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Najas flexilis (Najadaceae or *Hydrocharitaceae),* a Natura 2000 species – new for Austria

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Zusammenfassung: ***Najas flexilis (Najadaceae* bzw. *Hydrocharitaceae),* eine FFH-Art – neu für Österreich**
Najas flexilis ist erstmals im Jahr 2002 im Millstätter See (Kärnten) nachgewiesen worden. Dies ist nicht nur der Erstfund dieser Art für Kärnten und ganz Österreich, sondern hat auch hinsichtlich eines europaweiten Artenschutzes Relevanz. *Najas flexilis (Najadaceae* oder *Hydrocharitaceae)* ist eine untergetauchte Makrophytenart von elodeider Wuchsform. Sie ist heimisch in Amerika und Europa mit submeridionaler bis nordisch-temperater Verbreitung. Während die Art in Nordamerika noch verbreitet angetroffen werden kann, ist sie in Europa vom Aussterben bedroht. Aus diesem Grunde steht *Najas flexilis* nach der Berner Konvention unter Schutz und ist auch in den Anhängen II und IV der FFH-Richtlinie als „Art von gemeinschaftlichem Interesse" gelistet. *Najas flexilis* wurde im Rahmen einer Makrophytenkartierung nach der Wasser-Rahmenrichtlinie entdeckt. Die Unterscheidungsmerkmale zu anderen Vertretern der *Najadaceae* werden erläutert und mit Fotos von Herbarmaterial verdeutlicht. Die ökologischen Ansprüche der Art werden vor dem Hintergrund der Charakteristika des Sees und der Verhältnisse an den Fundorten diskutiert.

Abstract: *Najas flexilis* was found in Lake Millstätter See – the first record for Carinthia and for Austria, which is also highly relevant for the Europe-wide species protection plan. *Najas flexilis (Najadaceae* or *Hydrocharitaceae)* is a submersed macrophyte of elodeid growth form. It is native to America and Europe and has a submeridional to nordic-temperate distribution. While the species is still frequently found in North America, it is in danger of extinction in Europe. For this reason *Najas flexilis* is listed in Appendix 1 of the Bern Convention and in the Annexes II and IV of the EU Habitats Directive. In 2002, *Najas flexilis* was discovered during an extended macrophyte-mapping campaign according to the Water Framework Directive. The differential characters to other *Najas*-species are explained and illustrated using photos of herbarium specimens. The ecological demands of *Najas flexilis* are discussed in relation to limnological features of Lake Millstätter See and the particular characteristics of the finding sites.

Key words: EC Habitats Directive; flora of Austria; flora of Central Europe; *Najas flexilis*

Introduction

Najas flexilis was found in a number of sites in Lake Millstätter See in central Carinthia in October 2002. *Najas flexilis (Najadaceae,* order *Najadales = Potamogetonales;* recently [e.g. Mabberley 2008] classified into *Hydrocharitaceae* within the order *Alismatales* s. lat.; see further down), the Slender Najad, is a submersed macrophyte species of elodeid growth form. It has a submeridional to nordic-temperate distribution in America and Europe (Casper & Krausch 1980). Whereas it is still frequently found in North America (Haynes 1979), *Najas flexilis* is only very rarely recorded in Europe

(Casper & Krausch 1980). The focus of distribution lies in NW Europe, especially Great Britain and Ireland (Hultén & Fries 1986, Preston & Hill 1997, Preston & al. 2002), being currently on the retreat (Wingfield & al. 2006). Besides this, there are some single records from Scandinavia and Poland (Fitter 1978, Rorslett 1991, Zalewska-Galosz 2001).

Najas flexilis was more wide-spread in the post-glacial period. The species showed up in the peri-Alpine lakes shortly after retreat of the glaciers, established itself during the Atlantic period, and disappeared during the subboreal period (Paul 1925, Bertsch 1931, Backmann 1948). In Switzerland, the species recently had a colline distribution with recorded findings at 355 and 396 m a.s.l. In the 1920s, *Najas flexilis* could still be found near Rüdlingen in the Old Rhine (near Zurich) as well as in Lake Constance Untersee near Ermatingen, Thurgau (Ris 2007). Its last Central European records came from Lake Constance Untersee near Reichenau (Lang 1973). However, as there were no positive records ever since (Schmieder 1998, Dienst 2006), the species is regarded as extinct in Germany (Jäger & Werner 2005: 779). In Austria, *Najas flexilis* was known only as a fossil, as early as in the first half of the 20th century (Gams 1936, 1947). Therefore, it is not mentioned in the Excursion Flora of Austria (Fischer & al. 2008).

