The aquatic vegetation of the Upper Danube river

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Introduction

The inclusion of aquatic macrophytes into a set of biological indicators prescribed in the European Water Framework Directive in order to assess and control the water quality of running waters requires the development of monitoring programs by regional authorities. The implementation of a regional monitoring program in Baden-Württemberg, Germany, rendered it possible to conduct an extensive inventory of aquatic species and the mapping of the submersed vegetation of the Upper Danube river between the confluence of the headwaters Brigach and Breg in Donaueschingen and the inflow of the pre-alpine river Iller in Ulm. The results of this mapping may serve not only to develop and apply ecological evaluation systems but may also contribute to the reconstruction of the history of the aquatic vegetation (SCHÜTZ 1995). However, an obligate prerequisite to detect temporal changes in vegetation patterns is the existence of data collected by researchers in former times. Both, recent mapping and historical studies, enable the establishment of reference conditions of the aquatic vegetation for the Upper Danube.

Material and Methods

Surveys of the aquatic vegetation of the Upper Danube were made between 1988 and 1990 (KONOLD et al. 1989, 1991, SCHÜTZ 1992) and between 2003 and 2004 (PALL et al. 2004, SCHÜTZ et al. 2005) during low-water periods in summer by recording all water plants growing below the low-water level. In both surveys almost the total course of the river, its secondary channels and backwaters embracing 196 km length between the confluence of Brigach and Breg and Ulm was investigated by boat. The stream course was divided into contiguous sections of different length yielding in 171 relevees. Habitat parameters were assessed according to the guidance of the MIDCC (www.midcc.at). The mass of each species was estimated using the 5-level estimator scale of KOHLER (1978). The Relative Plant Mass (RPM) was calculated according to JANAUER (2003). Old regional Floras and Herbaria in Baden-Württemberg were surveyed for aquatic macrophytes collected in the Upper Danube. Moreover, published and unpublished literature was inspected in order to detect floristic and vegetation records of aquatic plants.

River characteristics: The Upper Danube is a a rhitro-potamal river with an average slope of 1 ‰ and considerable differences between high and low water discharge. The moderately eutrophic, calcareous stream is not, or slightly shaded by trees and mostly < 1.5 m deep thus providing good conditions for macrophyte growth. There are marked discontinuities associated with geomorphological properties of the landscape and it is appropriate to divide the Upper Danube into three sections (Fig. 1): (1) The meandering upper reach between the confluence of the two headwaters and Geisingen flows most of its course in the Black Jurassic through a wide valley. (2) The stretch between Geisingen and Scheer is incised into the hard White Jurassic (Schwäbische Alb) resulting in a steep and narrow valley. Part of this stretch can fall dry during summer due to the loss of water in Karst cave-systems. (3) A weak bedrock, the Freshwater Molasse, which is sensitive to

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bank and riverbed erosion, characterises the prevailingly wide Danube valley between Scheer and Ulm. This stretch includes also a chain of reservoirs near Ulm. The intensity of river regulation differed considerably between the three stretches. The Molasse-course is heavily modified and has been channelised to a large extent, whereas the degree of channelisation in the uppermost and the Karst-stretch has generally been much less.

