

## New localities of *Diphasiastrum* species in the Krkonoše Mts and elsewhere in the Czech Republic where three or more species of this genus are recorded

Nové lokality plavuníků v Krkonoších a další místa s výskytem tří a více druhů rodu *Diphasiastrum* v České republice

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Ten localities, found mostly after 1990, with the occurrence of three or more species of the genus *Diphasiastrum* Holub have been investigated in detail in the Czech Republic. One of the localities is in the Krkonoše Mts and harbours all 6 Central European species of the genus.

**Key words:** *Diphasiastrum*, Czech Republic, phytogeography, distribution, ecology, threatened taxa

### Introduction

In 1998, all known localities harbouring three or more species of the genus *Diphasiastrum* were investigated in detail in the Czech Republic; special attention was paid to those recently found (Fig. 1). This research not only yielded completely new findings regarding the occurrence of some species (re-discovery of *D. oellgaardii* Stoor, Boudrie, Jérôme, Horn et Bennert in Czechia being particularly remarkable) but also makes it possible to draw more general conclusions important from the nature conservation perspective. All the five species of the investigated genus [*D. alpinum* (L.) Holub, *D. complanatum* (L.) Holub, *D. issleri* (Rouy) Holub, *D. tristachyum* (Pursh) Holub, *D. zeilleri* (Rouy) Holub] distinguished in the Czech Republic until recently are included in the list of plant species deserving special protection (see App. No. II, Regulation of the Ministry of Environment of the Czech Republic No. 395/1992). However, the newly distinguished *D. oellgaardii* must be also regarded as a species protected in the sense of the cited decree because in the time of preparation of the decree, it was considered as a part of the species *D. issleri* (cf. Procházka 1997).

### Krkonoše Mts (The Giant Mts)

Altogether five taxa of the genus *Diphasiastrum* Holub (at that time *Diphasium* C. Presl emend. Rothm.) were given in the Šourek's work on the flora of the Krkonoše Mts (Šourek

1970: 93–95): *D. alpinum* subsp. *alpinum*, *D. alpinum* subsp. *kablikianum*, *D. complanatum*, *D. issleri* and *D. tristachyum*.

Later, it was discovered that *D. alpinum* subsp. *kablikianum* is not an independent taxon but belongs to *D. issleri* where it represents one of the marginal types of variation (Holub 1975, Kubát 1988). Four *Diphasiastrum* species had been thus known from the Krkonoše Mts. Another one, i. e. *D. zeilleri* was added later; this taxon was not recognized at a higher taxonomical level in Šourek's time. This species, previously included mostly in the group of *D. complanatum* (less frequently also in that of *D. tristachyum*) was reported by K. Kubát on the basis of revision of older herbarium material from the Modrý důl valley and near the town Pec pod Sněžkou (cf. Kubát 1988: 198).

The first author of this paper has been studying flora of the Krkonoše Mts since the mid 1960s. Until 1998, i. e. during more than 30 years of research, he had seen in the wild only *D. alpinum* and *D. complanatum*; the former growing scattered in alpine and sub-alpine locations, the latter found only since the end of the 1960s to the second half of the 1970s above the Lyžařská bouda chalet on the Liščí hora Mt. Despite of very intensive floristic research carried out in the Krkonoše Mts during the given period, no other species of *Diphasiastrum* was recorded.

*D. issleri* was discovered in the Czech part of the Krkonoše Mts only recently. This species had never been observed there by Šourek, the author of the Flora of Krkonoše, who only referred to historical localities of various authors from 1873–1916 (cf. Šourek 1970: 94) because the post-war occurrence of the species on the Luční hora Mt was not known to him (leg. B. Válek, 1949, HR ut *D. alpinum*, rev. F. Procházka). Since then, this occurrence has not been confirmed by anybody else. Until recently, there was only one known existing site harbouring *D. issleri*. This was found by H. Štursová as late as in 1996 on a slope of the Kotel Mt under "Růženka's garden" on an unfinished bunker's basement from before the World War II overgrown by vegetation (Štursová 1998). The herbarium specimen located in the Regional museum in Vrchlabí was revised by J. Holub of the Institute of Botany Průhonice.

With respect to *D. tristachyum*, only old literary data (cf. Šourek 1970: 94) have been known from the Czech and Polish parts of the Krkonoše Mts until recently. From the Czech part, the species was reported only by Schustler (1918: 142–143): "The heathers under young spruce stands at the locality 'Sedmidomí novosvětské' are interesting. They are formed by whole stands of *Lycopodium clavatum*, in places accompanied by the rare *L. chamaecyparissus* [= *D. tristachyum*, remark by the authors] and by *L. complanatum*; *L. selago* dared to enter here into a young spruce stand." As far as it is known, there are no specimens from this locality in our herbaria (cf. Kubát in Štursová 1998) and an erroneous determination cannot be thus completely excluded. For this reason, occurrence of *D. tristachyum* in the Czech part of the Krkonoše Mts has not been considered as unambiguously proven and hence the species was not reported in the Flora of ČSR (Kubát 1988)<sup>1</sup>.

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<sup>1</sup> During the galley-proof stage of the present paper, a herbarium specimen proving historical occurrence of *D. tristachyum* in the Krkonoše Mts was discovered in a so far not studied but very valuable herbarium (OH) deposited in the Ohrada castle in southern Bohemia. W. Hirsch collected *D. tristachyum* at the locality "Schwarzschatzbaude" (formerly "Bouda na Černé pasece" chalet, now "Černá bouda" chalet) near the town of Janské Lázně on 25 July 1928.

