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CHAPTER

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The Water Soldier (*Stratiotes aloides*)

An indicator for the conservation and management of riparian ecosystems

By

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Abstract:

The regulation of the Danube River has caused a decline in species diversity in riparian habitats throughout Europe. Aquatic macrophytes adapted to the ecology of backwaters are particularly affected by this decline. One such macrophyte is the water soldier (*Stratiotes aloides L.*) The water soldier, a suitable indicator for assessing the development of riparian ecosystems, could be found in only six locations of the eastern Danube floodplains in Austria in surveys from 2014 to 2017. While primarily endangered by gradual siltation due to a lack of regular flooding events, a large number of anthropogenic disturbing factors were also found to significantly compromise the habitats of water soldiers. The most desirable conservation approach would be to create or promote natural backwater dynamics for water soldiers' habitats. In the short term, however, less extensive local measures are also suitable for delaying the succession process.

Keywords:

Stratiotes aloides | aquatic macrophyte | endangered plant species | Danube floodplains | Austria

Introduction

A hundred years ago, visitors described huge expanses of water densely covered in white water soldiers' flowers (Sauberer, 1942; Hübl, 1952). But regulation of the Danube River eventually led to a loss of species diversity in the riparian habitats: backwaters were cut off from the main trunk, the dynamism of the river was restricted and areas with stagnant water gradually began to silt up. Besides direct anthropogenic interferences, various indirect influences like the introduction of certain nutrients and contaminants contributed to changes in fluvial landscapes (Jungwirth et al., 2014; Schratt-Ehrendorfer, 1999). Modern agricultural processes, in particular, have a massive ecological impact on rivers, lakes and backwaters as areas of high species diversity undergo eutrophication. European freshwater bodies are, therefore, among the most endangered landscapes (Harabiš et al., 2013) with progressive ecological impact as a result of increasing anthropogenic influences (Relyea, 2005; Richards et al., 1996; Oťaheľová & Valachovič, 2006).

Water plants are well-adapted to their aquatic habitats and represent an important element in river ecologies (Chaves et al., 2002). Their evolution has provided them with strategies to cope with the natural changing dynamics of rivers (Gurnell et al., 2012). Anthropogenic influences heavily affect macrophytes in riparian habitats. Knowledge of these plants and their ecology allow pressures from human interference to be assessed, and areas of particular ecological significance and value determined (Munné et al., 2003). In recent years, comprehensive management concepts for maintaining populations of water soldiers as a key species for ecologically valuable backwaters have been tested (Hudler et al., 2015).

