

# **Isoëtes lacustris L. in Europe: Biometrical data and environment**

**Margrit Vöge (1999)**

The results of field studies which were performed in lakes of Northern and Western Europe have been published (Vöge 1997a, b). In 1997/ 98 further results were gained in Northern and Central Europe. Accounting for all data established throughout Europe, the regressions between biometrical data have been revised; further relationships between plant features and connections between habitat characteristics and plant features are presented here.

## **Morphology and fertility characteristics of Isoëtes lacustris and relationships**

The following biometrical data were determined on each thirty sporogenous plants per lake. In using SCUBA equipment, the plants were collected in the centre of the population in a depth of two meters, on average. Plants inhabiting shallow water were not taken into account, as they may experience very special growth conditions, e.g. ice-scour, wave action, an increased light availability or water temperature. Mean values were calculated for each lake.

- Number of leaves per rosette (n)
- Mean leaf length per rosette (a)
- Mean leaf width per rosette (b)
- Number of macrosporophylls per rosette (ma)
- Number of microsporophylls per plant (mi)
- Number of spores per macrosporangium (s)
- Mean cormus diameter (c)
- Mean total root length per plant (r)

Two plant characteristics were calculated from some of the above-mentioned data:

- 1) Rosette surface area =  $2 * n * a * b$
- 2) Number of spores per plant =  $ma * s$

It was recognized (by use of SPSS) that the number of leaves per plant is the most suitable variable for describing the status of the quillwort in a particular lake (Fig. 1). After the determination of the mean number of leaves per rosette, the following five regressions (all highly significant:  $P < 0.001$ ) allow the evaluation of five important plant characteristics:

- 1) Rosette surface area =  $10.43 * 1.09^n$  (cm<sup>2</sup>),  $r = 0.86$
- 2) Number of spores per plant =  $29.95 * 1.08^n$ ,  $r = 0.78$
- 3) Number of spores per macrosporangium =  $2.48 * n + 12.78$ ,  $r = 0.80$
- 4) Cormus diameter =  $0.59 * n + 4.03$  (mm),  $r = 0.82$
- 5) Total root length =  $0.29 * n - 1.37$  (m),  $r = 0.92$   
(r is the correlation coefficient)

The number of macrosporophylls is connected with the number of microsporophylls per plant:  
Number of macrosporophylls =  $1.6 * \text{number of microsporophylls} + 0.56$ ,  $r = 0.92$

All the regressions are valid for *Isoëtes lacustris* and *I. echinospora*. The height of rosette proved connected with the number of spores per macrosporangium. Thus the monitoring of the number of leaves per plant provides an indicator of the quillwort status. Using SCUBA equipment the counting is possible without removing plants. Two examples of calculation, using the five regressions are given in Tab. 1; the mean number of

leaves per rosette is supposed a)  $n = 35$  and b)  $n = 10$ . It is evident that a plant poor in leaves ( $n = 10$ ), is characterized by a disproportionately low rosette surface area, number of spores per plant and total root length, compared with plants rich in leaves ( $n = 35$ ). These three parameters are highly important for a continued existence of the species: A small rosette surface area is equivalent to decreased photosynthesis, the low production of macrospores per plant negatively affects reproduction, and less and shorter roots limit the uptake of indispensable carbon dioxide. It was observed that the continued existence of the quillwort was endangered, if the number of leaves per plant was lower than ten, e.g. in eutrophicated or acidified lakes in a temperate climate.

### **Isoëtes variability reflecting habitat conditions**

The lake-to-lake variability in *Isoëtes* is very well known, in Europe, USA, and Canada. It is supposed that climate, pH, water colour and Secchi depth may determine the *Isoëtes* growth, however, no publication concerning this was found. The most useful parameter characterizing the climate proved the period of seasonal growth: the number of months per year with a mean temperature of at least ten degrees Celsius. Water colour (given as number of Hazen) determines the light quality: A high humic content changes the spectral composition of daylight. Secchi depth is a measure for water transparency. A low Secchi depth is often caused by an increased plankton production in an eutrophicated lake. It was found that the shorter the growing season, the higher the Hazen number and the lower the Secchi depth (in meter), the smaller is the number of leaves per rosette.

The regressions established are presented here:

- I) Number of leaves per rosette ( $n$ ) =  $8.77 * \text{number of months (S } 10^{\circ} \text{ C)} - 11.59$ ,  $P < 0,001$
- II) Number of leaves per rosette ( $n$ ) =  $- 0.37 * \text{Hazen number} + 28.9$ ,  $P < 0,001$
- III) Number of leaves per rosette ( $n$ ) =  $1.95 * \text{m Secchi depth} + 10.8$ ,  $P < 0,01$

No connection was found between the pH and any plant characteristic. However, using the pH- values and the corresponding numbers of spores per macrosporangium, which were determined in lowland clear- water lakes in a temperate climate, a parable was obtained (Fig. 2). It is recognized, that the maximum number of macrospores per sporangium (122) was found in water of pH 6.6. In acidic water (pH 4.8) or alkaline water (pH 8.4) most plants were without macrospores. Szymeja (1997) established the ranges of pH values tolerated by *Isoëtes lacustris* in Polish lakes: it is pH 4.5 - 8.8, accounting for 109 lakes; however, in natural lakes, i.e. those without conspicuous signs of anthropopressure, the range is narrower: pH 5.5 - 8.2. Climate, light availability and pH appear to determine *Isoëtes* growth. A problem in field studies is: the interaction of several ecological factors cannot always be excluded; however, the results gained in laboratory, cannot be transferred directly to nature, as there is no interspecific competition. It has to be considered, that the adaptation of *Isoëtes* to unproductive habitats requires well developed mechanisms of the carbon dioxide uptake and enrichment; this adaptation is at the expense of productivity and, hence, competitiveness. The pH may not influence the development of the quillwort directly, more likely it indicates the ecological situation of the particular lake. A high pH and a low Secchi depth are frequently connected and signs of eutrophication, which allow the penetration of competitive species, and an intense plankton development, which decrease the light availability. A low pH may indicate an acidified lake, where *Isoëtes* is often overgrown by mosses; again, competition decides. In further acid lakes dense algal mats cover the plants and the bottom, which may affect the substance exchange between water column and sediment, in addition. The evaluation of the number of leaves per rosette or the number of spores per