Materials and Methods

Najas flexilis was found during an investigation of Lake Millstätter See according to the European Water Framework Directive (Directive, 2000) by order of the Carinthian Institute of Lake Research and the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Pall & al. 2003a, Pall 2008a). The mapping method applied was especially developed for investigations according to the WFD and is described in detail in Pall & Moser (2006, 2009). This method, basically following Jäger & al. (2002, 2004) combines a dGPS[1]-supported echo-sounding of the complete littoral area (Dumfarth & Pall 2004) with macrophyte mapping via scuba-diving along selected transects (Pall 1996).

Herbarium specimens can be found in the herbarium of the author, Systema GmbH, duplicates are going to be deposited in KL and WU.

In October 2002 a total number of 30 transects were mapped by scuba-diving in Lake Millstätter See (Pall & al. 2003a). These transects were 25 m wide and reached from the long term mean water level to the lower limit of vegetation. Within these transects the species composition and abundance as well as additional relevant parameter, as e.g. sediment quality, slope, degree of shading, were investigated according to Pall (1996, 1999).

1 A global positioning system with a differential signal. By including a correctional signal from a reference station with an accurate position, mistakes of the GPS-signals can be corrected. This increases considerably the accuracy of defining the position.

Characteristic features of Lake Millstätter See

Lake Millstätter See is situated in the Central Alps in 588 m a.s.l. With an area of 13 km² it is the second largest lake of Carinthia. Due to its great depth of 141 m (average depth: 89 m) it is also the deepest lake in the federal state and has the largest water volume. The facts that this lake is relatively deep compared to its surface and that it is sheltered from wind contribute to its meromictic status (SAMPL & al. 1982).

The mountainous catchment area of 285 km² is mainly forested or used as grassland. However, the northern shoreline has some important tourist centres. Due to the increasing tourism in the 1960s, the lake was more and more polluted by domestic sewage water resulting into severe eutrophication (SAMPL 1974). At the beginning of the 1970s massive algal blooms caused temporal phases of reduced Secchi-depth with minima of 2.3 m. The total phosphorus concentration in the epilimnion was at times more than 30 µg/l. In addition, the lake was polluted by highly alkaline industrial sewages from a magnesite factory.

As early as in the late 1960s local authorities started to build a ring sewer and stopped the impact by industrial sewages. Consequently, water quality improved quickly. In 1980, the Secchi-depth had risen again to 10 m, and the total phosphorus concentration in the epilimnion reached an average of 12 µg/l. In the year of our mapping (2002) the average Secchi-depth was 6.6 m (max. 9.7 m) and the total phosphorus concentration varied between 7 and 12 µg/l. The lake could be classified as oligo-mesotrophic (SCHULZ & al. 2003). Currently the lake can be classified as oligotrophic again, according to SCHULZ & al. (2009) which applies at least for the centre of the water body.

Lake Millstätter See differs clearly from most other Austrian lakes in respect to chemical-physical conditions, due to its location in the silicious region of the Central Alps. Most characteristic features are the comparatively low values of pH, conductivity, acid binding capacity, low calcium content as well as low carbonate hardness and total hardness (Table 1).

The macrophyte vegetation of Lake Millstätter See differs considerably from most

Table 1: Selected parameters for characterizing the water of Lake Millstätter See, from SCHULZ & al. (2005). — **Tab. 1:** Ausgewählte Parameter zur Kennzeichnung des Seewassers des Millstätter Sees (aus SCHULZ & al. 2005).

