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Isoëtes echinospora and *I. lacustris* in the Bohemian Forest lakes in comparison with other european sites

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Abstract
The first discovery of quillwort (*Isoëtes lacustris*) in the Bohemian Forest lakes was in Černé Lake in 1816 by I. F. TAUSCH (1819). *I. echinospora* was discovered in Plešné Lake in 1892 by ČELAKOVSKÝ fil. (1894). Afterwards (until 1890) only FRIČ & VÁVRA (1898) reported on the distribution of both quillworts on the lake bottoms. They mapped colonies of *I. lacustris* in Černé Lake. Thanks to the diving colleagues M. VÖGE, C. WEILNER & al. and M. BÖHM in 1990–1999 we now know that *I. lacustris* stands have lost one of three colonies reported by FRIČ & VÁVRA (1898). Now, we estimate that about 2–3 thousand individual rosettes of *I. lacustris* occur there between 2.2 and 4.7 m water depth. In Plešné Lake, we estimate there are one larger and about 10 small colonies of *I. echinospora* each comprising about 1 200 – 2 000 individual rosettes, at 0.75 to 2.0 m water depth. In both lakes, the water chemistry was assessed by hydrobiologists such as FRIČ & VÁVRA (1898), JÍROVEC & JÍROVCOVÁ (1937) and others, see VESELÝ (1994). For the first time, the bottom soil from the rhizosphere of both species was sampled and analysed thanks to the divers mentioned above. As to the biology of both species in the lakes, there are much less informations available. In the last 15 years, M. VÖGE, studied the numbers of leaves per rosette and fertility characters of *Isoëtes lacustris* in different European lakes (VÖGE 1989, 1997a,b). In 1997, hundreds of *I. echinospora* were destroyed during filming of the fairy tale "The Queen Lake" in Plešné Lake. In the near future, we would like to study especially the sexual reproduction of both species and make analysis of their growth in relation to water and soil conditions.

Key words: Isoëtes, quillwort, water and soil chemical analyses, plant biometry and biology, lakes, Šumava NP/BR.

Introduction

Isoëtes is an evergreen perennial pteridophyte. The corm supports spirally arranged leaves surrounding the central shoot apex. Microsporangia and macrosporangia are produced by mature plants on the adaxial surfaces of the leaf bases. Old leaves become displaced towards the periphery of the corm by new leaves, which are produced by the apical meristem (KOTT & BRITTON 1983). The number of leaves per rosette and the composition of the rosette remain much the same in the mature plants, during their life span (RÖRSLETT & BRETTUM 1989, MÄKIRINTA & al. 1997).

Results

Development of knowledge about the presence of quillworts in South Bohemian lakes, as well as their quantity and water depth, is presented in Tables 1, 2 and 3 and Fig. 1. Before

Table 1. – Basic data on Černé and Plešné Lakes (from VESELÝ 1994).

	Černé Lake	Plešné Lake
Altitude (m)	1008	1090
Latidude	49°11'N	48°47'N
Longitude	13°11'E	13°52'E
Area (ha)	18.4	7.5
Maximum depth (m)	40	18
Water content (10^6 m^3)	2.88	0.62
Average bottom slope	13°18'	11°45'
Catchment area (km^2)	1.29	0.67