macrosporangium by use of the regressions I - III is presented on five lakes (they do not belong to the 50 sites studied, on which the regressions have been gained); the results of calculation and counting are given for compare (Tab. 2). It is demonstrated that, according to the law of minimum, the minimum factor (climate, water colour, Secchi depth or pH) limits the plant growth:

The alpine lake Baciver in the Spanish Pyrenees, studied by Gacia & Ballesteros (1993, 1994) experiences 3 months of seasonal growth, which means a rather low number of leaves per rosette. In a temperate climate, the clear water of the lake would enable rosettes rich in leaves. Lowland lake Wollingster See (in a temperate climate) water colour and Secchi depth limit the number of leaves per rosette in 1986 and even more in 1998, when water colour had increased and Secchi depth decreased. The Danish lake Kvie Sø (in a temperate climate) is inhabited by *Isoëtes echinospora*, *I. lacustris* is not observed. Unfavourable values of water colour and Secchi depth explain the small rosettes.

In the Danish lake Almindsø (in a temperate climate) the vigorous growth of *Myriophyllum alterniflorum* and *Potamogeton perfoliatus* and high pH = 8 indicate some eutrophication. In spite of favourable Secchi depth and water colour the number of spores per macrosporangium is rather low, as was determined and evaluated by means of the parable (Fig. 2).

No spores were found in the Norwegian lake Fotlandsvatnet, though climate is temperate and the light availability should be sufficient. The low pH = 4.9 is in agreement with a number spores about zero. Mosses are growing vigorously and suppress the quillwort.

Threatened by extinction, conservational work is needed. Here, the knowledge of the obtained data and relationships can be useful.

It is pointed out that in an extreme environment, e.g. a (sub)arctic tundra, the rosettes may possess more leaves than would be expected according to regression I. In the arctic tundra the horizontal bottom is warmed up slightly by sun. Steep southern slopes, however, receive a much higher radiation density and the warming up is about the four- to fivefold compared with the horizontal bottom. In such favoured lakes, e.g. in Greenland, *Isoëtes* may experience a warmer micro-climate, in contrast to arctic macro-climate.

Finally, the relationship between the degree of latitude and the number of leaves per rosette is given, valid for European lowland lakes between 53 and 70 °N:

Number of leaves per rosette = - 1.55 \* degrees of latitude + 120.18,  $r = 0.82$  ( $P < 0.001$ )

Possibly, this regression will not be valid in the late future, due to global change...

## References

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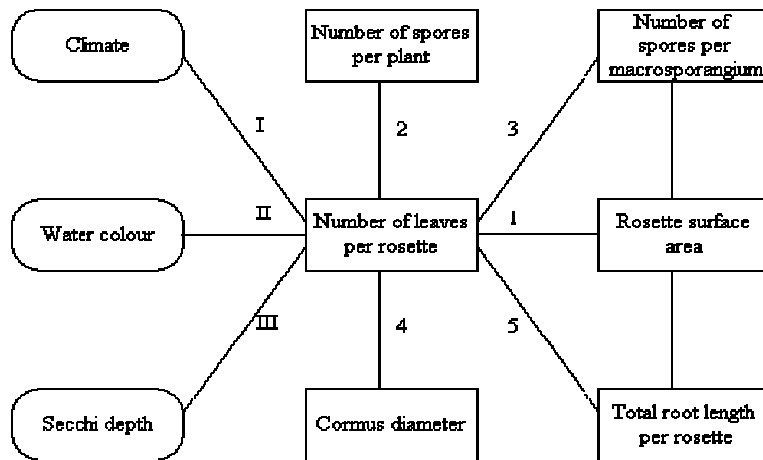
Table 1: Plant features calculated according to the regressions 1 - 5.

Mean number of leaves per rosette	Rosette surface area (cm <sup>2</sup> )	Number of spores per plant	Number of spores per macrosporangium	Cormus diameter (mm)	Total root length (m)
35	213	443	100	25	9.0
10	25	65	38	10	1.5

Table 2: Plant features calculated according to the regressions I, II, III, compared with the values determined

Name of the lake (Year of investigation)	The decisive habitat characteristics determined				<i>No. of leaves per rosette/ No. of spores per macrosporangium</i>	
	Climate (months)	Colour (Hazen)	Secchi depth (m)	pH	evaluated	determined
Lake Baciver (1993)	3				15 leaves (I)	14 leaves
Wollingster See (1986)		30	3.4		18, 17 leaves (II,III)	17 leaves
Wollingster See (1998)		55	1.3		10, 13 leaves (II,III)	11 leaves
Kvie Sjø (1998)		50	1.0		11, 13 leaves (II,III)	13 leaves
Almindsø (1996)				8.0	60 spores (parable)	57 spores
Fotlandsvatnet (1994)				4.9	0 spores (parable)	0 spores

**Fig. 1: Relationships between morphological and fertility characteristics and environmental features**



**Fig. 2: pH and number of spores per macrosporangium**