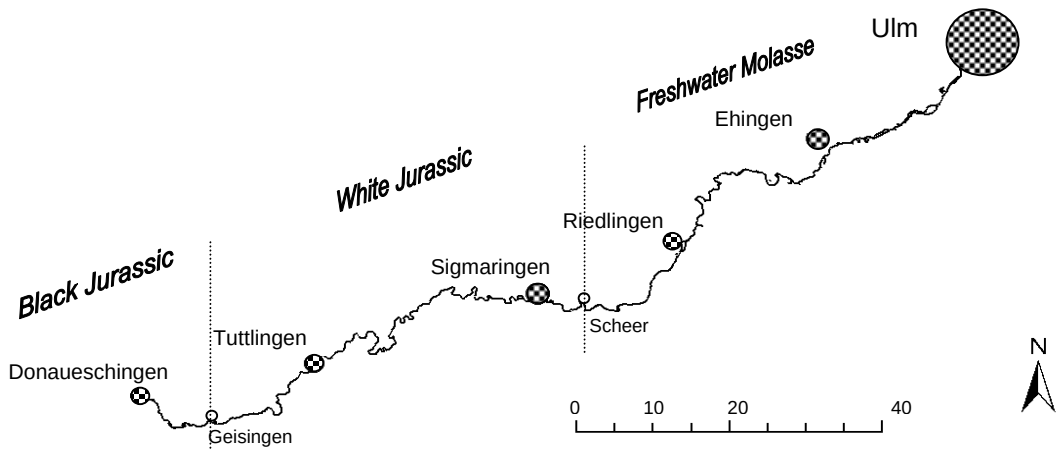

Fig. 1: The course of the Upper Danube between Donaueschingen and Ulm.

Results

Actual aquatic vegetation: The 2004-survey detected 25 vascular aquatic macrophytes and seven moss species in the Upper Danube below the low water level. Overall, *Ranunculus fluitans* und *Fontinalis antipyretica* made up more than 60 % of RPM (Fig. 2). Most sections in the upper stretches and the Karst-course contained abundant aquatic vegetation, consisting mainly of *R. fluitans* and *F. antipyretica* in fast flowing sections, *Elodea nuttallii, Sparganium emersum, R. fluitans, Nuphar lutea* and filamentous algae in slow flowing stretches. By contrast, species richness and abundance was low in many sections of the fast flowing, channelised Molasse-course, where aquatic vegetation consisted mainly of *R. fluitans, F. antipyretica, Zannichellia palustris* and filamentous algae. The chain of reservoirs near Ulm was dominated by a *Nuphar lutea*-community with considerable amounts of narrow-leaved pondweeds while many other backwaters upstream were devoid of submersed vegetation.

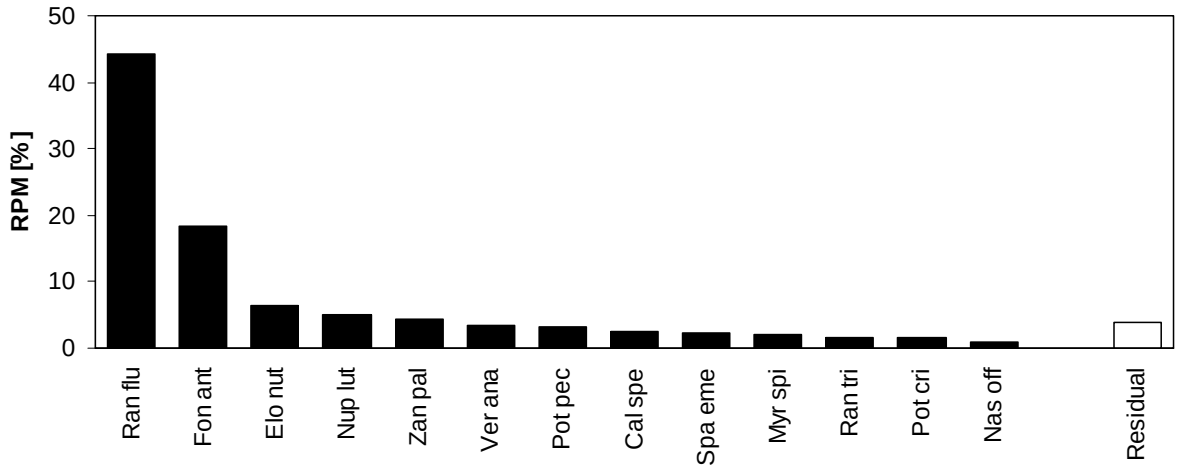

Fig. 2: Relative Plant Mass (RPM) in 2003/04 for aquatic plants in the Upper Danube (without channels and backwaters). Species with an RPM-value < 1 % are summarised in the residual.