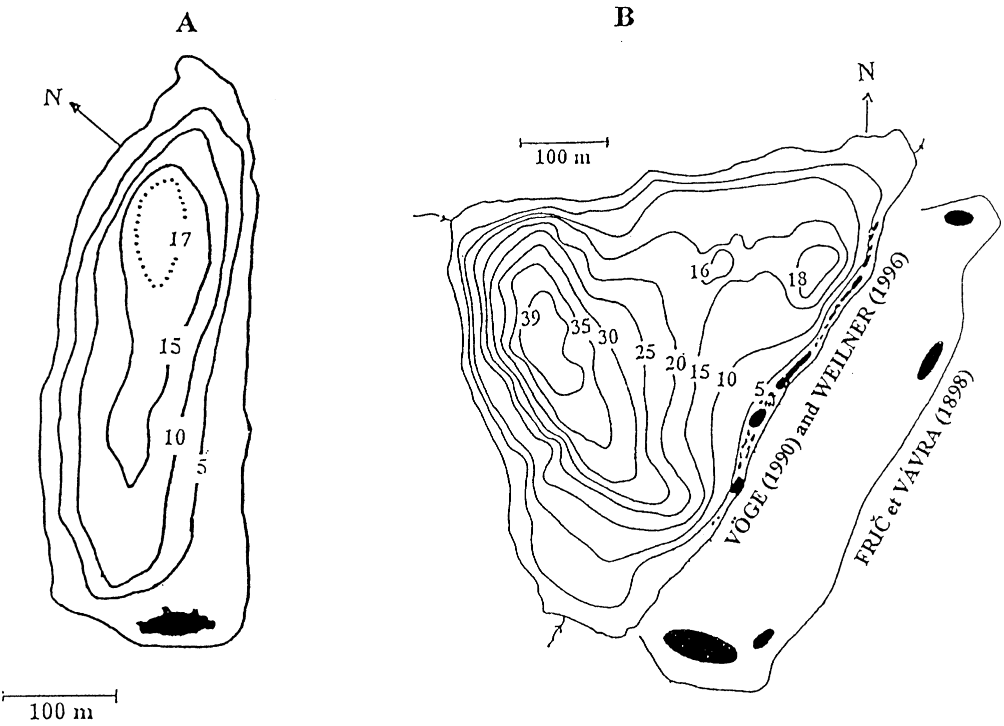

Fig. 1. – Stands of Isoëtes echinospora in Plešné Lake (A), which have more or less permanently occupied the same space (HIRSCH 1958, BLAŽKOVÁ 1969, HUSÁK & VÖGE 1990, WEILNER & al. 1996) and of Isoëtes lacustris in Černé Lake (B) according to the mapping by FRIČ & VÁVRA (1898). Crosses denote records of I. lacustris by VÖGE (1990), the spreading of the stands between the 0 and 5m contour lines was recorded by WEILNER & al. (1996).

Table 2. – Water depth (m) and estimated numbers of *I. echinospora* plants in Plešné Lake.

Date(s)	Water depth			Estimated amounts of plants	Reference
	minimum	maximum	mean		
1937–1945	-	-	≤ to 1.50	„sufficiently"	HIRSCH 1959
5.10.1947	-	-	-	„numerous colony"	MORAVEC 1963
13.9.1969	0.30 *	0.70	0.50	tract ca 10 x 0.5 m	BLAŽKOVÁ 1969
1977	0.50	2.00	1.25	-	TOMŠOVIC 1979
24.10.1990	0.50	1.10	0.70	a few colonies of 100% cover	HUSÁK & VÖGE 1996
18.9.1996	0.50	2.00	0.70	ca 3–5 thousands in ca 10 colonies	GUTZEROVÁ 1996, WEILNER & al. 1996, LUKAVSKÝ & al. 1997
3.8.1998	0.50	1.00–2.00	0.75	ca 1–2 thousands	PROCHÁZKA 2000

* emerged part of stand

Table 3. – Water depth (m) and estimated numbers of *I. lacustris* plants in Černé Lake.

Date(s)	Water depth			Estimated amounts of plants	Reference
	minimum	maximum	mean		
24.9.1816	(ca 1m) [a]	ca 3.5–4 m	-	-	TAUSCH 1819
16.8.1885	[b]	> 3.0	2.0–3.0	„numerous"	ČELAKOVSKÝ 1894, 1887
1898	[a]	1.95	0.80	4 „quillwort meadows"	FRIČ & VÁVRA 1898
	-	-	ca 3.5	„very numerous"	TOMŠOVIC 1979
1990	1.8	3.3	-	in the East part of lake	HUSÁK & VÖGE 1990, VÖGE 1997a
17.9.1996	2.2	4.7	ca 3.5	ca 2–3 thousand in 23 colonies	GUTZEROVÁ 1996, WEILNER & al. 1996, LUKAVSKÝ & al. 1997

[a] abnormal by low water level, [b] parts of stands emerged for 2–3 months

the diving of M. VÖGE, C. WEILNER (and his group) and M. BÖHM, the exact distribution of quillworts, was not known: how numerous they are and how deep they occur. All data were merely estimated (HIRSCH 1959, MORAVEC 1963, etc), see also Tables 2 and 3.

Chemical water analyses have been carried out for about one hundred years, since 1898 (see VESELÝ & al. 1994). Character of the main parameters has remained more or less the same in both lakes in the last years (see Table 4.) For the first time, the bottom soil from the rhizosphere of both quillwort species (see Table 5) has been analysed.