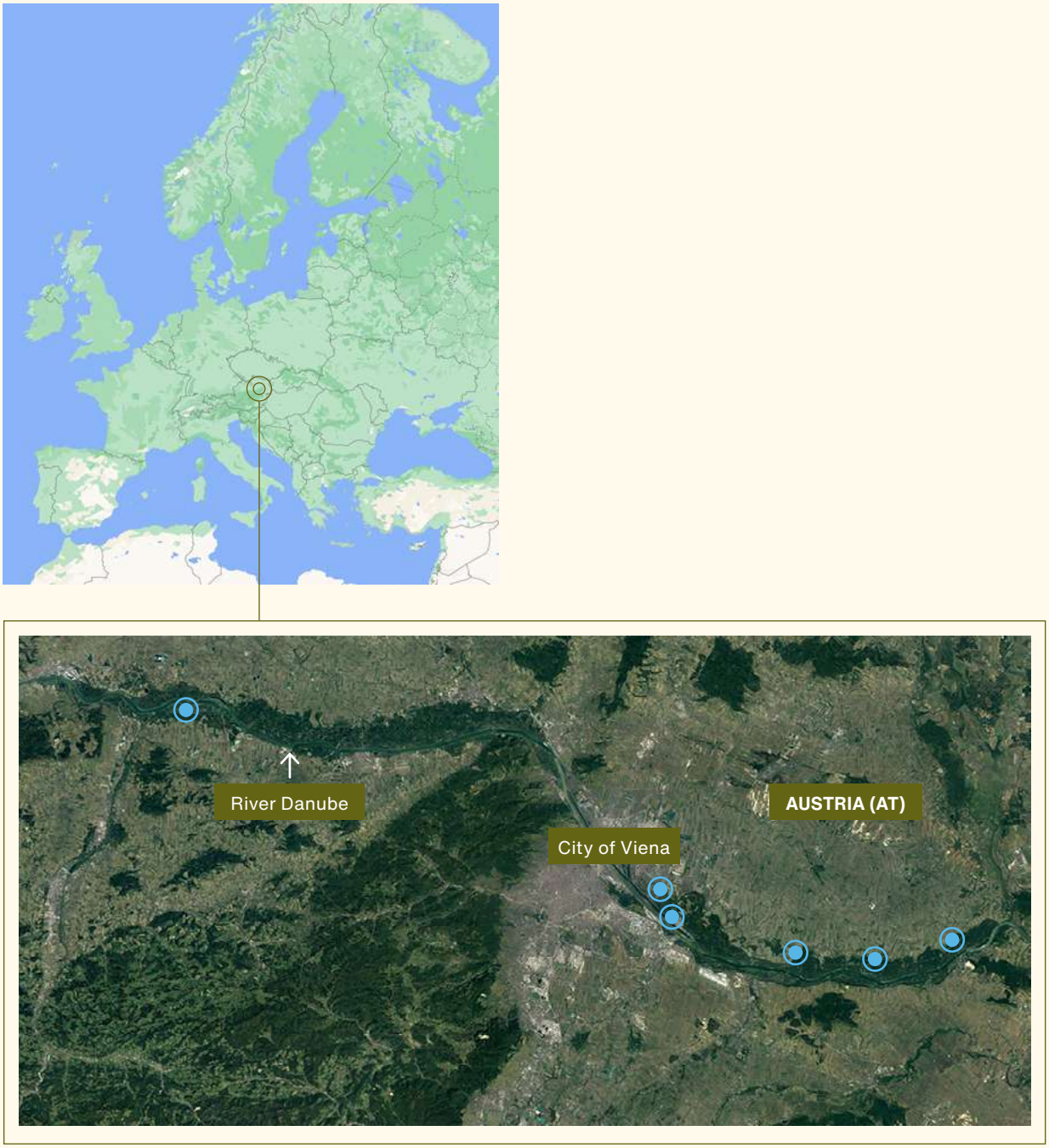

Figure 1. Location of the six remaining populations of water soldiers (*Stratiotes aloides L.*) in the riparian forests along the Danube in eastern Austria.

Map data: Google, Terrametrics

The water soldier

The water soldier is a perennial aquatic macrophyte that grows as a rosette of serrated leaves. Most specimens alternate between an emerged state in the winter and a submersed state in the summer, but a perennially submersed variant also exists (Hegi, 1981; Cook & Urmi-König, 1983). Its natural range extends across most of northern and eastern Central Europe and all the way to the Baltics and Siberia. The populations along the Danube are among the southernmost known occurrences (Cook & Urmi-König, 1983).

The water soldier is a typical representative of riparian forest flora, preferring slow-moving or stagnant bodies of water. Although it is a dioecious species, vegetative reproduction by way of offsets and turions is far more common than generative reproduction. Owing to its fast growth under ideal conditions (De Geus-Kruyt & Segal, 1973), the species plays an important part in siltation succession (Segal, 1971). The water soldier is a free-floating macrophyte whose life cycle (see Figure 2) requires water with high concentrations of carbon dioxide, typical of ponds, creeks and reed areas (Nielsen & Borum, 2008). The water soldier is noted for its close connections to other species such as the green hawker dragonfly (*Aeshna viridis*), which is listed as an Annex IV species in the 1992 EU 'Habitats Directive' (Rantala et al., 2004).