Parameter	Value from 1 m depth
pH	7.5
Conductivity [µS/cm]	161
Acid binding capacity [mmol/l]	1.7
Orthophosphate-P [µg/l]	2
Total Phosphorus [µg/l]	9
Nitrate-N [µg/l]	205
Ammonium-N [µg/l]	4
Chloride [mg/l]	1.9
Sulphate [mg/l]	9.8
Silicic acid [mg/l]	1.7
Calcium dissolved [mg/l]	17.7
Magnesium dissolved [mg/l]	8.7
Potassium dissolved [mg/l]	2.3
Sodium dissolved [mg/l]	2.7
Hydrocarbonate [mg/l]	107.7
Carbonate hardness [°dH]	4.76
Total hardness [°dH]	4.48

other Austrian lakes. Therefore, Lake Millstätter See and Lake Zeller See, both located in the Central Alps, constitute a separate lake type according to a macrophyte-based typology of Austrian lakes (Lakes of the Central Alps, Pall & al. 2005).

Results and Discussion

Description of the places and habitats where *Najas flexilis* was found

Najas flexilis was discovered in 5 out of a total number of 30 investigated transects in Lake Millstätter See (see Fig. 1). The records are mainly on the western part of the northern shore near Gritschach and Lechnerschaft (both in grid[2] 9147/3), but some also on the middle part of the southern shore close to Schlossvilla (9247/1) and north of Schlossegg (9247/2). The species was found in low abundance at all five stations, mostly at a water depth between 1.1 and 2.6 m (minimum 0.5 m and max. 3.5 m). The shore slope was mainly moderate. The sediment was sandy-silty or sandy-gritty with a thin detritus layer and mostly covered with fallen leaves. *Najas flexilis* was found in Lake Millstätter See

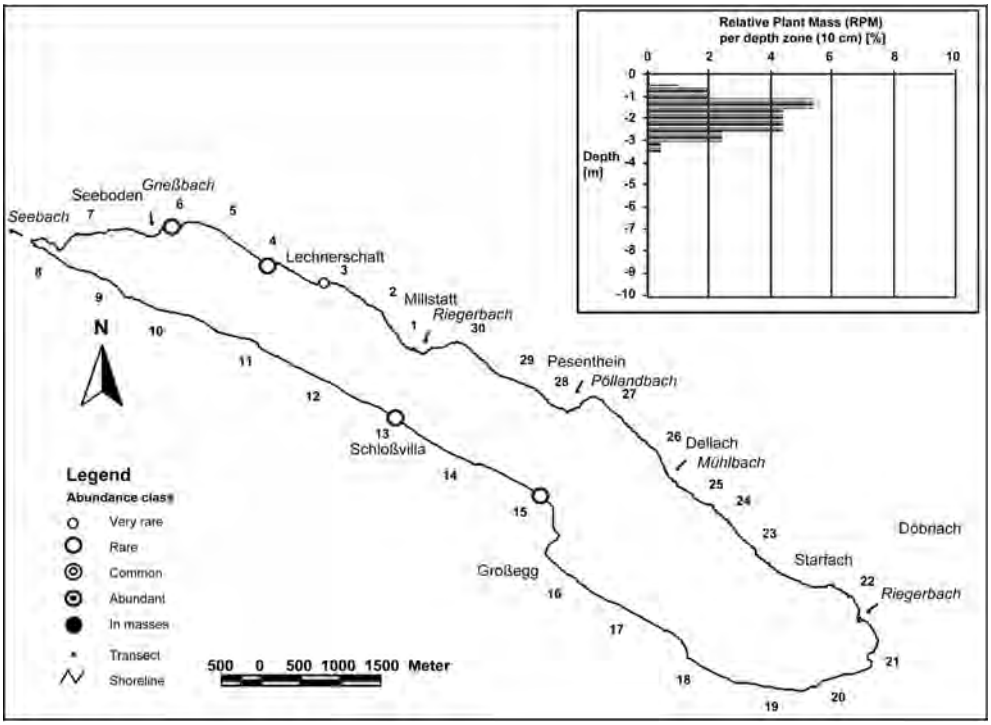

Fig. 1: Occurrence and depth distribution as RPM (Pall 1996) of *Najas flexilis* in Lake Millstätter See. — **Abb. 1:** Vorkommen und Tiefenverbreitung als RPM (Pall 1996) von *Najas flexilis* im Millstätter See.