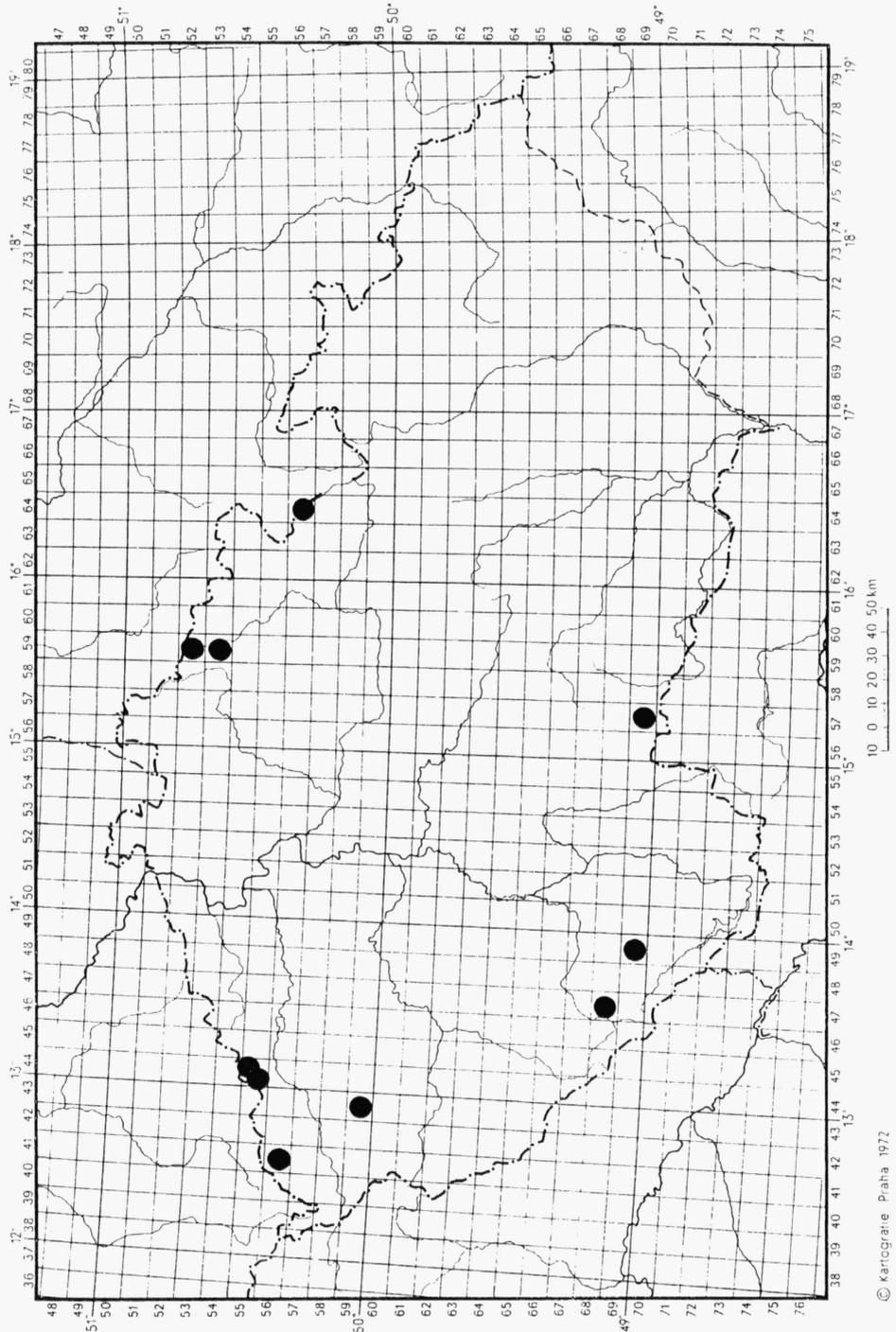


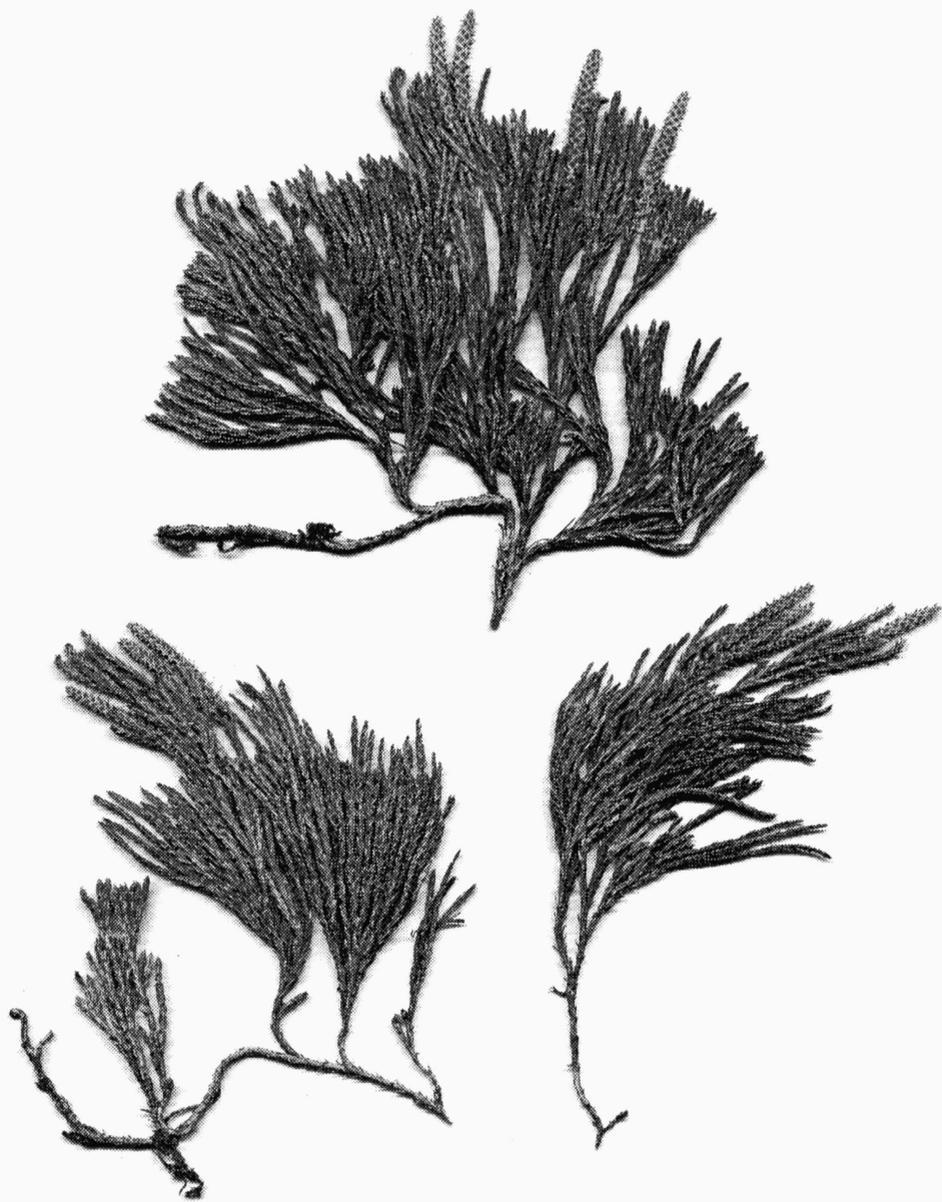
Fig. 1. – Localities harbouring three or more species of the genus *Diphasiastrum* in the Czech Republic (state in 1998).