Floristic changes: *Hippuris vulgaris, Potamogeton lucens, P. alpinus* and *P. natans*, not rare in former times, are probably extinct, *P. perfoliatus, Groenlandia densa* and *Butomus umbellatus* have decreased strongly in frequency and abundance since the 1960s. An increase may be assumed in *R. fluitans* and *F. antipyretica* though these species were common also in former times. Furthermore, there is ample evidence that filamentous algae were much less frequent some decades ago. *Elodea canadensis* was observed first 1882 in a tributary of the Upper Danube and spread out rapidly in subsequent decades. *Elodea nuttallii*, invaded the Upper Danube only recently (approximately 15 to 20 years ago) but has spread out quickly in the uppermost stretches ever since. Little or no long-term changes are detectable in the other aquatic species. The historical data resulted in the definition of specific reference conditions of the aquatic vegetation typical for the Upper Danube (Tab. 1). Community structure, diversity and species composition were defined for fast and slow flowing stretches.

Overall differences were small between the surveys 1988/90 and 2003/04 although vegetation dynamics were high at a small scale. Since 1988/90 the very last populations of *Hippuris vulgaris* and *Potamogeton natans* have apparently disappeared from the main river, while *Myriophyllum spicatum* and *Sparganium emersum* decreased in abundance. No significant change in frequency could be detected in other species. However, some common aquatic and riparian species have increased in abundance at a local scale in the Molasse course due to several restoration measures.

Tab. 1: Reference conditions of the aquatic vegetation in the Upper Danube river.

	Reference community	**„disturbance indicators“**
Slow-flowing stretches Rich in species and growth forms (Batrachids, Magnopotamids, Haptophytes, Nymphaeids, Peplids, Helophytes); Parvopotamids und Pleustophytes always subdominant oder lacking.		
	- *Ranunculus fluitans* co-dominant - Magnopotamids (*P. natans, P. alpinus, P. lucens, P. perfoliatus, Groenlandia densa*), *Hippuris vulgaris, Nuphar lutea, Sparganium emersum* co- to subdominant - Mosses subdominant - Species number > 7	- Lack or subdominance of Parvopotamids and filamentous Green Algae - Lack of *Elodea* spp., *Lemna* spp., *Zannichellia palustris, Potamogeton crispus*
Fast-flowing stretches Moderately rich in species and growth forms (Batrachids, Magnopotamids, Haptophytes, submersed Helophytes); lack of Parvopotamids und Pleustophytes.		
	- *Ranunculus fluitans* dominant - *Fontinalis antipyretica* codominant - Mosses (*Rhynchostegium riparioides, Cinclidotus* spp.) and *P. perfoliatus* subdominant - Species number > 5	- Lack or subdominance of filamentous Green Algae - Lack of *Potamogeton pectinatus*

Discussion

Compared to many other rivers in central Europe, the Upper Danube still accommodates a relatively rich aquatic flora. The characteristic *Ranunculus fluitans*-dominated community is

present in many other western and central European streams with a rhitro-potamal character, provided that they are not polluted too severely. There is strong evidence from herbarium material and old phyto-sociological records embracing a time span from ca. 1850 to 1960 that the actual species composition and distribution patterns presently existing are different from those prior to 1960. Old floristic data also reflect the various degrees of human impact on the three distinguished stretches of the upper Danube. Extensive channelisation, resulting in sediment instability, caused an impoverishment of aquatic vegetation in the Molasse-stretch before the onset of severe eutrophication in the 1960s (SCHÜTZ et al. 2005). A second period of major floristic changes affecting the entire course of the Upper Danube can be fixed between 1960 and 1970 coinciding with a rapid increase of eutrophication (SCHÜTZ 1992, 1995). A decline of species considered as being sensitive to pollution has been reported over the same time period for numerous other streams in Central Europe (e.g. SCHÜTZ 1992, RIIS & SAND-JENSEN 2001). It holds true for most rivers, however, that the composition of former aquatic plant communities is not fundamentally different from those presently existing, but extant communities are generally poorer in species and growth forms.

Summary

The Upper Danube is characterised by the dominance of *Ranunculus fluitans* and the sparse occurrence of species sensitive to eutrophication. A comparison of extant vegetation patterns with vegetation data recorded prior to the 1960s revealed a considerable decline in species richness and structural diversity. These floristic changes occurred to a lesser extent after the channelisation carried out mainly in the early 20th century and again after extensive eutrophication of the Upper Danube in the 1960s and the early 1970s. Ample historical data from the Upper Danube allow an assessment of reference conditions with respect to aquatic macrophytes.

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