2 Central European Floristic Mapping Scheme

at more or less pristine sites as well as in sections with artificially stabilized shoreline and/or local nutrient enrichment sections (from local discharges and tributaries). The Macrophyte-Index according to MELZER & al. (1986) can be used as measure for the nutrient enrichment of the single shoreline sections. It reaches on a five-level scale from 1 = slight to 5 = massive nutrient enrichment. In the places where *Najas flexilis* was found the Macrophyte-Index shows values from 2.4 (low nutrient enrichment) to 3.2 (considerable nutrient enrichment), corresponding approximately to oligo-mesotrophic to mesotrophic conditions (MELZER 1988).

Associated hydrophytes

(Taxonomy of *Spermatophyta* according to CASPER & KRAUSCH 1980, 1981 and of *Charophyta* according to KRAUSE 1997.)

In Lake Millstätter See *Najas flexilis* was mainly found in the transitional zone between the sparse pondweed *(Potamogeton)* belt and the vegetation of the shallow water. Apart from *Najas flexilis,* there were also *Myriophyllum spicatum* and, as a neophyte, *Elodea nuttallii* present at almost all sites. Furthermore, *Chara aspera, Ch. globularis, Myriophyllum alterniflorum* and *Potamogeton panormitanus* (= *P. pusillus* s. str.) were found in most places. Moreover, in one or at most two transects *Chara delicatula, Myriophyllum verticillatum, Potamogeton crispus, P. perfoliatus,* and *Zannichellia palustris* were found. Of all the species mentioned, especially *Myriophyllum alterniflorum* and *Chara delicatula* are known for a preference for waters with low conductivity and pH. The same applies *to Littorella uniflora*, which was also found in Lake Millstätter See (PALL 2003a).

Only *Myriophyllum spicatum* and *Chara aspera* reached a higher abundance (abundance class "common" to "abundant"). *Chara delicatula, Elodea nuttallii, Potamogeton perfoliatus,* and *P. panormitanus (P. pusillus)* were still "rare to common" in the sites mentioned. The abundances of the remaining species were assessed as "rare" and "very rare" only.

Description of the species

Najas flexilis (Willdenow), Rostkovius & W. L. E. Schmidt 1824, first described as *Caulinia flexilis* from Pennsylvania, U.S.A., is a rooted, submerged macrophyte of elodeid (elodea-like) growth form (DEN HARTOG & SEGAL 1964). The slender, flexible stem (the species epithet is appropriate, as the stem of all other *Najas* species found in Austria is stiff or even fragile) appears filiform, less than 1 mm thick and multiply branched, reaching a length of up to 30 cm (CASPER & KRAUSCH 1980). The plants found in Lake Millstätter See in contrast only reached a length of 10 to 15 cm (Fig. 2). Their leaves are narrowly linear, about 1 cm long (CASPER & KRAUSCH 1980 report leaves of 1 to 2 cm length), less than 1 mm wide, acuminate, and flexible. Their margins carry numerous (20–30) yellow-brownish prickly teeth, which arise from an expansion between two green leaf-cells, consist of only one 0.05–0.10 mm long terminal cell, and are directed to the leaf apex. The lamina base gradually merges into the

Fig. 2: *Najas flexilis* from Lake Millstätter See (Herbarium Systema Company). — **Abb. 2:** *Najas flexilis* aus dem Millstätter See. (Herbar der Fa. Systema GmbH).