At present, the situation is quite different because of the discovery of a new locality of *Diphasiastrum* species in the Špindlerův Mlýn, at the lower part of the Černá sjezdovka ski slope leading from the Medvědin Mt [altitude 790–840 m a. s. l., prevailing exposition SE (SSE or ESE on places), slope declination 20–40°]. This locality was first recorded by the latter author of the present paper during an excursion with J. Chrtek jun. (Průhonice) on 27 September 1991; no closer attention was paid to the discovery then. First specimens (*D. alpinum* and *D. tristachyum*) were collected here as late as on 12 October 1994 by J. Harčarik and determined by F. Procházka in 1998. The locality was studied in more detail by J. Harčarik during an excursion with M. Kociánová (Vrchlabí) as late as after another three years (on 14 October 1997). Several specimens were collected then, preliminarily determined as *D. complanatum*, *D. issleri*, *D. tristachyum* or *D. zeilleri*. These plants were sent for revision to J. Holub who could, on the basis of an insufficient material, only prove without any doubt *D. complanatum*, marking the other specimens preliminarily as “*D. tristachyum* vel *D. zeilleri*” and “*D. issleri* vel *D. oellgaardii* (J. Holub in litt., 19 November 1997).

Without knowing the above mentioned facts, the first author of the present paper visited the described locality on 28 July 1998, accompanied by other botanists (V. Faltys, M. Jatiová, J. Šmiták, V. Šuk, Č. Čihalík, P. Lustyk, P. Batoušek, V. Tlusták and others) on an excursion guided by H. Štursová (Vrchlabí). During a short visit in an extremely unfavourable weather, they succeeded to determine reliably, directly on the locality, *D. alpinum*, *D. complanatum*, *D. zeilleri*, *D. tristachyum* and *D. oellgaardii*. A detailed study of the material collected confirmed the determination made in the field. The occurrence of *D. tristachyum* was therefore reliably proved in the Czech part of the Krkonoše Mts for the first time. This record also represents the only existing locality in the Krkonoše Mts as a whole, since no recent occurrence has been known from the Polish part.

The local occurrence of *D. oellgaardii* (Fig. 2) is even more surprising. This hybridogenous species was distinguished already several decades ago by J. Holub in collections from the Czech Bohemian Forest. Its valid name, however, was not published until the autumn of 1996 (cf. Procházka 1997). Until the discovery in the Krkonoše Mts, this species had not been known for the Czech Republic from any existing locality because attempts to verify its former occurrence in the Bohemian Forest localities were not successful; it grows only on the Bavarian and Austrian part of the Bohemian Forest. Hence the locality in the Špindlerův Mlýn represents the only currently known occurrence in the Czech Republic. The distribution area of *D. oellgaardii* spread from France (the Massif Central) eastwards as far as to the Czech Bohemian Forest. The discovery of the species in the Krkonoše Mts therefore shifts the eastern border of its world distribution further to the East.

During our last visit to the locality (on 26 September 1998), on an excursion guided by M. Krukowski (Wrocław) and J. Kovářiková (Vimperk), the occurrence of the five above mentioned species of the genus *Diphasiastrum* was verified but, in addition, we also found the last, until now missing Central European species, i. e. *D. issleri*. Herbarium specimens of all six species growing on the described locality are deposited in PRC. Ski slope on which the *Diphasiastrum* species occur covers an area of approximately 0.4 hectares. Apart from all Czech species of the genus *Diphasiastrum*, other representatives of the order *Lycopodiales* such as *Lycopodium clavatum* and *Huperzia selago* also occur here.



Krkonoše: Špindlerův Mlýn, 1998

Fig. 2. – Scanned herbarium specimen of *Diphasiastrum oellgaardii* from the Krkonoše Mts (leg. Č. Čihálik, det. F. Procházka, 28 July 1998).

Confirmed localities of particular *Diphasiastrum* species located nearest to that in the Špindlerův Mlýn are as follows (with the only exception of *D. oellgaardii*, see above, these localities do not exist any longer): *D. alpinum* was found on the Medvědin Mt (Luerssen 1889 sec. Šourek 1970); *D. complanatum* grew in a spruce stand on the Kozí hřbety ridge between Špindlerův Mlýn and Bílé Labe valley until 1881 according to C. Purkyně in Čelakovský 1882; Šourek 1970 refers to this locality vaguely as “Špindlerův Mlýn: under the Kozí hřbety ridge” and there is a little more recent specimen [deposited in the herbarium of the natural-historical section of the Museum in Hradec Králové (HR), dated 1882, collector’s name undecipherable] from a locality vaguely described as “Spindelmühl”. For *D. issleri*, the nearest confirmed locality was Špindlerův Mlýn: Sedmidolí [leg. J. Kablík sec. Domin (1937: 13) ut *Lycopodium alpinum* subsp. *kablikianum*], for *D. tristachyum* it was foothills of the Orlické hory Mts, in pine woods at Bolehošť (leg. L. David, 1952, OP), and on other localities in the Orlické hory Mts (cf. Kubát 1974: 317), and for *D. zeilleri* Modrý důl valley in the Krkonoše Mts (leg. J. Dostál, PR sec. Kubát 1982: 29). This survey shows that the historical occurrences, similarly as the recent ones, were from several kilometres (in *D. alpinum*, *D. complanatum*, *D. issleri*, *D. zeilleri*) to several tens (*D. tristachyum*) or hundreds of kilometres (*D. oellgaardii*) distant from the present locality.

The described locality is remarkable in that it appears to be the only one in the Czech Republic in which all the six native species of the genus *Diphasiastrum* grow together; for that reason we tried to collect as much ecological data as possible. According to the records from a nearby meteorological station in Špindlerův Mlýn (Sedmidolí, 922 m a. s. l.), the mean annual temperature (50-years average) is 4.7 °C and the mean annual sum of precipitation is 1 322 mm (see Vacek 1990: 69 for a climatic diagram). Selected soil properties were investigated to compare ecological conditions of the locality with those under which the *Diphasiastrum* species grow in other areas of Central Europe. Horn (1997b) published a comprehensive study on distribution, ecology and threats to five species of the genus *Diphasiastrum* (*D. alpinum*, *D. complanatum*, *D. issleri*, *D. tristachyum* and *D. zeilleri*). He gives selected chemical properties of soil (Table 1) from localities of particular species: pH (CaCl<sub>2</sub>), total nitrogen content (%), total carbon content (%), humus content (%), and total carbon to total nitrogen ratio. The same soil features were ascertained in samples taken on 12 September 1998 in *Diphasiastrum* stands on the ski slope in Špindlerův Mlýn. Three soil samples were taken from the depth of 5–10 cm in different places where several *Diphasiastrum* species grew together, and analysed by R. Řezničková in the laboratory of the Krkonoše National Park Administration in Vrchlabí. The following methods were used: pH was determined in extraction with 0.01 M CaCl<sub>2</sub> leach; humus contents was stated by annealing in a muffle furnace at 550 °C; total C was taken as the volume of organic substances divided by 2; total nitrogen in soil was determined as ammonium after Kjeldahl digestion. Soil from the studied locality taken from the transition part between upper humus layer and humous horizon is very strongly acid, with a low nitrogen contents. Humus content corresponds rather to humous horizons of spruce stands than to horizons created by litter and products of its decomposition. The C/N ratio indicates a raw form of humus which is characteristic for the nearby Krkonoše spruce stands (cf. Vacek 1990). Although the studied locality is without a tree cover, it was deforested a short time ago and even at present there is a continuous deposition of raw organic material (litter) from adjacent forest, closing the rather narrow ski slope from both sides. Table 2 shows that *Diphasiastrum* species in both Lower

Saxony and the Krkonoše localities investigated in the present study grow on soils of the same chemical properties, with C/N ratio being the only exception.