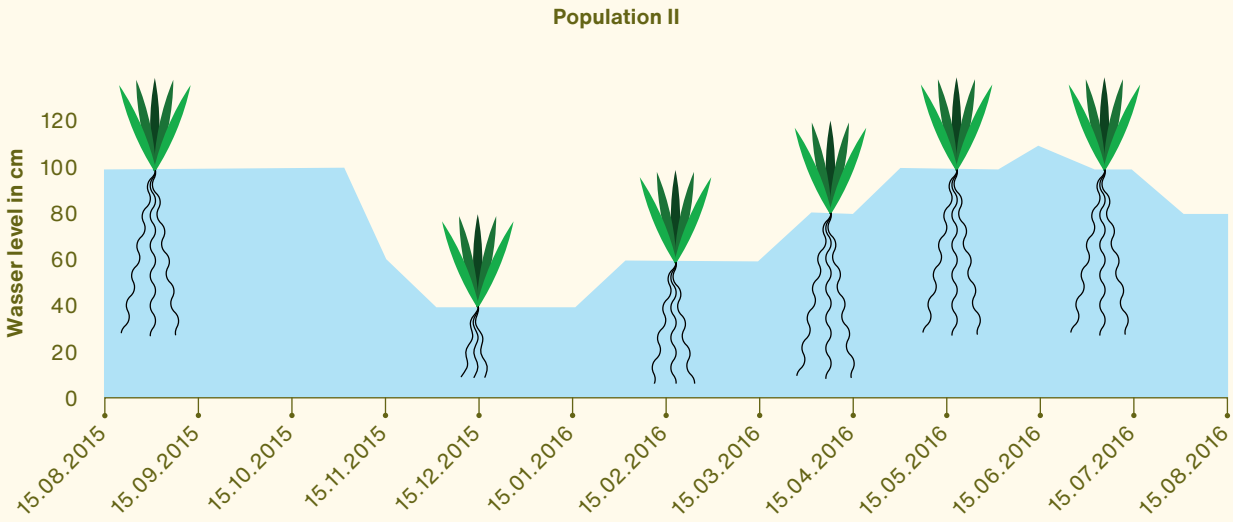

Figure 2: Ideal annual life cycle of water soldiers in a water body with water level fluctuation in centimetres.

Source: K. Lapin.

Current situation

The last remaining Austrian populations of water soldiers can be found in two conservation areas: the Natura 2000 area Tullnerfelder Donau-Auen and the Donau-Auen National Park (Bernhardt & Naumer-Bernhardt, 2010; Hudler et al., 2015). These populations were monitored over one year (July 2015 to August 2016 at intervals of 14 days). All locations are between 150 and 320 m above sea level, and all are subject to seasonal fluctuations in pH and oxygen partial pressure (Table 1). Factors like water depth and water quality (conductivity, pH value and oxygen partial pressure) also differ among the locations (see Figure 3).

Figure 3: Pictures (2015) of the water bodies where the last remaining Austrian populations of water soldiers can be found in two conservation areas: Natura 2000 Tullnerfelder Donau-Auen (Zwentendorf) and in the Donau-Auen National Park (Tischwasser, Öllager, Ortzonau, Eckartsau and Stopfenreuth).

Source: K. Lapin.

The depths fluctuate significantly depending on precipitation and groundwater levels. Furthermore, large amounts of deadwood are present in the water. Siltation of the inhabited waters appears advanced and extensive reed beds are present in three of them.

Table 1. Hydrological description of the waters with populations of water soldiers, 2015