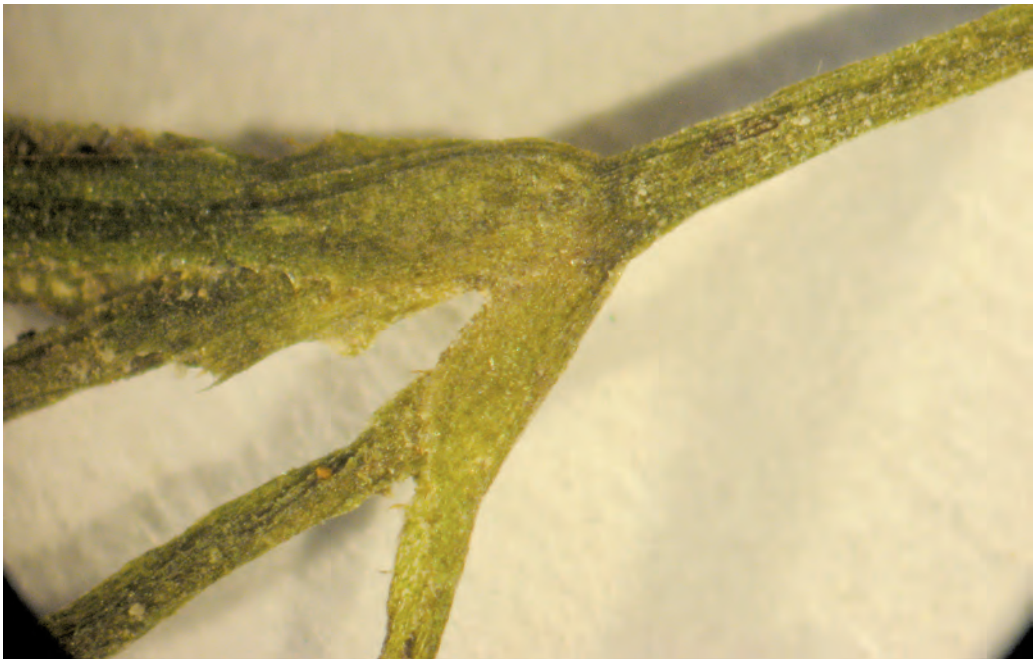

Fig. 3: *Najas flexilis* from Lake Millstätter See, leaf sheath (Herbarium Systema Company). — **Abb. 3:** *Najas flexilis* aus dem Millstätter See, Blattscheide (Herbar Fa. Systema).

leaf sheath that has the double width of the lamina (Fig. 3). Each of the sheath shoulders carries 6 to 12 thin prickly teeth.

The plant is monoecious and hydrogamous, pollination takes place in the water (underwater pollination). The stamina have only one anther, and the style has quadruple apiculate stigmas (CASPER & KRAUSCH 1980). Flowering and fruiting period is from June to August. Due to the mapping late in the season (October), the examples from Lake Millstätter See had no flowers, but seeds. The seeds are about 2 mm long and 0.6 to 0.7 mm wide (Fig. 4). The testa is glossy yellow-brown to dark brown and smooth. It shows the pattern typical for *Najas flexilis* of regular, 4–6-angled areoles (proportion length : width = 2–3 : 1), arranged in 30 to 40 longitudinal rows (TRIEST 1988). CASPER & KRAUSCH (1980) mention a seed length of 2.0–3.5 mm and a width of up to 1 mm, their length corresponding to three times the width in each case.

The plants in Lake Millstätter See grew in a loosely outspread way, were almost completely buried in the soft and sandy mud, so that only their shoot tips could be seen. This corresponds to the general habit of the species (CASPER & KRAUSCH 1980). According to ELLENBERG (1996), *Najas flexilis* appears mostly in groups and can, fol-

Fig. 4: *Najas flexilis* from Lake Millstätter See, seed (Herbarium Systema Company). — **Abb. 4:** *Najas flexilis* aus dem Millstätter See, Same (Herbar Fa. Systema).

lowing Casper & Krausch (1980), even build dense submerged meadows. However, in Lake Millstätter See only single specimens or at most single plant stands could be found.

Comparison with other *Najas* species

The genus *Najas* – the only one of the family of *Najadaceae* in the traditional system, formerly classified among *Najadales = Potamogetonales*, but currently (Stevens 2001) regarded as more closely related to the *Hydrocharitaceae (Alismatales)* and thus included in this family within *Hydrilloideae* – consists of 39 species according to Cook (1996), 40 according to Mabberley (2008). Casper & Krausch (1980) describe six species from (Central) Europe. For two of them, *Najas marina (subsp. marina* and *subsp. intermedia)* and *Najas minor*, numerous records from Central Europe exist (Casper & Krausch 1980) as well as from Austria (details see below). *Najas flexilis* was last confirmed for Lake Constance in 1973 (Lang 1973).

Due to its very delicate appearance with flabby, spineless stems and flexible leaves with inconspicuous teeth, *Najas flexilis* can easily be distinguished from *Najas marina (subsp. marina* and *subsp. intermedia).* Both subspecies of the latter species are developed as mostly big, strong plants being stiff and fragile. Stems and leaves are conspicuously denticulate, the teeth being longer than the width of the lamina, spreading almost horizontally. Their colour is dark-brown and they rise from a multi-cellular, green basis prominently protruding from the leaf margin.