Table 1. – Chemical parameters of the soil sampled in the localities of different species of the genus *Diphasiastrum* in the Lower Saxony (Horn 1997b: 40). For each parameter, range and mean values are given.

Species	pH		Total N (%)		Total C (%)		Humus (%)		C/N Ratio	
<i>D. alpinum</i>	3.6–4.8	4.2	0.12–0.68	0.34	1.39–13.35	6.20	2.8–26.7	12.4	11.4–20.4	16.9
<i>D. complanatum</i>	3.2–5.1	4.2	0.07–0.78	0.29	1.99–16.93	5.30	1.8–33.9	10.6	10.6–22.7	16.6
<i>D. issleri</i>	3.6–4.8	4.1	0.12–0.68	0.35	1.39–13.35	6.47	2.8–26.7	13.0	11.4–20.4	17.0
<i>D. tristachyum</i>	2.7–4.8	3.7	0.02–0.55	0.19	0.37–17.00	4.24	0.7–34.0	8.5	10.2–30.9	20.7
<i>D. zeilleri</i>	2.8–4.8	3.8	0.14–0.68	0.28	2.14–13.35	5.35	4.3–26.7	10.7	14.8–24.5	19.0

During the above mentioned excursion in September 1998 under the guidance of M. Krukowski, we visited a very rich locality of *D. alpinum* on the Polish side of the Krkonoše Mts, on a ridge located north of the Luční bouda chalet. The species occurs here in a several hundred meters long belt from which the vegetation was completely removed in the past for guarding of the state border and which is slowly overgrowing with vegetation again. One of the reasons for the visit was to find out if some other representative of the genus occurs here together with *D. alpinum*. This assumption was not proven. However, on the way back we noticed two localities from the car in which the occurrence of the *Diphasiastrum* species seemed probable. During a brief examination, we found another, new locality for the Krkonoše Mts of three *Diphasiastrum* species at the margins of a road, about 800 m NE of the Husí Boudy (Strážné) at the altitude of 1030–1060 m. Inside a road curve, *D. issleri* grows on one of the three localities at present known in the Krkonoše Mts, together with *D. alpinum*. The latter species further occurs about 200 m NW of this place, above the road, together with *D. zeilleri*. Size of both plots does not exceed 0.05 hectares; the order *Lycopodiales* is further represented there by *Huperzia selago* and *Lycopodium clavatum*.

Table 2. – Comparison of chemical soil parameters common for more species of *Diphasiastrum* in the Lower Saxony (*D. alpinum*, *D. complanatum*, *D. issleri*, *D. tristachyum*, *D. zeilleri*) and in the Krkonoše Mts. (*D. alpinum*, *D. complanatum*, *D. issleri*, *D. oellgaardii*, *D. tristachyum* and *D. zeilleri*). Range of values is shown.

	Lower Saxony (Horn 1997)	Krkonoše Mts (Špindlerův mlýn)
pH	3.60 – 4.80	3.80 – 3.90
Total N (%)	0.14 – 0.55	0.12 – 0.25
Total C (%)	2.14 – 13.35	6.33 – 7.91
Humus (%)	4.30 – 26.70	12.70 – 15.90
C/N Ratio	14.80 – 20.40	29.74 – 32.73

Apart from so far not published localities of *D. alpinum*, *D. complanatum*, *D. issleri* and *D. zeilleri*, one species completely new to flora of the Krkonoše Mts (*D. oellgaardii*) is given in the present study. The occurrence of *D. tristachyum* in Krkonoše is documented for the first time; this species has not been reliably proven until now. *D. alpinum* grows on the Černá sjezdovka ski slope at Dívčí lávky at the lowest altitude known from the Krkonoše Mts (800 m) because the altitudinal minimum given for this species so far (from an overgrowing soil slide in a riverbed of the Krátká strouha brook in the Svatý Petr settlement) refers to the same altitude (Štursa & Štursová 1982).

### Tepelské vrchy hills

Only one *Diphasiastrum* species, i. e. *D. complanatum*, was documented from more localities in the Tepelské vrchy hills in the past (cf. Kubát 1982). On 21 May 1998, J. Michálek from the Regional museum in Sokolov found (after a notification from J. Frouz) a remarkable new locality of *Diphasiastrum* species 2 km E of the Bečov nad Teplou, in a clearing with a young fir stand, above the left bank in the valley of the Bečov brook at the altitude of 620 m a. s. l. *Calluna vulgaris* with *Lycopodium clavatum* occur in this site, which covers an area of about 600 m<sup>2</sup>. J. Michálek collected several specimens of *Diphasiastrum* here and determined them preliminarily as *D. alpinum* and *D. issleri*. Two specimens marked by the collector as *D. issleri*, however, belong to *D. zeilleri* (rev. F. Procházka). The specimens are deposited in the herbarium of the Regional museum in Sokolov. This locality is extraordinarily significant for several reasons; not only because there are three *Diphasiastrum* species growing together but also because all of them were found in the phytogeographical district Tepelské vrchy for the first time (the described locality is located in a sub-district of the Toužimská vrchovina hills). The nearest occurrence of *D. zeilleri*, most probably not existing any longer, is documented from a nearby (about 10 km) adjacent area of the Slavkovský forest (Špičák between Krásno and Čistá villages, 1888, leg. Čelakovský fil., PR). *D. issleri* was also recorded in the Slavkovský forest near Mariánské Lázně (Kubát 1988: 199). However, the nearest localities of *D. alpinum* are as remote as in the rather distant Ore Mts.

Undoubtedly, the most significant finding on the described locality is *D. alpinum* which grows here at a remarkably low altitude (only 620 m a. s. l.). Until its discovery, the altitudinal minimum of this species at the territory of the Czech Republic was considered to be another locality, investigated a month later in the Javořická hornatina hills in SE Bohemia which is situated at 680 m a. s. l. (Procházka et al. 1998). Although both these occurrences of *D. alpinum* are located at extremely low altitudes, localities from even considerably lower altitudes have been known from Germany. In 1997, *D. alpinum* was found by K. Horn in Upper Palatinate (Oberpfalz) at the altitude of only 432 m a. s. l. (Horn 1997a).