During field studies, which were performed on *Isoëtes lacustris* in more than 50 lakes throughout Europe, the mean number of leaves per rosette (an important morphological character) and the mean number of spores per macrosporangium (characterising the fertility) have been determined (VÖGE 1997a,b). Maximum values (about 40 leaves and 110 macrospores) were found in clearwater lakes with about 10 m Secchi depth and a pH between 6 and 7.

Within the sample, which was taken in Černé Lake in 1990, the number of leaves per individual was 23 and 63 spores per macrosporangium were counted. These data reflected some-

Table 4. – Chemical analyses of lake water of Plešné and Černé Lakes.

Lake	Sampling date	pH	Conduct. µS.cm^{-1}	TA* meq.l^{-1}	NO_3-N mg.l^{-1}	NO_2-N mg.l^{-1}	NH_4-N mg.l^{-1}	PO_4-P mg.l^{-1}	Determined by
Plešné Lake	24.10.1990	4.70	36.8	0.02	-	-	-	-	M.Vöge
	20.4.1998	4.80	64.0	0.08	0.47	0.05	0.68	0.00	H. Strus-
	2.8.1998	5.44	40.0	0.14	0.27	0.00	0.33	0.02	ková
Černé Lake	24.10.1990	4.9	34.0	0.02	-	-	-	-	M.Vöge
	20.5.1991	4.95	33.3	-	1.08	1.00	0.09	-	A.Klaus et al.1992
	4.8.1998	5.05	27.0	0.08	0.95	0.00	0.29	0.00	H. Strusková

*TA = total alkalinity

Table 5. – Bottom soil chemical analyses of Plešné and Černé Lakes.

Lake	pH(H_2O)	pH(KCl)	C %	N %	PO_4-P	Ca^{2+}	Mg^{2+}	K^+
					mg.kg^{-1} d.w.			
Plešné Lake	4.4	4.0	16.26	0.96	13.46	62.00	19.90	116.25
Černé Lake	4,8	4,3	4.68	0.37	2.89	28.50	12.90	44.06

what sub-optimal growth conditions. It was supposed by the fact that the Secchi depth of 5 m and pH 5 (both in 1990) explained the low numbers. The field studies in European lakes have resulted in the discovery of several relationships between ecological and plant characteristics, (VÖGE submitted), e.g. of the regression between Secchi depth and number of leaves per rosette (a), and the relationship between pH and the number of spores per macrosporangium (b).

a) Number of leaves per rosette = 1.95 × (Secchi depth) + 10.80, $P < 0.01$. With the 5-m Secchi depth the number of leaves is 21 ($n = 23$).

b) The relationship is given in Fig. 2. The pH 5 corresponds to about 50 macrospores (measured: 63). Light availability and acid water appear to determine the plant characteristics in the lake. According to SZMEJA (1988a,b) *Isoëtes* can endure in waters anthropogenically or naturally acidified up to pH 4,5, which agrees with the information given in Fig. 2.

The development of filamentous algae (as observed in Černé Lake in 1990) or of mosses (as that found in Plešné Lake) was obvious, too, in some acidified lakes of South Norway. In lake Mjavatni the reduction of the mean number of leaves per individual from 49 (in 1976) via 28 (in 1987) to 25 (in 1995) was pursued, where an intense development of filamentous algae was observed first in 1982 (VÖGE 1989); they made up a layer on the ground up to 4 cm, in 1995 (VÖGE 1997a). In lake Fotlandsvatnet *Isoëtes* plants were in parts overgrown by mosses, in 1982. A dense layer, up to 40 cm high, covered the *Isoëtes* population completely in 1986. The leaves were unusually long (up to 29 cm), but without macrospores; only the upper third of the leaves contained chlorophyll (VÖGE 1989). *Sphagnum* mosses made up a layer up to a height of 60 cm, the quillwort was not found any more in 1995 (VÖGE 1997b).