CONSERVATION AREA	NATURA 2000	DONAU-AUEN NATIONAL PARK				
	ZWENTENDORF	TISCHWASSER	ÖLLAGER	ORTH/DONAU	ECKERTSAU	STOPFENREUTH
COORDINATE N	N 48° 22´	N 48° 11´	N 48° 10´	N 48° 08´	N 48° 08’	N 48° 11’
COORDINATE O	E 15° 47´ 03.80˝	E 16° 28´ 54.84˝	E 16° 29´ 47.30˝	E 16° 41´ 00.30˝	E 16° 46’ 52.8”	E 16° 28’ 56.6”
NATURAL BACKWATER	×	×		×	×	×
POPULATION	250 m²	100 m²	890	232	150	1 m²
INDIVIDUALS/m²	12	4	12	9	7	1
INDIVIDUALS TOTAL	3,050	15	11,760	2,552	800	1
SEX	Female	male	male	?	male	?
OFFSETS AND TURIONS	3,00	2,18	10,8	nn	8,4	0
pH	7,3	7,78	7,03	nn	8,4	7,36
WATER LEVEL (cm)	30	150	100	100	130	20
CONDUCTIVITY µS/cm	405	699	627	784	694	445
O² LEVEL mg/L	4,02	6,45	3,84	6,14	5,1	6,3
INFLUENCED BY FLOODING	No	no	no	yes	yes	no
LIGHT CONDITION	Shady	sunny	semi-sunny	sunny	semi-lit	shady
STREAMING	No	no	no	yes	yes	no
ACCOMPANYING SPECIES (N)	21	16	17	15	20	10
THREATS AND CONFLICTS						
VITAL POPULATION			×	×	×	
ENDANGERED BY SILTATION	×		×	×		×

CONSERVATION AREA	NATURA 2000	DONAU-AUEN NATIONAL PARK				
	ZWENTENDORF	TISCHWASSER	ÖLLAGER	ORTH/DONAU	ECKERTSAU	STOPFENREUTH
AFFECTED BY DROUGHT EVENTS	×			×		×
LACK OF FLOODING EVENTS	×		×	×		×
LIMITED BY SHADED LOCATIONS	×				×	×
NO GENERATIVE REPRODUCTION	×	×	×	×	×	×
DIRECT HUMAN INTERFERENCE		×				
PLASTIC WASTE		×	×			

Note: Measurements were taken in September 2015 during the monitoring period of August 2015 to August 2016.

Source: Bernhardt et al., 2016.

Identified threats and conflicts

Habitat loss

The phytosociological analysis shows that backwaters with populations of water soldiers are extremely rich in species. Many species found in the backwaters are red-listed and extremely endangered (see Table 1). What these species have in common is the loss of their backwater habitats, which are natural parts of riparian areas. Backwaters are an individual habitat type with particular flora and fauna, while at the same time providing partial habitat for other animals. Anthropogenic influences, however, have caused a significant decline in the incidence of backwater habitats (Lange et al., 2000).

Natural backwaters are created by the dynamics of watercourses, which cause seasonal variance in water levels and temporary regional flooding. However, this dynamic is barely present today. To allow human settlement of former vast (temporary) floodplains, rivers were engineered into permanent channels to protect against flooding, thereby preventing the natural creation of backwaters.

As revealed by the phytosociological analysis, backwaters are a rich and important habitat for water soldiers, but also for many other species, for example, European water-plantain (*Alisma plantago-aquatica*), broadleaf cattail (*Typha latifolia*) and bladderworts (*Utricularia australis*). Where other aquatic vegetation occurs extensively covering much of the water surface, water soldiers' surface emersion and submersion cycles can be inhibited. Furthermore, different vegetation units compete in terms of light absorption and encroachment can increase the succession pressure on various species, promoting the decline of certain populations.

Siltation succession

Water soldiers play an important role in siltation succession (Segal, 1971), not least because the species' high biomass production contributes significantly to the siltation of the water bodies it inhabits. It grows in naturally occurring oxbow lakes and backwaters – habitats cut off from the dynamics of the main river that tend to experience an acceleration in succession processes leading to siltation (Hudler et al., 2015). Thus, water soldier populations like the one in Orth an der Donau are heavily affected by droughts (Figure 4). The low precipitation between June and September further promotes this effect. Low water levels during periods with little precipitation influence the vitality of water soldiers' populations because rosettes frequently drift off and wither at the water's edge. All populations face the dangers of siltation in the long term and this risk is mainly a result of the lack of flooding events.