### Ore Mts (Krušné hory)

All *Diphasiastrum* species of the Czech flora except for *D. oellgaardii* have been confirmed from the territory of the Ore Mts (cf. Kubát 1974, 1982, 1988). Data on their actual occurrence in this area are presently being collected by Č. Ondráček in the Regional mu-

seum in Chomutov (specimens mainly from localities in the Chomutov region are deposited in the local herbarium CHOM) and by J. Michálek in the Regional museum of Sokolov, where herbarium specimens from the western part of the Ore Mts are deposited. On 4 August 1998, the first author of the present paper, accompanied by A. Pavlíčko (Prachatice) and Č. Ondráček, visited both localities of three and more species of the genus *Diphasiastrum* in the Chomutov region in order to check its present state and revise the determination of particular species.

The larger of the two localities lies SW of the Kryštofovy Hamry village on slopes above a motor road along a western bank of the water reservoir Písečnice, ca 760 m a. s. l. There are three micro-localities spatially separated from each other. The first of them (at a crossing of roads about 2.2 km ESE of the Černý Potok village) was discovered by Č. Ondráček (Chomutov) who collected *D. issleri* here on 31 July 1989. Later, on 19 July 1992, he investigated another adjacent micro-locality in wider surroundings of a road-turn to the Kovářská village; apart from *D. issleri*, he collected also *D. zeilleri* here (det. K. Kubát, CHOM). On the third micro-locality (rocky sites with wiped-out sod gradually overgrowing with natural regeneration of tree species above a road W of a dam of the Písečnická reservoir at SSW border of Kryštofovy Hamry), *D. alpinum* (det. K. Kubát, CHOM) was collected for the first time by J. Bílek in August 1993, and a year later (29 July 1994) again by Č. Ondráček who collected here not only *D. alpinum* but also *D. issleri* and *D. complanatum* (herbarium specimens were determined by J. Holub and are deposited in CHOM).

During the revision in 1998, it was found that all four species (*D. alpinum*, *D. complanatum*, *D. issleri*, *D. zeilleri*) known from the locality grow there and other representatives of the family *Lycopodiaceae*, i. e. *Lycopodium clavatum* and *L. annotinum*, were also recorded in the locality. The entire area of the locality SW of Kryštofovy Hamry is very large but all four species of *Diphasiastrum* can be found on an area smaller than one hectare.

In this locality, we searched unsuccessfully for *D. tristachyum* which was allegedly found opposite to the dam of the Písečnická reservoir during an excursion of several botanists (K. Kubát, Č. Ondráček, V. Žíla, and others) on 2 September 1995. The only herbarium specimen available, determined as *D. tristachyum* (leg. Č. Ondráček, CHOM), contains parts of sterile plants which belong to more than one species and the material is insufficient for a reliable determination. It is clear that *D. tristachyum* is not present among these species; only *D. alpinum* and *D. issleri* can be reliably determined (rev. F. Procházka). Despite of the fact that the occurrence of *D. tristachyum* has not been reliably documented from the described locality, it cannot be completely excluded namely due to a documented historical occurrence on nearby sites in the Ore Mts. The species was collected by F. Keil in the middle of the 19th century (a non-dated specimen is deposited in PR) nearby Kraslice and since the middle of the 1960s, it was growing E of the road to Měděnec, N of the Klášterská Jeseň village (leg. J. Lorber et K. Kubát, 1967, LIM). The Keil's locality has not been later verified and the latter site disappeared some time ago, being completely shadowed by trees. The last locality in the Ore Mts, documented in the herbarium of the Museum in Plzeň (PL), is "Boží Dar raised bog, leg. V. Krausová". Although the collected specimen is not dated, according to J. Sofron it was almost surely collected by V. Krausová during a university excursion to the Ore Mts in 1968. The occurrence in

this locality was not later verified either, hence *D. tristachyum* is nowadays a species missing from the Ore Mts.

The second locality in the Ore Mts harbouring four *Diphasiastrum* species lies about 1.5 km NE of the Kovářská village on a waste place nearby an abandoned mining tower at the elevation point 878.9, about 1.9 km SSW of Velký Špičák Mt (elevation point 965). There is a spruce forest overgrowing this site. The locality was discovered on 29 July 1993 by Č. Ondráček who collected *D. issleri*, *D. complanatum*, and *D. zeilleri* here (specimens were determined by K. Kubát and are deposited in CHOM). A specimen with correctly determined *D. issleri* contains, however, also plants (even fertile!) which undoubtedly belong to *D. alpinum* (rev. F. Procházka). On 8 August 1998, the occurrence of all four species (*D. alpinum*, *D. complanatum*, *D. issleri*, and *D. zeilleri*) was verified in this locality; of other representatives of the family *Lycopodiaceae*, only *L. clavatum* was recorded. The total area N to NE of an old mining tower harbouring *Diphasiastrum* species does not exceed 0.04 hectares and the locality is already heavily shadowed by grown-up trees (the tree cover is formed by native spruce and birch, but also introduced North-American *Picea pungens*).

The third locality in the western part of the Ore Mts has been known as long as since the 1970s. It lies on southern parts of spoil heaps formed by tin-rich autometamorphic biotitic granite in an area of abandoned mine “Boží Požehnutí” ca 5 km from Přebuz; the heaps are covered by spruce. The locality was discovered by I. Wiesner who reported on “several more or less numerous colonies of *Lycopodium clavatum* and *Diphasiastrum complanatum*” (Wiesner 1979). This locality lies at the territory of the “Velký cínový důl” tin mine, an extensive waste place ca 300 × 400 m in size surrounded by water-logged spruce stands and raised bogs, 2.5 km W of the Jelení settlement, on the right side of a forest road to the Rolava village at the altitude of 925–930 m a. s. l. Since the second half of the 1980s, it has been investigated in detail by a number of botanists who have not only proved the occurrence of *D. complanatum* there (3 August 1986, leg. J. Hadinec, rev. K. Kubát; 5 August 1986, leg. A. Lepšová, rev. J. Hadinec et K. Kubát; 11 July 1988, leg. Michálek, rev. J. Hadinec et K. Kubát; 10 August 1989, leg. J. Michálek, rev. J. Hadinec et K. Kubát; 13 July 1994, leg. V. Cejnarová, HR, rev. F. Procházka) but found also *D. issleri* (4 August 1986, J. Hadinec, rev. K. Kubát; 5 August 1986, leg. A. Lepšová, rev. J. Hadinec et K. Kubát; 11 July 1988, leg. J. Michálek, rev. J. Hadinec et K. Kubát; 20 August 1990, leg. J. Michálek, rev. J. Hadinec; 16 July 1991, leg. Č. Ondráček, rev. K. Kubát, CHOM; 13 July 1994, leg. V. Cejnarová, HR, rev. F. Procházka; 16 August 1997, leg. J. Michálek, rev. F. Procházka) and later on, *D. alpinum* as well (27 August 1993, leg. J. Michálek et J. Hadinec, rev. F. Procházka; 13 July 1994, leg. Č. Ondráček, rev. K. Kubát, CHOM; 13 July 1994, leg. V. Cejnarová, HR, rev. F. Procházka; 27 August 1996, leg. J. Štěpánek, det. J. Michálek, rev. F. Procházka)<sup>2</sup>. Other representatives of the order *Lycopodiales* accompanying *Diphasiastrum* species present in this locality are *Lycopodium clavatum*, recorded already by Wiesner (1979: 8), *L. annotinum* and *Huperzia selago* (Michálek 1997: 13). The development of the occurrence of *Diphasiastrum* species in this extensive locality was reported by J. Michálek (in litt.):

