube river reveals such an unusual pattern. It is most likely a result from a combination of former scarcity of macrophyte growth in the flow-sensitive flood plain habitats and the main channel, which was without much plant growth at all. The diversion of the water and the successive re-introduction of (in parts) rather constant flow and water level regime by the two Flood Plain Water Supply Systems has made the river habitat more gentle, and the flood plain habitats more "active" with respect to ground and surface water hydrology. Most likely the conditions we see today are prone to change and to the establishment of different species richness and composition in the near future, until a dynamic equilibrium is reached again.

Conclusion

The Szigetköz area is one of the most interesting areas of the Danube river corridor, as the diversion of much water from the former main channel into the Gabcikovo hydro-power scheme in 1992/93, and successive activities for rehabilitation of the water bodies in the active and the protected flood plain since then, created a situation of changing habitat conditions for the aquatic macrophyte vegetation. On one hand the main channel has gained in species number, but this is a situation far from natural conditions. On the other hand several important water bodies in the flood plain lost a considerable number of species which had grown in that part.

Future investigations of the outcome of these life-size experiments should be planned to better understand the effect of man-made, drastic water regime changes on the aquatic plants communities.

At present it can not be finally decided if these changes must be seen as a definite loss in ecological richness or if former conditions may be reconstructed – at least in part – again. Regarding these facts this report does not draw a picture of great promise. Further monitoring and habitat related hydraulic modelling will be indispensable for a better understanding the processes during the present rapid development of the aquatic plant communities. This could finally lead to a situation in which the present status of reporting changes would be overcome by prediction-based management.

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Tables:

Table 1: Szigetköz Area (Hungary) / Species List

Table 2: Number of species in different water bodies in the fluvial corridor of the Danube river

Table 3: Habitat parameters

Table 1: Szigetköz Area (Hungary) / Species List

OD: Old Danube (main channel). FP: Flood plain.

ac = active FP. pr = FP protected by levee. Grey shade: presence.

Full scientific name	Abbrev. name	OD	FP ac	FP pr
[*Filamentous algae*]	[Fil alg]	x		
Butomus umbellatus L.	But umb	■		■
Ceratophyllum demersum L.	Cer dem	■	■	■
Elodea canadensis L. C. RICH	Elo can	■		
Elodea nuttallii(PLANCHON) ST. JOHN	Elo nut	■		
Hippuris vulgaris L.	Hip vul			■
Hydrocharis morsus-ranae L.	Hyd mor			■
Lemna minor L.	Lem min	■		■
Lemna trisulca L.	Lem tri			■
Myriophyllum spicatum L.	Myr spi	■	■	
Najas marina L.	Naj mar	■	■	■
Najas minor ALLIONI	Naj min		■	
Nuphar lutea (L.) SIBTH. & SM.	Nup lut			■
Nymphaea alba L.	Nym alb			■
Nymphoides peltata (S.G. GMEL.) O. KTZE.	Nym pel			■
Polygonum amphibium L.	Pol amp			■
Potamogeton lucens L.	Pot luc	■	■	■
Potamogeton nodosus POIR.	Pot nod	■		
Potamogeton pectinatus L.	Pot pec	■	■	
Potamogeton perfoliatus L.	Pot per	■		
Potamogeton pusillus L. sec. DANDY & TAYLOR	Pot pus	■		
Ranunculus circinatus SIBTH.	Ran cir		■	
Sagittaria sagittifolia L.	Sag sag			■
Salvinia natans (L.) ALL.	Sal nat			■
Spirodela polyrhiza (L.) SCHLEIDEN	Spi pol			■
Utricularia vulgaris L.	Utr vul			■
Zannichellia palustris L.	Zan pal	■		
Number of species	26	13	7	16

*The occurrence of filamentous algae is noted in the field. In this presentation they are not differentiated taxonomically and not included in the graphic presentation.

Table 2: Number of species in different water bodies in the fluvial corridor of the Danube river
aFP: active flood plain, between main river channel and flood protection levee
pFP: protected flood plain, behind flood protection levee
*gradient: gradient of hydrological dynamics in a system of flood plain water bodies, connected to the main channel at the mouth section
**semi-aFP: the flood plain is separated from the river by a small levee, but several openings and intensive groundwater connection provide high connectivity between both compartments.