In this context it seems necessary to remark that the two subspecies of *Najas marina* can be distinguished from each other very well. The morphological differences and, above all, the different habitat demands of the two taxa would, in my opinion, justify their status as autonomous species. In this case, a revision of taxonomy seems appropriate. In fact, these two taxa have been found to live in different ecological niches as was already shown by Lang (1973) who distinguishes two associations in Lake Constance: Najadetum marinae and Najadetum intermediae (compare Najadetum marinae in Casper & Krausch 1980 and Schratt 1993: 67).

The small and delicate *Najas minor* is also distinctly stiffer and more fragile than *Najas flexilis*. In contrast to those of *Najas flexilis*, the leaves of *Najas minor* are recurved. The teeth are horizontally protruding to slightly bent forward and their basis, consisting of three green cells, emerges distinctly from the leave margin. There is also a clear difference in the transition from lamina to leaf sheath: being gradual in *Najas flexilis* (Fig. 3), it is almost rectangular in *Najas minor.*

Najas tenuissima has also a rather delicate appearance. However, this species is endemic to SE Finland (South Karelia) and NW Russia (Waldai and Ilmensee region) (Casper & Krausch 1980). This taxon is supposed to be a relict from the Tertiary (Kolesnikova 1965, Meusel & al. 1965). The restricted distribution makes it very unlikely that this species could occur in Austria. *Najas tenuissima* is easily to be distinguished from *Najas flexilis* by its prickly teeth: the leaves of *Najas tenuissima* have only 8 teeth on both sides and in contrast to *Najas flexilis* the leaf apex has 2 teeth. The leaf

base provides us with another distinctive character as the lamina passes over rather suddenly into a broad-shouldered, irregularly, and roughly denticulate sheath.

Najas japonica is native to East Asia and appears as paddy-field weed. It was discovered in Northern Italy in 1952 and is currently found there in large amounts (Casper & Krausch 1980). It is very unlikely to appear in Austria. A safe distinction from *Najas flexilis* can be made regarding the leaf sheaths which are auriculate in *Najas japonica*.

Najas graminea is very similar to *Najas flexilis* concerning its habit. This species is wide-spread in tropical and subtropical regions and has already been found on North Italian paddy-fields (Casper & Krausch 1980). It is also very unlikely to appear in Austria. In contrast to *Najas flexilis,* the leaves of *Najas graminea* are often densely tufted on short lateral shoots, grooved at the leaf basis and slightly carinate at the reverse side. The clearest distinctive feature, however, is again the shape of the leaf sheath. Here, the thorny auricles appear even more distinctively than in *Najas japonica*.

Professor Dr. Luise Schratt-Ehrendorfer from the Department of Biogeography of the University of Vienna was so kind as to check the correctness of my determinations and to confirm them. In order to certify the classification results, a comparison of my specimens with material of *Najas flexilis* in the herbarium WU was carried out.

Ecological demands of *Najas flexilis*

We have only little and even partly contradicting information about the ecological demands of this species.

Najas flexilis is an annual which reproduces exclusively by means of seeds. It has not been reported to possess any method of vegetative reproduction (Hutchinson 1975). The necessary phosphorus for the plant is gathered primarily from the sediment (Carignan & Kalff 1980, Moeller & al. 1988). Dissolved carbon dioxide is the only carbon source for photosynthesis and, since bicarbonate is not used (Hough & Wetzel 1978, Hough & Fornwall 1988), there are no chalk deposits in the plant which, probably therefore, is not fragile, but flexible instead.

According to Casper & Krausch (1980) *Najas flexilis* occurs in stagnant water, especially in quiet bays. The species is mostly present in shallow water (0.2–2.0 m), it only rarely reaches a depth of 6.0 m. Pip & Simmons (1986), however, reported occurrences in up to 14.0 m depth. In Lake Millstätter See the species grew preferably in 1.1 to 2.6 m depth, which confirms observations by Casper & Krausch (1980).

In Lake Millstätter See *Najas flexilis* grew in sandy-silty sediment. A preference for such substrates was also stated by other authors (compare, e.g., Weyer 2005).