The number of leaves per rosette and the number of spores per macrosporangium have been found to be connected. By counting the leaves of 30 fertile individuals whilst diving,

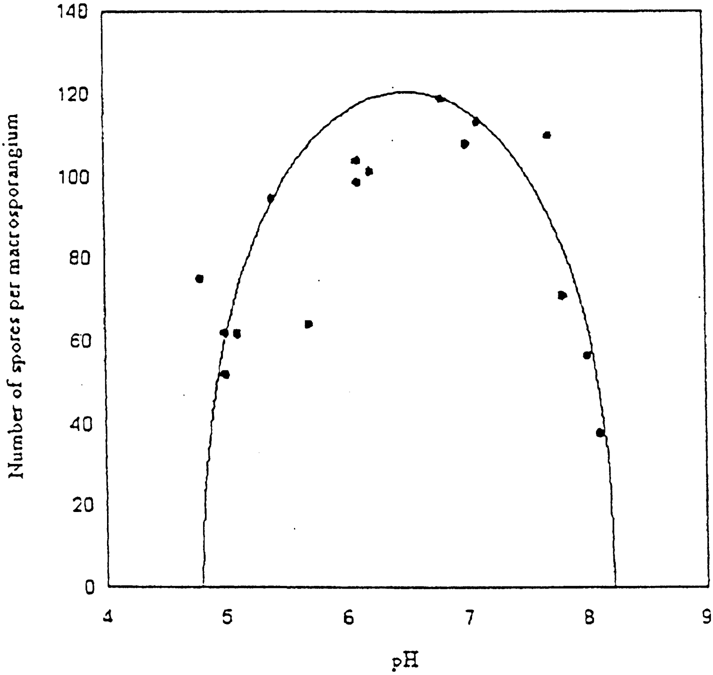

Fig. 2. – Water pH and number of spores per macrosporangium in *Isoëtes lacustris.*

without removing the plants, an evaluation of the number of macrospores per sporangium and per plant is possible, when the following two regressions are used:

c) Number of macrospores per macrosporangium = 2.48 × (number of leaves per rosette) + 12.78, P < 0,001.

d) Number of macrospores per plant = 29.95 × 1.08^(number of leaves per rosette), P < 0,001.

When the regressions are applied to the 1990 sample from Černé Lake, 70 spores per macrosporangium (measured: 63) and 170 macrospores per plant are calculated. Hence, by monitoring the number of leaves per rosette, the success of reproduction in *Isoëtes* in a particular lake may be evaluated. For a comparison: in 13 out of 47 lakes studied and inhabited by *Isoëtes lacustris*, the plants possess between 20 and 24 leaves, representing the largest group of lakes (< 10 leaves: 2 lakes, < 15 leaves: 8 lakes, < 20 leaves: 11 lakes, < 25 leaves: 13 lakes < 30 leaves: 7 lakes, < 40 leaves: 5 lakes, and > 40 leaves: 1 lake.

Additional information on the status of *Isoëtes* in a lake is obtained by studying the age-states within the population. A population, is usually, evaluated as being capable of survival, if most of the individuals pass through their life cycle. For characterising this cycle, four age-states were defined (Vöge, submitted). The maximum leaf length (6 cm in the 1990 sample) does not give information concerning the age of the plants, and it is not connected with any ecological or plant characteristics. The number of leaves per individual, again, is decisive. The age-states are defined as follows: 1) the early-juvenile state: plantlets with about 3 leaves, no rosette, 2) the late-juvenile state: infertile plants with less than ten leaves (means), the rosette is developing, 3) the fertile state: mature plants with more than ten leaves (means) per rosette, 4) the senile state: without freshly green leaves and sporophylls. (Because of the remarkable phenotypic plasticity in *Isoëtes* the calculation of mean values of the number of leaves is required). The presence of all age-states within a population can be studied whilst diving and may be combined with the monitoring of the number of leaves in fertile plants. We would like to perform these studies in the Bohemian lakes in near future.

Conclusions

The contribution provides information on water level fluctuations in both lakes, water and bottom soil chemistry, map of the distribution of both species in the two lakes and data on biometry and reproductive relations, especially in *Isoëtes lacustris*. There is an urgent need to know the growth and reproductive status of both *Isoëtes* species in a particular lake, by monitoring the number of leaves per rosette and the number of spores per macrosporangium, whilst diving. Additionally, both characters may be evaluated by means of highly significant regressions and a graphic expression, if the following actual environmental data are given: length of seasonal growth, water conductivity, pH and colour and the Secchi depth. Comparing the determined and the calculated *Isoëtes* characters, negative impacts on habitat and plants may be recognized. In case the necessary measures are used, the species, hopefully, may be preserved from becoming extinct.

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