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Aspects of Wetland Habitat Restoration and Monitoring in the Danube Delta: Water Macrophytes as Quality Indicators in Evaluation Processes

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Abstract: This paper presents the results of a long-term monitoring on water macrophytes used as quality indicators in four restoration areas: Babina, Cernovca, Popina and Fortuna, of the Danube Delta Biosphere Reserve, Romania. The development of these areas under the restored hydrological regime is discussed and the results of the measures are analysed in terms of habitat restoration and wetland ecosystem health. The key ecological factors for the functioning of the ecosystem, the most important being the hydrological regime, are highlighted. The author underlines, that not only the inundability of a site is important for the analysis during long term monitoring, but also the knowledge of the yearly water level dynamics, the seasonality of floods, its duration, its height and frequency, which are crucial for the macro- and microhabitat ecological development and diversity. The macrophyte community species composition and their abundance-dominance values can indicate the trends in evolution of the habitat quality after restoration. The water macrophytes are used as indicators for the restoration of the water flow regime, for the functioning of filtering processes and the trophic state.

Keywords: Wetland restoration, Danube Delta, water macrophytes, quality indicators, monitoring, evaluation

Introduction

During the second half of the 20th century, particularly in the last three decades, large scale drainage as well as transformation of wetlands into agricultural lands and fishponds took place in the Danube Delta. Severe consequences of the human impact became visible shortly after with changes of the hydrological regime in certain areas, related hydro-morphodynamic processes, salinisation and steppisation of the drained areas, the loss of many site typical macro- and microhabitats and important wetland ecosystem services, etc. Beginning with the 1990 changes of thinking have taken place and led to the commencement of large scale proposals for restoration projects. Following first discussions and plans, a large international pilot project started in the Romanian part of the Danube Delta with the restoration of two embanked areas, the agricultural polders Babina (2100) and Cernovca (1580). These were followed by three additional restoration projects, the fishpond area of Popina (3600 ha), the fishponds of Holbina (5630 ha) and the forestry polder Fortuna (2115 ha). Applied research has been conducted in all of those areas to monitor the project results.

The aim of this study is to present the results of the long-term monitoring on aquatic macrophytes, used as quality indicators on two of the restoration areas: Babina and Cernovca, and of the short-term monitoring in the restoration areas of Popina and

Fortuna. The investigations were realised by the Danube Delta Institute in Tulcea, Romania, in close cooperation with the WWF-Institute for Floodplain Ecology at Rastatt, Germany. The development of these areas under the restored hydrological regime is discussed and the results of the measures are analysed and discussed in terms of habitat restoration and wetland ecosystem health.

The hydrological regime is the main and deciding ecological factor to be considered for the ecosystem functioning in order to evaluate the ecological state of the restoration sites before and during the restoration and after the implementation of the hydrotechnical measures. Usually the inundability of the different sites is analysed as the first step in an evaluation. Such data are presented in the Danube Delta's inundability map (Munteanu, Curelariu 1996), which differentiates five categories of inundation levels. The data give only general information about the mean values of water levels over a long period, without showing a particular situation for a certain year or season in a year. But for a long-term monitoring of floodplains and deltaic ecosystems it is important to know also the yearly water level dynamics, the seasonality of flooding, its duration, as well as its height and frequency, which are crucial for the macro- and microhabitat ecological development and diversity. Furthermore, all of these factors vary greatly between the years. This fact is clearly visible, if we compare very different years from the hydrological point of view, *i. e.* two years, one with extremely high and one with extremely low water levels measured at gauge Tulcea (Fig. 1).

Studied Sites

The studied restoration areas in the Danube Delta are presented in Fig. 2.

Disturbed hydrological regimes are common to all of the polders planned for restoration, with different preconditions at each site. In 1983, Babina (2100 ha) and Cernovca (1580) were agricultural polders surrounded by circular dykes, drained, dried out and provided with a system of drainage and irrigation canals. In these two polders a remarkable salinisation and steppisation occurred. The Popina fishpond area (3600 ha) was also surrounded by a dyke (1970) and divided into several water basins with a canal system and pumping stations. The wetlands and water surfaces remained but with changed surface proportion and species composition. The lack of water exchange and circulation inside the polders and between the two compartments of the large polder of 3600 ha influenced negatively the former natural habitats. At least the Fortuna polder (2115 ha) was provided with canals and dykes, which in the northern part were not finished, allowing for significant water inflow from the surrounding area. In the southern part, a direct connection to the main Delta branch Sulina diverted large amounts of sediment rich water into the polder causing remarkable sedimentation mainly in the lakes Fortuna and Rotund.