Wetzel & McGregor (1968) described *Najas flexilis* as specialist for soft-water lakes prefering Ca-concentrations of 10–15 mg/l and mesotrophic conditions (compare also Preston & Croft 1997, Murphy 2002). Furthermore, the authors indicated that only a maximum of mesotrophic conditions is tolerated. However, according to Samuelsson (1934), *Najas flexilis* can also appear in eutrophic waters.

Casper & Krausch (1980) again mention mesotrophic water bodies as places of growth. Investigations by Wingfield & al. (2006) also resulted in the fact that *Najas*

flexilis has its best condition in mesotrophic water bodies. Under more oligotrophic conditions (together with pH < 7) they observed a drastic reduction of the number of reproductive structures. Some plants only produced single seeds, a fact which is fatal for annual plants like *Najas flexilis*. Titus & Hoover (1993) also noticed a decline in reproduction in water with low pH-values.

Under more eutrophic conditions combined with a pH > 8, the plants developed longer internodes in spite of a constant growth-height. On the one hand this reduces the number of reproductive structures, on the other hand the photosynthetic activity is reduced due to a decrease of the total leaf-surface. Wingfield & al. (2006) regard changes of trophic status in both directions as a possible reason for the breakdown of *Najas flexilis* populations.

One can deduce from the forecast models of Wingfield & al. (2006) about the "fitness" of *Najas flexilis* under different habitat-parameter that acidification and eutrophication are the main threats to *Najas flexilis* in Scotland and Ireland. The concentration of phosphate in the water body and in the sediment as well as the concentration of calcium and the alkalinity turned out as main factors. Wingfield & al. (2006) postulated that under too oligotrophic conditions (combined with low pH-values) it is only the reproduction of the plants that is affected, but not their photosynthetic activity. However, a considerable reduction of the photosynthetic activity of *Najas flexilis* is attributed to eutrophic conditions.

On the one hand pH, alkalinity, and calcium concentration of a lake are defined by the conditions in the catchment area; on the other hand they also closely depend on the primary production in the water. The pH may rise considerably when there is a high rate of photosynthesis of plankton algae or macrophytes, mainly in calcium-poor, low-buffered waters. With higher pH-values carbon is practically only present as hydrocarbonate. However, *Najas flexilis* cannot make use of this kind of carbon-source (Hough & Wetzel 1978, Hough & Fornwall 1988) and therefore has a decisive disadvantage in competition.

Lake Millstätter See was to be classified as oligo-mesotrophic (Schulz & al. 2003) in the year of investigation. However, it is currently again being classified as oligotrophic by Schulz & al. (2009). Due to a previous phase of eutrophication of the lake, the nutrient concentrations in the sediment seem to be slightly higher than the current corresponding conditions in the pelagial. Since *Najas flexilis* draws phosphor mainly from the sediment (Carignan & Kalff 1980), there should neither currently nor in the near future arise any "nutritive problem" for *Najas flexilis* in Lake Millstätter See.

Although Lake Millstätter See is located in the silicious region of the Central Alps, the buffering capacity of the lake is regarded as high enough to buffer eventual acidification through atmospheric deposition (Wolfram & Donabaum 2009). The increase of pH up to 9.8 (1970) as the result of a previous discharge of wastewater from the magnesite factory had no negative impact on the production of algae (Sampl 1974). After stopping this contamination the lake levelled off very fast on to – for this lake type – expected pH-values (Schulz & al. 2005). Under these circumstances there should

currently be enough free, dissolved CO_2 in the water. This assumption is proven by the presence of *Myriophyllum verticillatum*, one more obligatory carbon dioxide user (Casper & Krausch 1981, Tracy & al. 2003).

Differences in ecological demands to other *Najas* species

With its preference for oligo-mesotrophic waters, in terms of trophic condition *Najas flexilis* has similar demands as *Najas marina subsp. intermedia*. However, occurrences of *Najas flexilis* are restricted to places that are deficient in lime, whereas *Najas marina subsp. intermedia* populates rather calcium-rich waterbodies. The two other taxa recorded for Austria, *Najas marina subsp. marina* and *Najas minor,* are restricted to higher nutrient levels. According to own experiences, they are met under meso- to eutrophic or eutrophic conditions mainly (see also Casper & Krausch 1980 and Oberdorfer 2001; Floras such as, e.g., Jäger & Werner 2005 and Fischer & al. 2008 probably also follow these sources). However, relatively high water temperatures are essential for their occurrence. A high annual fluctuation of abundance dependent on temperature can be confirmed through personal observations.