<sup>2</sup> If not given otherwise, herbarium specimens are deposited in collections of the Regional museum and library in Sokolov

"The Wiesner's finding of *D. complanatum* was confirmed by J. Hadinec in 1986. During a detailed investigation of dams built of granite gravel in the N part of the area of the "Velký cínový důl" tin mine, we found several populations of *D. complanatum* and *D. issleri*. Some populations that were abundant in the 1980s suddenly became extinct (mainly in the northern part of the area); the most remarkable decline can be observed in *D. complanatum*. On the contrary, an abundant stand of fertile plants of *D. issleri* appeared in other places, e. g. on the inner slope of an artificial granite gravel dam on the eastern edge of the area. *D. alpinum* was recorded for the first time in the southern part of the area as late as in 1993. Three years later, a small clone of *D. alpinum* was found on the border of the northern part and in 1998, it already covered a surprisingly large area. This development was surprising because the entire locality is gradually being overgrown by spruce, constituting thus optimum conditions rather for *D. complanatum* than for more heliophilous species such as *D. alpinum* and *D. issleri*. As to the present situation, *D. complanatum* is more abundant in the southern part of the locality adjacent to the Velký močál nature reserve, under young spruce trees in the peripheral part of a former POW camp left of the road Jelení-Rolava opposite to the "Velký cínový důl" tin mine. In a close neighbourhood, there is a shallow ditch with dispersed groups of *D. issleri*, and in a stand of *Calluna vulgaris* above the ditch, there is also a small group of *D. alpinum*. In 1997, the whole mine was proposed to protection as a part of the larger complex of raised bogs in the surroundings."

### Orlické hory Mts

Only four *Diphasiastrum* species have been known from the Orlické hory Mts in the past (cf. Kubát 1974, 1988; Procházka 1980), i. e. *D. complanatum* (locality Šerlich), *D. issleri* (Velká Zdobnice, Šerlich), *D. tristachyum* (Arnoštka, Říčky) and *D. zeilleri* (Kunvald). The most recent documents from this region, however, are from the 1950s and beginning of 1960s. Since then, no representatives of the genus had been recorded in the whole mountains until 4 October 1993, when J. Kučera (Dobré) discovered a new locality about 2 km NE of Sedloňov at the margin of a mountain road near a crossing of roads on the NW slope of the Polomský kopec hill (elevation point 1050) at the altitude of ca 820 m. He visited the locality again on 22 August 1995 together with J. Holub who determined three species there: *D. alpinum*, *D. tristachyum* and *D. zeilleri*. Three years later (on 5 August 1998), during a visit of the locality made by J. Kučera, F. Procházka and A. Pavlíčko, the occurrence of these three species was confirmed; they spread on an area less than 0.01 hectares. Another co-occurring *Lycopodiaceae* is *Lycopodium clavatum*. *D. alpinum*, the rarest species on the locality, is new to the flora of the Orlické hory Mts (including their Polish part). Other localities of *D. alpinum* are known from as far as the nearest mountains ranges of the High Sudetes (Krkonoše Mts, Králický Sněžník Mts). Herbarium specimens (leg. F. Procházka) are deposited in PRC.

### Jihlavské vrchy hills

On 20 June 1998, J. Švarc (Třešť) visited an abandoned sand-pit (built by weathered coarse-grained granite) not far from a blue-marked tourist path in the Červenka forest (1 km SW of the town of Terezín) about 2.7 km NW of the Matějovec village. This locality is situated in the Javořická hornatina hills about 2 km NE of the summit of the Javoří hora Mt (700.1 m a. s. l.) at the altitude of about 680 m. After a preliminary notification from L. Vaněčková (Matějovec), he found *D. complanatum* and had a suspicion that there are other species of *Diphasiastrum* occurring there. During a detailed research carried out by J. Švarc, F. Procházka and L. Vaněčková on 25 June 1998, four species of the genus (*D. alpinum*, *D. complanatum*, *D. tristachyum*, and *D. zeilleri*) were found on an area of

0.02 hectares, together with *Lycopodium clavatum* representing another *Lycopodiaceae* species (cf. Procházka et al. 1998). On 14 August 1998, the locality was visited again by A. Pavlíčko, K. Matoušek (Jindřichův Hradec) and K. Boublík (Jindřichův Hradec) who not only verified the occurrence of all four species but found some of them (*D. tristachyum*, *D. complanatum*) on other places in the neighbouring forests.

*D. alpinum* grows here in the site where it was first found in the Jihlavské vrchy hills. This locality had been until recently considered as the altitudinal minimum in the Czech Republic. At present, another locality situated at even lower altitude (ca by 60 m) has been known from the Tepelské vrchy hills (see above).

### Bohemian Forest (Šumava Mts)

Until now, the Bohemian Forest was the only area in the Czech Republic from where the all six Central European *Diphasiastrum* species have been reported (Kubát 1988, Procházka 1997). However, no existing occurrence of *D. oellgaardii* has been known at present; this species grows on the Bavarian and Austrian side of the mountains. More details on the present distribution of particular representatives of the genus in the Bohemian Forest can be found in Pavlíčko & Procházka (1998). To this study, numerous additions can be already made concerning numerous new localities of *D. alpinum*, *D. complanatum* and *D. issleri* found in 1998. Discovery of a new rich locality of *D. zeilleri* in an adjacent part of the Prachatické Předšumaví phytogeographical district [Miletínky, on the SW slope of the Ostrá Mt (elevation point 780.4 m) at the altitude of ca 740 m a. s. l., 1998, leg. A. Pavlíčko, rev. F. Procházka] is also remarkable.