Besides water levels, the amount of sunlight is also important to water soldiers' survival. Various vegetation – especially overhanging trees – can influence the intensity of light reaching ground level. Locations with current or detectably recent populations of water soldiers can be described as semi-shady or semi-lit. However, populations in less shaded locations showed noticeably more vital development.

Figure 4. Drought in Orth an der Donau in September 2015 with water levels at 0 cm.

Source: K. Lapin.

Endangerment of genetic variance

Generative reproduction is an important factor for the vitality of water soldier populations (Orsenigo et al., 2017). Despite large numbers of flowers in two locations, generative reproduction was limited in all examined populations because the male populations in the Donau-Auen National Park are too far away from the only female population in the Natura 2000 area Tullnerfelder Donau-Auen to allow successful pollination. Proliferation through drifting and introduction of new specimens from other populations, which could potentially alter the gender distribution and thus result in generative reproduction, do not occur (Hameister et al., 2013; Bernhardt et al., 2014).

Recreational use

Water soldiers were affected by direct human interference in two of the examined waterbodies. Swimmers (people or dogs) can easily cause rosettes to be mechanically damaged or overturned, causing their

growth to be stunted because their leaves are no longer oriented towards the sun and their bases dry out because they are no longer submerged. In locations with biking or hiking trails near a waterbody inhabited by water soldiers, as is the case for the Öllager population, plastic refuse can frequently be found stuck to the plants' leaves (Figure 5).

Figure 5. Plastic refuse on water soldiers.

Source: K. Lapin.

Recreational fishing

The population of water soldiers covering the largest area can be found at the Öllager location near the OMV oil depot site Lobau. The depot is located immediately to the east of the waterbody housing the population. Originally situated in the nearby Panozzalacke, an easily accessible and flat-shored lake frequented by bathers and recreational fishermen, the water soldier plants were moved to the artificial lake close to the OMV oil depot in the 1970s by anglers seeking to increase the attractiveness of their fishing site (Schratt-Ehrendorfer, 1988). This population has since grown to be the largest in Austria, with more than 11.100 individuals per m^2. No new occurrence of water soldiers has been recorded in Panozzalacke.

Agricultural resource use

For three of the six examined populations, nutrients may come from nearby low-intensity farming plots and more distant but intensively farmed areas connected to the sites via small channels. The water levels at Eckartsau were particularly affected by a period of drought, with water levels dropping by more than a meter during the vegetation period. This development is most likely attributable to the drying up of the Fadenbach brook. Water usage for agricultural irrigation likely accentuated the low water levels (Smolders et al., 2003).

Management conflicts

Management to protect and preserve water soldier populations will have to deal with conflicting interests for water use (Hudler et al., 2015). Many of these conflicts are the result of the backwaters fulfilling multiple functions simultaneously. The main ecosystem functions of the affected habitats are recreational use, water use for agricultural irrigation, resource production (fishing), resource protection (water) and wildlife conservation.

Perceptions of the management of water soldiers differ. In the Natura 2000 area, the selection of substitute habitat locations was discussed. Four water bodies in the study area fulfilled all the requirements for substitute habitats for the endangered populations. However, massive resistance by the landowners and fishermen was encountered, as the establishment of water soldier populations would entail significant changes to the structure and usability of these bodies of water.

In order to protect the water soldier populations and the ecologically valuable habitats characterized by them, many regions have recently commenced comprehensive conservation measures. Conservation areas

have been established and re-population projects undertaken. Despite these efforts, the decline in water soldiers' numbers has continued. Water soldiers are also endangered in many other European countries, requiring a more extensive international effort to protect the species.

Solutions

Reconnection of cut offs

Reconnection of cut-offs and backwaters to the Danube promotes the formation of a dynamic river system and enlarges habitat for the water soldiers. The restoration of the shorelines of water body ecosystems, reconnection of separated waterbodies, optimization of low-water regulation, and granulometric improvement and stabilization of the riverbed is the declared goals of the Water Management Authority of the city of Vienna and the Donau-Auen National Park. Many projects have already been successful. Over the long term, the intent is to ensure continuous water exchange with the main stem of the Danube.