Water body	Number of species	Reference
Danube river, (A), left & right bank	22	Pall & Janauer (1998)
Gießgang, (A)	29	Janauer & Pall (1999)
Rosskopfarm, (A), gradient*	19	Janauer (in press)
Bad Deutsch-Altenburg, semi-aFP**	14	Janauer (in press)
Danube river, (H), Vac (r-km1670-1694)	6	Rath (1994)
Danube river, (H), Szigetköz, right bank	15	Rath (1997)
Old Danube, (H), Szigetöz, right bank	13	This study
Szigetköz, (H), aFP (total)	29	Pall et al. (1996)
Szigetköz, (H), aFP (total)	7	This study
Cikola side arm, aFP	21	Pall et al (1996)
Cikola side arm, aFP	7	This study
Dunaremete system, aFP	10	Rath (1987)
Dunaremete system, aFP	12	Pall et al. (1996)
Szigetköz, (H), pFP (total)	25	Pall et al. (1996)
Szigetköz, (H), pFP (total)	16	This study
Zatonyi Danube, pFP	25	Pall et al. (1996)
Zatonyi Danube,pFP	8	This study
Lipot – canal section, pFP	11	Pall et al. (1996)
Lipot – canal section, pFP	4	This study
Lipot – lake, pFP	11	Pall et al. (1996)
Lipot – lake, pFP	12	This study

Table 3: Habitat parameters

Habitat parameter	Type	
Bank	rip-rap	23
	gravel	1
	fine/gentle	6
	fine/steep	3
Sediment	gravel	17
	sand	14
	organic	2
Flow	stagnant	4
(cm s^{-1})	5 - 30	8
	35 - 65	20
	>70	1
Connectivity*	1	3
	8	6
	22	1
	71	2
	99	21
Land use**	21	1
	32	25
	311	2
	11908	5

*Connectivity types
1: small side arm, permanently connected;
8: flood plain lake;
22: oxbow, inflow from upper end;
71: small channel and water body outside levee;
99: main river channel (Old Danube)

**Land use type
21: permanent crops;
32: scrub;
311: broad-leafed forest;
11908: village

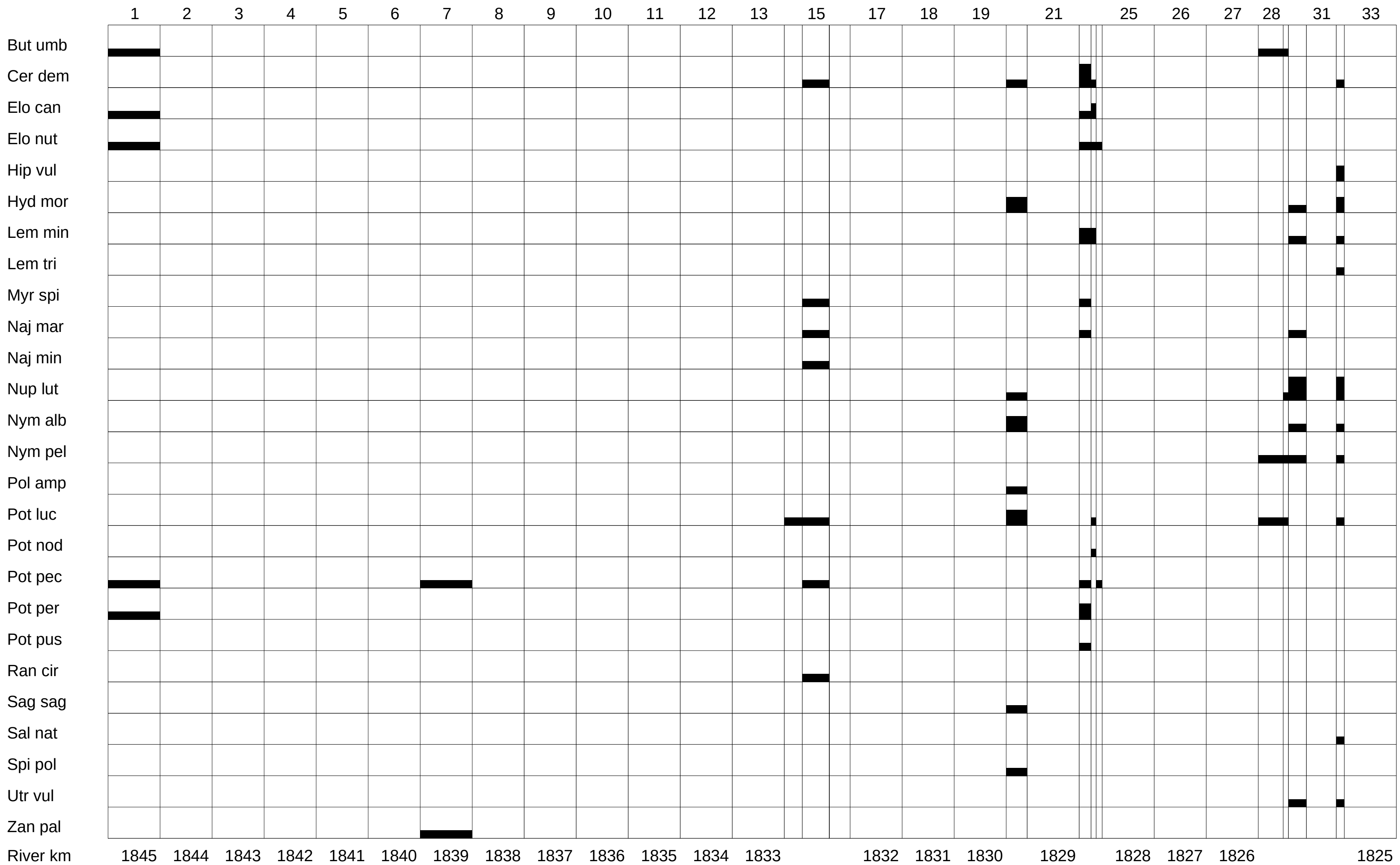
Figure captions:

Figure 1: Szigetköz Area (Hungary) / Distribution Diagram. The width of the columns is equivalent to the real length of the survey units. Horizontal bars indicate the plant mass estimate (PME) for each species in each survey unit. Small bar: estimate levels 1 and 2. Medium bar: estimate level 3. Large bar: estimate levels 4 and 5.

Figure 2: Szigetköz Area (Hungary) / Relative Plant Mass (RPM)

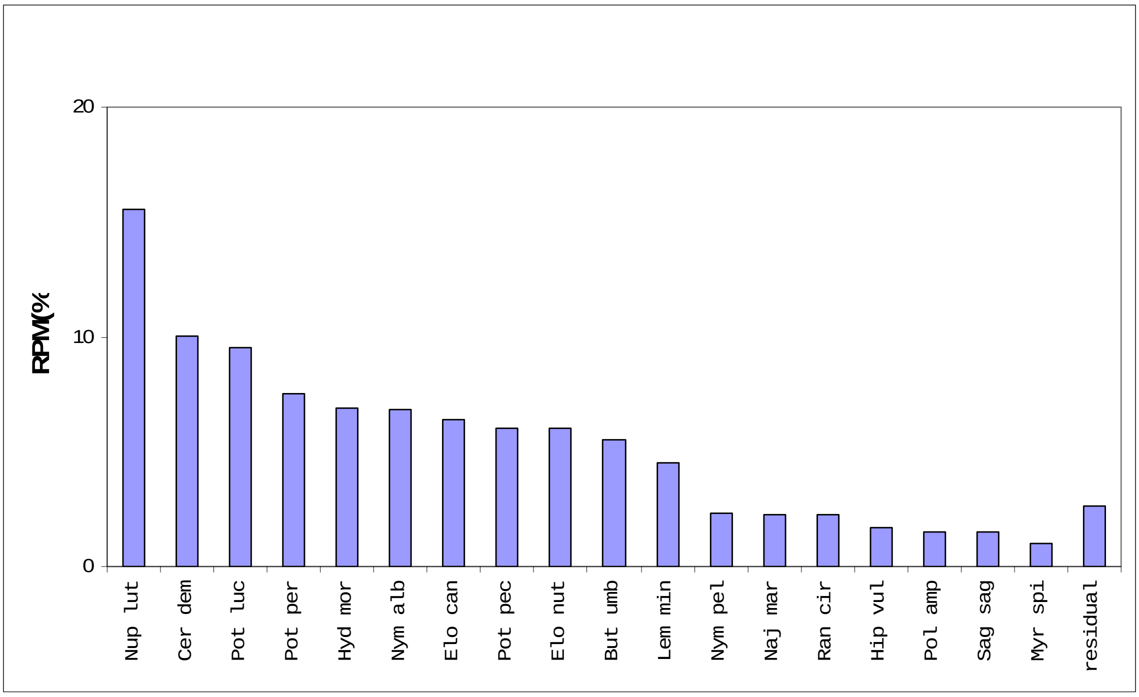
Figure 3: Szigetköz Area (Hungary) / Mean Mass Indices (MMO/MMT) and Distribution Ratio (d). White bar: Mean Mass Index, calculated on the basis of survey units of occurrence of a species (MMO). Black bar: Mean Mass Index, calculated on the basis of all survey units (MMT). Distribution ratio (d): Ratio between MMO and MMT. It is of special importance when comparing very low numerical values (= very small bars) of MMO and MMT. Detailed explanation in the "Methods" chapter in this volume.