The longest known locality of four *Diphasiastrum* species, located on the border between the Bohemian Forest and its foothills, is the “Pod Popelní horou” nature reserve about 3 km W of Stachy at the altitude of ca 1020 m. The first two species (*D. complanatum*, *D. issleri*) were discovered here by Moravec (1963) on the verge of 1950s and 1960s. Later on, the locality was almost regularly visited by a number of botanists (V. Chán, J. Kovářiková, A. Pavlíčko, F. Procházka, V. Skalický, M. Štech, J. Vaněček, V. Žíla and others) and two more species were gradually found there: first *D. alpinum* (Stachy, Studenec: N edge of the Popelní hora Mt, 1973, leg. J. Vaněček, PL) and later *D. zeilleri* by V. Skalický and J. Vaněček (leg. J. Vaněček 1970, CB; Procházka 1990). During a thorough revision conducted by F. Procházka, A. Pavlíčko and German botanists K. Horn (Karlsruhe) and M. Haug (Grafenau) on 22 September 1996, *D. alpinum* and *D. zeilleri* (cf. Pavlíčko & Procházka 1998) were not verified there. The latter species, however, was found again by A. Pavlíčko on an excursion with J. Vondrák (Písek) on 4 September 1998. To summarize the present situation, *D. issleri* still grows there abundantly on an area of ca 1 hectare, *D. complanatum* occurs only sporadically, and *D. zeilleri* is very rare. *D. alpinum* must be considered extinct from this locality. Of other *Lycopodiales*, *Lycopodium clavatum* occurs directly on the locality and *Huperzia selago* in its close vicinity.

The second locality of the Bohemian Forest harbouring currently four species of the genus *Diphasiastrum* was discovered in 1995 by a high-school student J. Vondrák at Včelná pod Boubínem, ca 1 km S on the village “Na Pile” in an old soil-pit crossed by a forest path to the Poušť hill, ca 30 m E of a forest road, at the altitude of ca 930 m a. s. l. It was repeatedly studied by J. Vondrák as well as by other botanists (V. Chán, A. Pavlíčko,

F. Procházka, J. Sofron, V. Žíla, M. Haug, K. Horn) in 1995–1996, and *D. alpinum*, *D. complanatum*, *D. issleri* and *D. tristachyum* (Chán et al. 1995, Pavlíčko & Procházka 1998, Procházka 1998) were gradually found here on an area of ca 0.01 hectares. For *D. tristachyum*, it is the only currently known existing locality in the Czech part of the Bohemian Forest. As to the other representatives of the order *Lycopodiales*, *Lycopodium clavatum* can be found directly on the locality and *Lycopodium annotinum* and *Huperzia selago* in its close vicinity. The occurrence of the mentioned species was confirmed on 2 September 1998 at last.

Overview of distribution of particular *Diphasiastrum* species on described localities, harbouring at least three species of the genus, is presented in Table 3.

## Discussion

Sites harbouring more species of the genus *Diphasiastrum* are not unusual as indicated not only by those described above in detail, but also by a number of new localities at the territory of the Czech Massif which were recently (1989–1998) discovered:

- Ore Mts, Kalek: places with removed turf in a young spruce plantation, ca 3 km ENE of the village, 800 m a. s. l., locality discovered in 1992 – *D. alpinum* + *D. zeileri* (leg. Č. Ondráček, det. K. Kubát). In the past, *D. issleri* (1934 Flossner sec. Rauschert 1967) was also recorded nearby (Kalek: forest opening at an old lime-kiln).
- Ore Mts, Boží Dar–Jáchymov (Božidarské vrchoviště raised bog): deforested area (probably used as a shooting-range in the past), today partly overgrown by naturally regenerating spruce, ca 700 m NW of Abertamy crossing, 3 km SW of Boží Dar, 980 m a. s. l. The locality was discovered in 1989 – *D. alpinum*, *D. issleri* (leg. J. Lepš, det. J. Hadinec). In 1998, however, no species of the genus were found here (J. Michálek, in litt). Nevertheless, *D. tristachyum* (1968, leg. V. Krausová, PL) was recorded on the Božidarské vrchoviště raised bog as early as several tens of years ago.
- Ore Mts, Horní Blatná: an old embankment E of railways 0.65 km S of the village. The locality was discovered in 1998, it harbours less frequent *D. alpinum* (19 August 1998, leg. Č. Ondráček, CHOM, rev. F. Procházka) and more frequent *D. issleri* (19 August 1998, leg. Č. Ondráček, CHOM, rev. F. Procházka). An extensive locality of *D. alpinum* is being registered since 1990; it was discovered by P. Kulíšek closer to the village (see further text for more details).
- Ore Mts foothills (Podkrušnohoří), Výsluní: margin of an old soil-pit in a spruce forest 0.7 km W of the village, ca 700 m a. s. l.; locality known since 1992 – *D. complanatum* + *D. issleri* (leg. Č. Ondráček, det. K. Kubát).
- Krkonoše Mts, Harrachov–Rýžoviště: lower part of the Černá sjezdovka ski slope, 770–880 m a. s. l.; found in 1998 – *D. alpinum* + *D. zeileri* (leg. J. Harčarik, det. F. Procházka).
- Bohemian Forest, Churáňov: in the vicinity of ski-jumps, ca 1070 m a. s. l.; locality discovered in 1998 – *D. alpinum* + *D. issleri* (leg. A. Pavlíčko, det. F. Procházka).
- Bohemian Forest, Churáňov: end of the ski slope in a counter-slope beneath ski-jumps, ca 1020 m a. s. l.; known since 1998 – *D. alpinum* + *D. complanatum* (leg. A. Pavlíčko, det. F. Procházka).
- Bohemian Forest, Bučina: forest path in the place of the former border belt deforested for the purpose of border guarding, N of the former hotel Pešl, 1170 m a. s. l.; the occurrence of *D. alpinum* has been monitored here annually for several years (Pavlíčko & Procházka 1998). *D. issleri* has not been found on the regularly monitored areas of this locality until 1998 (leg. A. Pavlíčko, det. F. Procházka). The latter species was collected for the first time somewhere at the territory of Bučina as long as almost 100 years ago (1903 leg. Hartman, DRESD, sec. Rauschert 1967).
- Bohemian Forest, Kvilda: NE of the village in a gap between the Hůrka Mt and Přebila Mt above a road near SW edge of a sandpit, ca 1030 m a. s. l.; *D. issleri* has been monitored here since 1989 (Procházka 1990). V. Žíla (Strakonice) found two young plants of *D. alpinum* (det. F. Procházka) here on 24 May 1998.
- Bohemian Forest, Kyselov: at the margin of a forest path in the place of the former border belt deforested for the purpose of border guarding on NNW slope of the Soví vrch hill, ca 760 m a. s. l. Locality was discovered in 1998 – *D. complanatum* + *D. issleri* (leg. et det. A. Pavlíčko et F. Procházka). From its very close vicinity, *D. issleri* has been known already since 1994 (Balda, Kirschnerová, Kovářiková, Majer, Štech & Žíla in Pavlíčko & Procházka 1998). *D. alpinum* also grows there (Pavlíčko & Procházka 1998).

Table 3. – Occurrence of several taxa (three or more) of the genus *Diphasiastrum* in one locality in the Czech Republic: ! = present occurrence (1998); (!) = earlier occurrence documented, at present not verified; ? = doubtful (not verified) records; 0 = species absent from the locality.