It is not possible to bring back the above mentioned areas entirely into their original natural

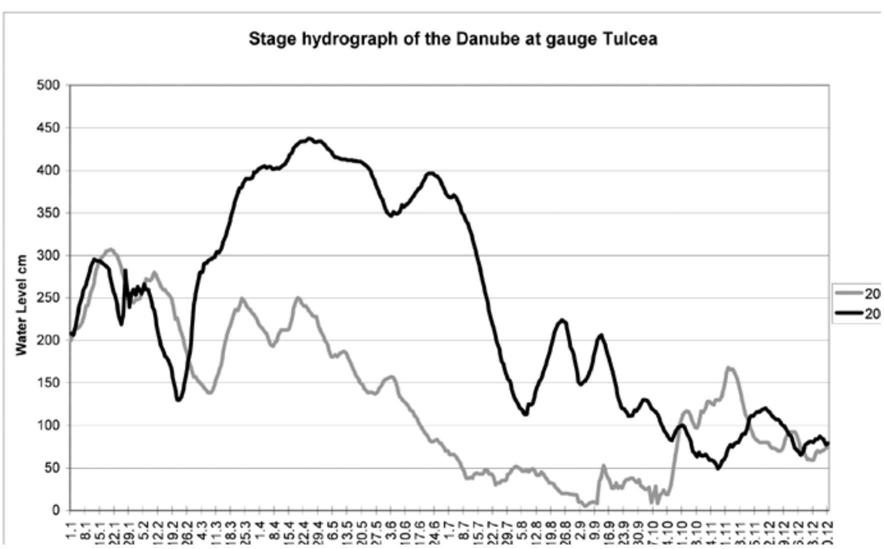

Fig. 1. Stage hydrograph of the Danube River at gauge Tulcea for two years: 2003 with generally low water levels and 2006 with high water levels during the vegetation period

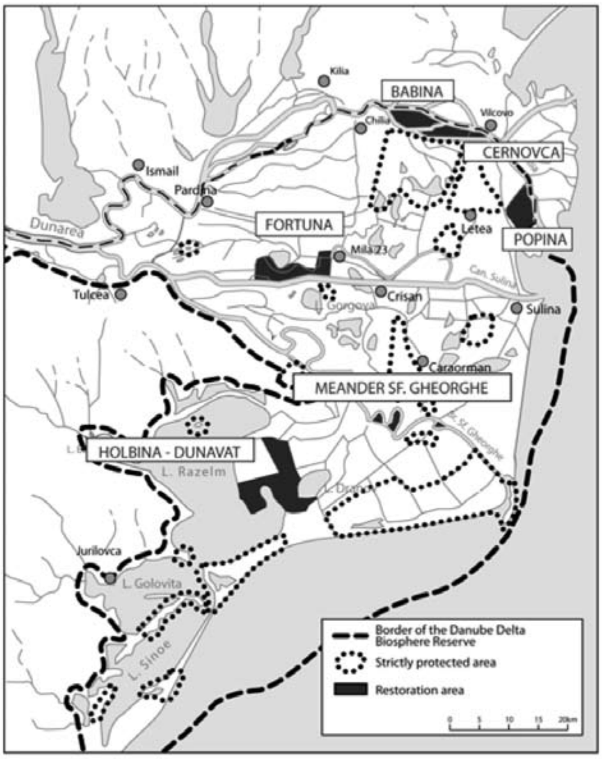

Fig. 2. The studied restoration areas in the Danube Delta (the area Holbina-Dunavăţ of 5630 ha is not subject of this paper); map from the archive of WWF-Auen-Institut, Rastatt, Germany

state, since the natural system itself is in permanent evolution and subject to changing processes. Nevertheless, the objective was to restore a largely self-maintaining ecosystem in an equilibrium state, revealing largely intact ecological functions providing site-specific ecosystem services.

In Babina and Cernovca the hydrotechnical measures as starting point for the habitat restoration consisted of the realisation of inlet and outlet openings in hydraulic important localities in order to re-flood the drained polder area. Babina opening started in 1994 and Cernovca followed in 1996.

In Popina Polder the first restoration measures started in 2000 with a reconnection to the Danube River by a canal in order to allow the exchange of water between the Danube River and the inner of the polders. Furthermore, an opening between the two large southern polders was built in order to reactivate the old natural water course of Gârla Popina that crossed the two large basins of 3600 ha.