Further *Najas* occurrences, especially in Carinthia

There are no further representatives of the genus *Najas* in Lake Millstätter See other than *Najas flexilis*. Other species of *Najas* are widespread in Carinthia, in particular in the "Lakes of the Inneralpine Basins" (Pall & al. 2003b). Especially, *Najas marina subsp. intermedia* belongs to the distinctive inventory of this lake type (Pall & al. 2005). This subspecies has been found so far in Lake Faaker See (Pall & al. 2004), in Lake Keutschacher See and in Lake Längsee (Pall & al. 2003b), in Lake Ossiacher See (Pall & al. 2009) and in Lake Wörthersee (Pall 2008b). In the latter two lakes it is even the dominant macrophyte species (Pall 2008b, Pall & al. 2009). The occurrence of this species in Lake Längsee probably is neophytic according to Schratt-Ehrendorfer (pers. comm.), as it was missing in the northern bay until the late 1970s (see also Schratt 1993: 67). Beside *Najas marina subsp. intermedia* there is mostly also *Najas marina subsp. marina* in small to very small amounts. *Najas minor* we could find in Carinthia only in Lake Wörthersee up to now (Pall 2008b). Further occurrences are indicated in the Carinthian Distribution Atlas of Ferns and Flowering Plants (Hartl & al. 1992).

Najas marina subsp. intermedia is also the formative taxon in the Lakes of the Northern Peralpine Region (Pall & al. 2005). In contrast to that, *Najas marina subsp. marina* only rarely occurs here. In this lake type *Najas minor* has only been found in Lake Grabensee so far (Pall 2009).

Further Austrian lakes with occurrences of *Najas* are Lake Neusiedler See and Lake Constance (not to mention occurences in several rivers). Single specimens of *Najas marina subsp. marina* and *subsp. intermedia* have recently been found in Lake Mondsee and for the first time also specimens of *Najas marina subsp. intermedia* in Lake Attersee in 2009. While in the first-mentioned lakes representatives of the genus *Najas* can

be included in the type-specific species spectrum, the occurrence of *Najas* in the two last-mentioned lakes has been unknown so far and is not to be expected. This phenomenon of expansion of the species into "Lakes of the Lower Calcareous Alps" situated in higher altitudes and therefore colder (Pall & al. 2005) can possibly be interpreted as a result of global warming. A similar behaviour of *Najas marina subsp. intermedia* has been reported from Bavaria and is there also regarded as having a possible connection with global warming (A. Melzer, pers. comm.).

Is *Najas flexilis* indigenous in Lake Millstätter See?

The earliest and most accurate description of the macrophyte vegetation of Lake Millstätter See can be found in Haempel (1923). In this study, neither *Najas flexilis* nor any other *Najas* species is mentioned. Due to its rare occurrence and its distinctive growth-form of delicate shoots, almost completely hidden in silt, *Najas flexilis* might very easily have been overlooked. This can be assumed to have happened as a result of the mapping methods of that time (inspection by boat!).

Probably due to the fact that *Najas flexilis* was hard to find, even by means of scuba-diving, no occurrences in Lake Millstätter See have been reported so far. As, on the one hand, *Najas flexilis* was known from Germany and Switzerland until the last century and there is at least fossil evidence for Austria and, on the other hand, the conditions in Lake Millstätter See match the demands of the species, it is very well possible to imagine that *Najas flexilis* has always existed in Lake Millstätter See. Thus, a recent immigration of this – in Europe – poor competitor in the recent past, does not seem likely.

Nature protection

Najas flexilis is cited in the Red List of Germany and Switzerland as "extinct" (Korneck & al. 1996, Käsermann & Moser 2002). It is "in danger of extinction" in Europe and therefore protected according to the Bern Convention (Council of Europe 1979). It is also listed in the Annexes II and IV of the Habitats Directive (EWG 1992).

In the Carinthian law gazette (2007) *Najas flexilis* is listed as a "completely protected, non-native species" (Federal State Carinthia (ed.), Klagenfurt, 2007: 9. Ordinance: Plant Protection Act). The evaluation of the species as "non-native" should be corrected as soon as possible.

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