Visitor monitoring

Use of riparian forests and waterbodies for recreation by the Viennese population has a long tradition and requires consideration in the establishment of plans for water soldiers' conservation. Awareness about the species in well-frequented waterbodies needs to be raised and measures need to be taken against its mechanical disturbance and removal for transfer to private ponds. Removal of water soldiers is already forbidden in the Donau-Auen National Park area (Nationalpark Donau-Auen GmbH, 2015).

Projects undertaken in the national park have shown that visitor information campaigns and visitor monitoring are effective. A further solution for usage conflicts is to offer alternatives. Tischwasser Lake, for example, has been used for bathing, with a concrete pier available to bathers entering the backwater. Influences on the ecology of this lake due to this activity are to be expected. By creating more accessible and attractive public bathing opportunities in the vicinity, managers could reduce the use of Tischwasser Lake with an expected reduction of pressures on the aquatic ecosystem.

Creation of substitute biotopes

Human-made substitute biotopes can serve as safe habitats for many rare plant species. Naturally, environmental influences like intensively cultivated and heavily fertilized agricultural plots in the vicinity need to be taken into consideration for the choice of location for such sanctuaries. Selected locations could be settled with water soldiers to compensate for the loss of their existing habitat due to the siltation. The new locations should provide opportunities for the plants for natural propagation through flood drifting,

Monitoring conditions

Especially in months with little precipitation, it is necessary to protect the populations of water soldiers in shallow, cut-off waterbodies from desiccation. The population in the Natura 2000 area was preserved thanks to active monitoring in a critical phase during 2014 when the waterbody felt dry for an extended period and was regularly refilled with external water to ensure the survival of the plants. To protect water soldiers' populations in the short term, supplying endangered locations with external surface water to maintain water levels during periods of drought is an urgent need.

A further important measure is improving light conditions. The removal of single trees overhanging the shoreline and water surface could allow water soldiers to receive more light. This measure, however, needs to be evaluated in regards to conservation targets to avoid unwanted habitat disturbances. Furthermore, the increasing thicknesses of the soil, hydro-chemical aging of the water bodies, and associated eutrophication can likewise significantly alter the living conditions in the examined habitats.

Conclusion

Loss of habitat, changes in water chemistry and the immediate destruction of individual plants and entire populations (Schratt-Ehrendorfer, 1999) have caused water soldiers to become endangered in Austria (Niklfeld & Shratt-Ehrendorfer, 1999; Fischer et al., 2008). The important role of wildlife conservation areas is exemplified by the case of this species. However, without clear goals and strict measures for wildlife preservation, macrophytes like water soldiers face the risk of extinction. Therefore, we propose recording the water soldier as a threatened species in eastern Austria and including the species in future conservation management activities.

The majority of selective local protection measures are cost-intensive and not viable in the long term. It is, therefore, all the more important to ensure the reconnection of dissociated riparian water networks, thereby allowing natural dynamics to contribute to wildlife conservation. River restoration is an important element of such processes and measures to revitalize riparian backwaters are necessary for preserving them as habitats in the mid and long term. The entire extent of the Danube backwater network likely cannot be comprehensively restored to its original state, but small-scale and large-scale projects like the river bed stabilization efforts along the Danube (Nationalpark Donau-Auen GmbH, 2015) can contribute significantly to preserving riparian landscapes and their waterbodies.

The aquatic macrophyte *Stratiotes aloides*, commonly known as the water soldier, is an excellent indicator for the assessment of the situation of species in riparian areas. The development of water soldiers' populations is affected not only by the degradation of its habitats in the vicinity of and affected by rivers on a larger temporal and spatial scale, but also by more immediate small-scale interferences. It is therefore a key species to illustrate the many-facetted challenges of wildlife conservation in riparian landscapes.

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