In Fortuna area the opposite situation had to be settled, with much unfiltered sediment rich water entering the area. Closing of some canals was needed to stop the large inflow of sediment rich water into the inner of the polder area, silting up the lakes Fortuna and Rotund. Again, an old water course, the Gârla Fortuna, was reactivated, flowing from the west through a large reed area that functioned as a filter and thus contributing greatly to water quality improvement. These measures were implemented step by step in two phases between 1997 and 2002, with all the hydrotechnical works being followed by ecological monitoring (publication in preparation).

Material and Methods

Following the implementation of the hydrotechnical measures in each of the studied polder areas, a network of sampling points was established for the monitoring of water macrophytes and macrozoobenthos at the same sites (Marin, Schneider 1997, Lagendijk, Schneider 2000, Schneider *et al*. 2008, Schneider 2009). In order to document the re-colonisation process of macrophytes and their communities, as well as the habitats quality in the polders after implementation of the hydrotechnical works, sampling was repeated over a number of years. In addition, vegetation data was collected at a number of transects in order to document the ecological gradients (Oosterberg, Staras 2000). The sampling of aquatic vegetation was implemented using the methods for the evaluation of species abundance-dominance and sociability according to the seven point scale of Braun-Blanquet (1964). In some stretches the method of Kohler (1978) was applied. Comparing a large number of sampling sites and measuring physical and chemical parameters allowed for the identification of species which indicated the ecological state of the water bodies, the improvement of water circulation, restoration of the filtering function, water quality, degree of salinity and the general habitat quality.

Results and Discussion

Within the frame of the monitoring program, the multiannual sampling of the sampling plots could demonstrate the abundance-dominance value fluctuations at various sites over several years (Schneider *et al.* 2008, Schneider 2009). The yearly control of the sampling plots of Babina (1994-2001, 2005) and Cernovca (1996-2001, 2005) allowed to draw comparisons and made it also possible to show the development trends of the vegetation with the re-

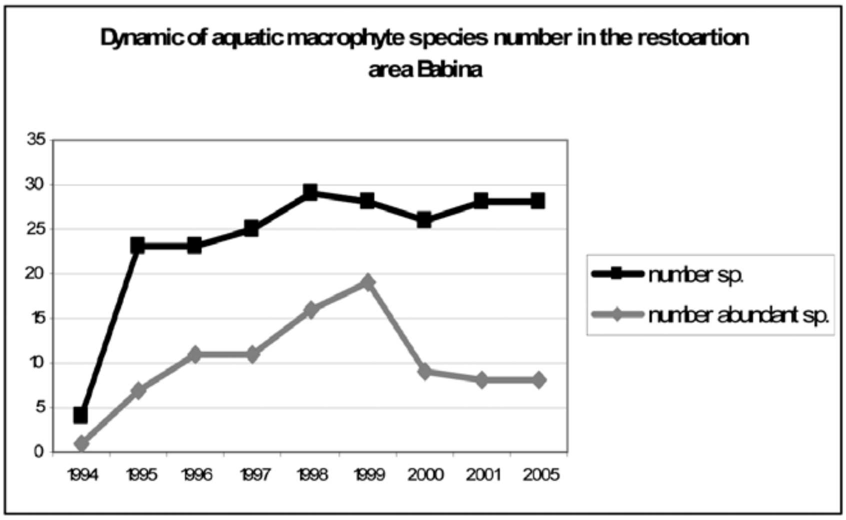

Fig. 3. Dynamics of aquatic macrophyte species number in relation to the number of abundant species in the restoration area Babina in the period 1994-2005

establishment of the site typical species and habitats, and the ecosystem functions and services. Moreover, the changes resulting from hydro-morphodynamics could also be documented (Schneider *et al.* 2008). After the reconnection of the island polders to the hydrodynamics of the Danube River, a very quick evolution of water macrophytes was observed. Beginning with the third year after re-flooding, the number of species was becoming more and more stable (Fig. 3). But not the number alone indicated an improvement and re-establishment of the former type of vegetation. The macrophyte community species composition and their abundance-dominance values could indicate the trends in evolution of the habitat quality.