Fig. 1



14-16: Cikola side arm system, 20: Zátonyi-Danube, 22-24: ponds in the abandoned river bed, 28-32: Lipót mortlake in the protected floodplain

Fig. 2


RPM(%
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Nup lut
Cer dem
Pot luc
Pot per
Hyd mor
Nym alb
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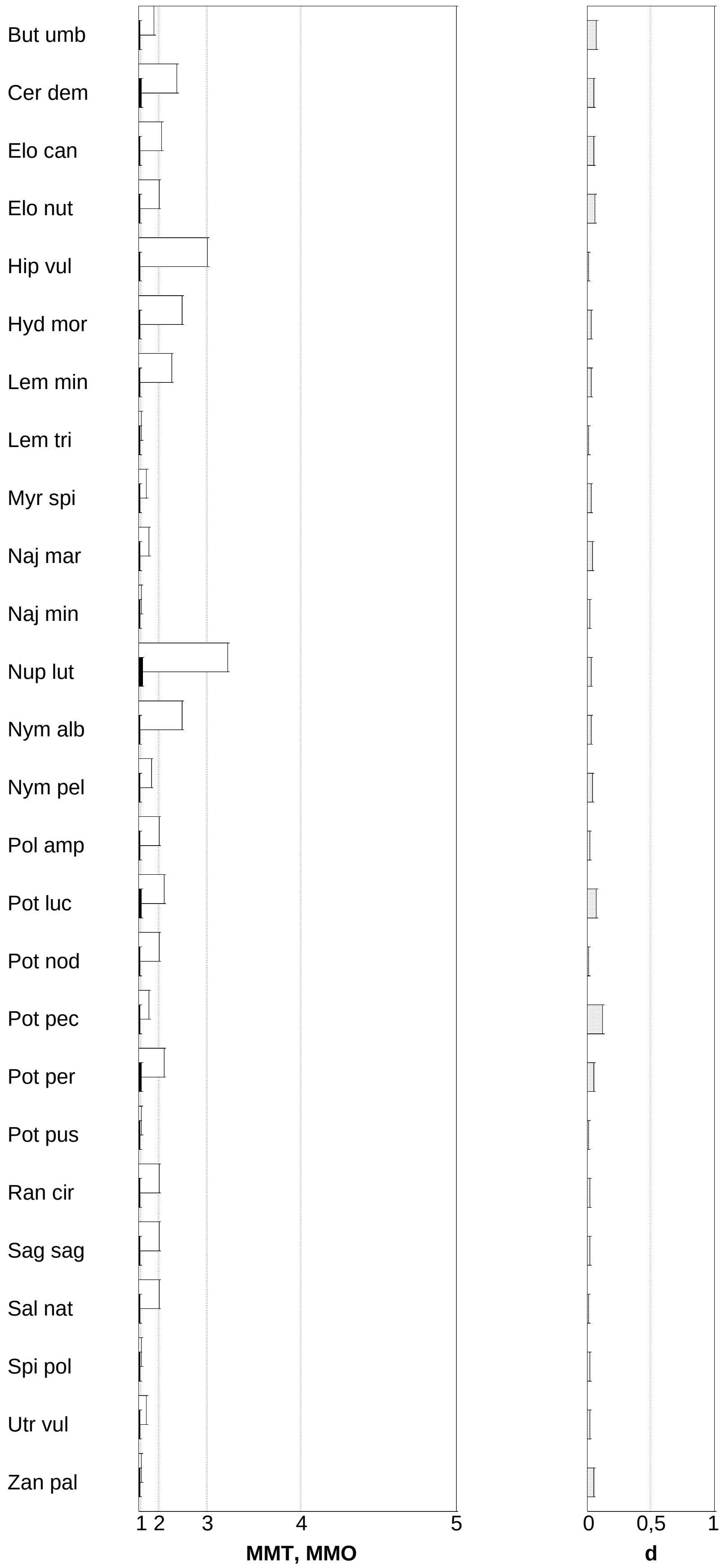
Fig. 3



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Naj mar
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Nup lut
Nym alb
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Pol amp
Pot luc
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Pot pus
Ran cir
Sag sag
Sal nat
Spi pol
Utr vul
Zan pal
1 2 3 4 5
MMT, MMO
0 0,5 1
d