The first colonising plants in the water bodies were – as expected – some free-floating macrophytes, such as *Salvinia natans* and *Lemna minor*, but also rooting plants as *Polygonum amphibium* and *Potamogeton crispus.* In the second year certain species characteristic of flowing waters, such as *Potamogeton pectinatus* and *Sagittaria sagittifolia* (flowing form) were abundant in the inlets and outlets, and their surroundings. Also *Nymphoides peltata* was found in large quantities near the inlets of Babina and Cernovca, as well as at Popina, but this was due to the sedimentation rate of inflowing water. Species of moderate eutrophic and clear water, such as *Nymphaea alba*, *Hydrocharis morsus ranae* and *Lemna trisulca,* occurred in places with regenerating reed, which indicated a beginning filter function. Water soldier *Stratiotes aloides* that is characteristic of initial phases of floating reed, showed high abundance-dominance values beginning with the fourth year in both polders. Good evidence for the working filter capacity of the restored wetlands was given by high abundance values of *Utricularia vulgaris* up to the fifth year from re-flooding (sampling sites canal CC2-Babina and CP1 Cernovca). This species formed large belts on the edge of the reeds, where clear water without any suspended solids poured out (Fig. 4, Table 1).

Some changes and fluctuations in the number of macrophytes and covering degree of species were caused by the changes in water levels between the years and the related changes in habitats. This was proved by the occurrence of *Chara contraria* in Babina Polder in the fifth year of re-flooding and in Cernovca in the third year of re-flooding, since the lower water levels allowed this stonewort species to occur in shallow, clear and meso- to light eutrophic sites (Table 1). In the following year the long-lasting higher water levels with changed dynamics at the same sites caused that species to disappear. In the following years the eutrophication owing to the cattle and pig grazing on the water edges caused complete changes of these sites.

In Popina the water circulation and habitat development was recorded only for two subsequent years, but the trends of the evolution became clearly visible by the increasing abundance of macrophytes such as *Potamogeton nodosus* and *P. pectinatus* (Table 1), characteristic of slowly running waters. The improvements of water exchange and circula-

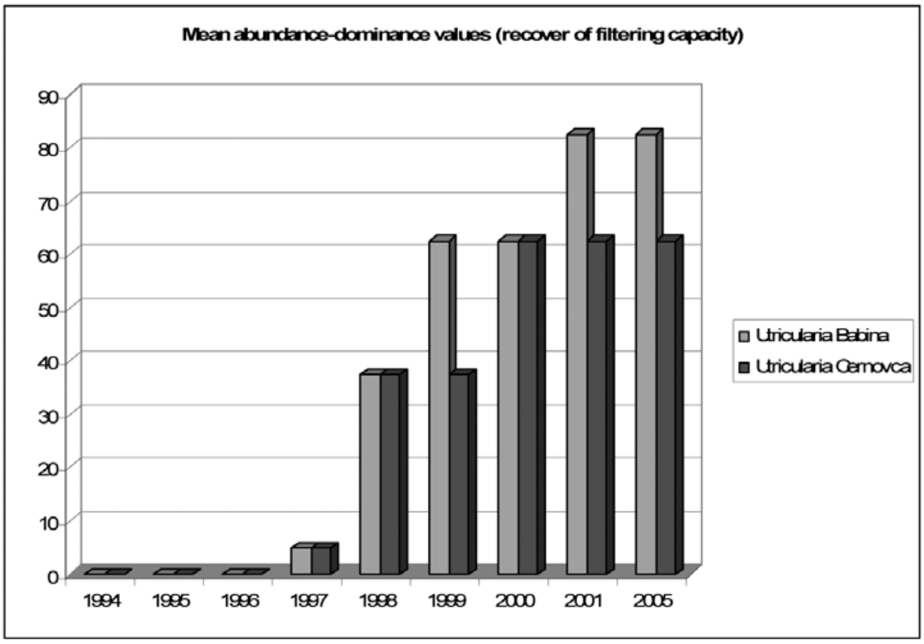

Fig. 4. Abundance-dominance values (in %) of *Utricularia vulgaris*, a species with filtering capacity monitored from 1994-2001 and in 2005 in the same sampling stretches of Babina and Cernovca polders

Table 1. Covering degree of macrophyte associations (in % – rounded) in selected sampling points of the restoration sites before (b) and after (a) the hydrotechnical measures. Sampling points: in Babina – western Babina and a stretch of the canal CC1; in Cernovca – stretch of the canal CP1; in Popina – the Gârla Popina sampling point and a stretch of the Eastern canal Popina; and in Fortuna – a sampling point of Rotund Lake and area of Crânjala

Species / **Sampling Year**	**Babina W and CC1**					**Cernovca CP1**				**Popina**		**Fortuna**	
	b	**a**	**a**	**a**	**a**	**b**	**a**	**a**	**a**	**b**	**a**	**b**	**a**
	94	**96**	**98**	**99**	**2001**	**95**	**97**	**98**	**2001**	**99**	**2001**	**2000**	**2001**
Zannichellietum palustris	-	40	45	35	-	-	-	75	-	-	-	-	-
Ranunculetum circinati	-	65	100	90	60	-	-	40	-	100	70	-	-
Myriophylletum spicati	-	40	60	65	-	-	40	-	-	40	40	45	40
Potamogetonetum perfoliati	-	70	70	-	-	-	-	-	-	-	-	-	-
Hydrocharitetum morsus-ranae	-	20	-	70	65	-	60	60	60	20	25	-	-
Stratiotetum aloidis	-	40	60	65	85	-	65	70	75	65	65	-	-
Lemno-Utricularietum vulgaris	-	-	40	65	80	-	5	35	60	60	70	-	-
Potamogetonetum lucentis	-	-	-	-	-	-	40	45	60	-	-	-	-
Potamogetonetum trichoidis	-	-	65	65	-	-	-	40	-	80	75	75	40
Trapetum natantis (L. Ro)	-	-	-	-	-	-	-	-	-	-	-	80	90
Nymphaeetum albae	-	-	-	-	-	-	-	-	-	75	80	-	-
Ceratophylletum demersi	-	-	-	-	40	-	-	60	70	-	-	35	70
Elodeetum canadensis	-	-	-	80	60	-	-	-	-	-	-	65	80
Potamogetonetum crispi	-	-	62	-	-	-	-	65	-	-	-	5	-
Potamogetonetum nodosi	-	-	-	-	-	-	-	-	-	40	65	90	40
Potamogetonetum pectinati	-	-	-	65	-	-	-	-	-	60	80	65	80
Chara globularis & contraria	-	-	80	-	5	-	-	90	40	90	90	-	-
Myriophylletum verticillati	-	-	-	-	-	-	-	-	-	40	45	-	-

tion led to a mix of habitats typical of standing and slowly running freshwaters, with different loads of suspended solids and slightly saline waters (the polder being close to the Black Sea). Macrophytes have been present in the area before and after restoration measures, but with a changing proportion in abundance-dominance index. Only near the opening, some typical species for running waters were present. In the other parts of the Popina polder, species of almost standing waters, encountered also in very slowly running waters occurred. A well developed habitat with characteristic macrophytes and rich in structure created suitable conditions for the return of the specific fauna of macroinvertebrates and fish (Marin, Schneider 1997, Schneider *et al.* 2009, Lagendijk, Schneider 2000).

In the Fortuna polder the state of macrophytes was monitored in different working phases of the restoration area. The changes in direction of an improved water circulation and related sedimentation processes resulted in a stopping of the rate of sedimentation in Fortuna Lake. Lake Rotund still suffers from sedimentation as the functions of the natural filtering did not recover after the restoration of Gârla Fortuna stream in the west-east direction, which had crossed the compact reed area in the time before the restoration measures. Sediment rich water still enters in smaller amounts from a narrow natural channel in the southern part of the polder area. For this reason, we found in the autumn of 2012 that in the eastern part of Fortuna polder the sedimentation is still a progressive process.

Conclusions

During about two decades the water macrophytes and their communities as indicators for water quality and physical parameters have been studied over a large part of the Danube Delta. These indicators can be used successfully for revealing the evolution processes after restoration works, as they are characteristic of standing or running waters, as well as of the waters rich in suspended solids or of clear waters with many transition stages. Furthermore, the macrophytes indicate the trophic state of a water body and the salinity of waters. They can also show whether the restoration efforts result in an improved water regime with increased circulation and exchange of waters, with working filtering processes and with restoration of ecosystem services. Not only reeds, but also water macrophytes with well developed large root systems, such as *Utricularia vulgaris*, *Stratiotes aloides* and *Trapa natans*, contribute to the filtering.

In all study sites the restoration of the hydrological regime has been the base for the restoration of supporting, provisioning, regulating and not the least cultural ecosystem services. These services, in particular the provisioning services, are of crucial importance for the sustainable use of the restored areas by local communities, in particular for food (fish), wood and reed, for climate and flood regulation as well as for water purification.

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