<i>Diphasiastrum</i>	<i>alpinum</i>	<i>complanatum</i>	<i>tristachyum</i>	<i>issleri</i>	<i>oellgaardii</i>	<i>zeilleri</i>
<b>Krušné hory Mts:</b>						
Kryštofovy Hamry	!	!	?	!	0	!
Kovářská	!	!	0	!	0	!
Přebuz	!	!	0	!	0	0
<b>Tepelské vrchy Hills:</b>						
Bečov nad Teplou	!	0	0	!	0	!
<b>Krkonoše Mts:</b>						
Špindleruv Mlýn	!	!	!	!	!	!
Husí Boudy	!	0	0	!	0	!
<b>Orlické hory Mts:</b>						
Sedloňov	!	0	!	0	0	!
<b>Jihlavské vrchy Hills:</b>						
Matějovec	!	!	!	0	0	!
<b>Šumava Mts:</b>						
Pod Popelní horou	(!)	!	0	!	0	!
Včelná pod Boubínem	!	!	!	!	0	0

A completely new locality of *Diphasiastrum* species was discovered on the Austrian side of the Bohemian Forest in 1996 [ski slope on the eastern slope of Zwieselberg (elevation point 1162), at the altitude of 945–1100 m a. s. l.]. Five Central European species of the genus, i. e. *D. alpinum*, *D. complanatum*, *D. issleri*, *D. tristachyum* and *D. zeilleri*, grow there together with *Huperzia selago*, *Lycopodium annotinum* and *L. clavatum* (Procházka et al. in Žila & Štech 1998: 112). Two of them (*D. tristachyum* and *D. zeilleri*) represent the first record at the Austrian territory (cf. Procházka & Kubát 1998). During our visit to this locality on 12 September 1998, together with A. Pavlíčko, we found there also the last Central European species, i. e. *D. oellgaardii* (rev. K. Horn, Karlsruhe). In the area of the Czech Massif (Krkonoše Mts, Austrian part of the Bohemian Forest), there are at present at least two localities with all six European species of the genus *Diphasiastrum*.

Localities with several species of *Diphasiastrum* are not, however, an exclusively Central European phenomenon; such localities have been known from other parts of the world as well. For example in eastern Canada, there are three species (*D. digitatum*, *D. sabinifolium* and *D. tristachyum*) growing on forest roads nearby Chertsey at Rawdon N of Montreal. They grow there together with *Lycopodium lagopus* and *L. obscurum* (leg. F. Procházka, 1982, PRC).

The highest number of sites with *Diphasiastrum* in the Czech Republic is located in colder areas of the Mesophyticum phytogeographical region and in lower altitudes of Oreophyticum. All localities harbouring three and more species are found only in mountains of the Czech Massif at altitudes from 620 to 1030 m. All the localities lie in Bohemia, none has been found in either Moravia or Silesia so far.

During the whole history of botanical research in the Czech countries, lasting as long as two centuries, *D. alpinum* has been only exceptionally recorded at altitudes of about 800 m a. s. l. (Svatý Petr in the Krkonoše Mts and Žákova hora hill in the Žďárské vrchy hills). Since 1990, new localities have been found at the same altitudes in the Krkonoše Mts and Orlické hory Mts and even at much lower altitudes hory in the Krušné hory Mts (760 m a. s. l.), Jihlavské vrchy hills (680 m a. s. l.) and Tepelské vrchy hills (only 620 m a. s. l.).

Migration of *Diphasiastrum* species to newly originating sites (with heavily disturbed vegetation) over long distances (tens to hundreds of km) is made possible by production of a great number of spores of negligible weight. Presence of more species of the genus in one locality is only apparently surprising, considering the fact that rare species are in question. Ten species of *Carex* found on a relatively small area of a peat meadow is not considered as surprising (e. g. 19 species of *Carex* have been found in eastern Bohemia on an area smaller than one hectare at a small fishpond Necky in the Rychnov region – cf. Procházka & Černohous 1979). Similarly at lower altitudes of Oreophyticum, where wet meadows come to contact with ruderalized road margins, it is quite common that *Cirsium arvense*, *C. helenioides*, *C. oleraceum* and *C. palustre* grow together (e. g. in numerous localities of the Bohemian Forest). More similar examples could be given. The fact that this often happens in the representatives of those families whose early phases of ontogenetical development are conditioned by endotrophic mycorrhizae can be explained by the possibility that in certain phases of succession, mycorrhizal fungi are provided with optimum conditions. This is the reason why multispecies sites are found not only as *Diphasiastrum* species (and other representatives of *Lycopodiales*) are concerned but also among members of the family *Pyrolaceae* (e. g. *Pyrola chlorantha*, *P. minor*, *Chimaphila umbellata* and *Orthilia secunda* on Výrovčice at Husinec of the Bohemian Forest) or *Orchidaceae* (*Epipactis atrorubens*, *Gymnadenia conopsea*, *Platanthera bifolia* and even *Ophrys insectifera* in an abandoned limestone quarry at Sudslavice in the Volyně region of the Bohemian Forest foothills). Several members of *Ophioglossaceae* (*Botrychium matricariifolium* grows very often together with *B. lunaria*) or *Gentianaceae* (number of localities with common occurrence of *Gentianella praecox* subsp. *bohemica*, *G. amarella* and *Gentianopsis ciliata*) in one site are also frequently found. These habitats almost always represent initial successional stages or sites where the development of a closed vegetation cover is prevented for some reason. It is not unusual to find representatives of the above mentioned higher systematical units in one locality (e. g. *Orchidaceae* + *Ophioglossaceae* + *Pyrolaceae* or *Orchidaceae* + *Gentianaceae* or *Lycopodiaceae* + *Huperziaceae*, etc.). In the locality at Kryštofovy Hamry, the two above mentioned species of the family *Lycopodiaceae* grow together with representatives of the family *Pyrolaceae* (*Pyrola minor*, *Orthilia secunda*).

It has been found, by monitoring a number of localities of *Diphasiastrum* species in the Czech Republic during the last four decades, that these localities originate always on sunny sites with low and/or heavily disturbed herb cover (i. e. forest clearings, margins of forest paths and roads, ski slopes, erosion slopes, deposits of timber, deforested border belts in the Bohemian Forest, spoil heaps after mining, quarries etc.). Initial phases of succession in such localities are characterized by a low vegetation cover ranging between (10–) 20–60 (80)%. In situations with a closed vegetation cover (up to 100%), moss layer prevails remarkably whereas the cover of the herb layer is low. In the moss layer, representatives of the genus *Polytrichum* are never missing, species of the genus *Cladonia* are

also often present. In the herb layer with a low cover, other representatives of the order *Lycopodiales* are regularly present. *Lycopodium clavatum* (in Canada replaced by *L. lagopus*) is always found, *Huperzia selago* or *Lycopodium annotinum* are rather frequent; less frequently, both the latter species grow together. As to the grasses, *Avenella flexuosa* is regularly present, *Nardus stricta*, *Agrostis capillaris* and *Calamagrostis villosa* are often found as well. *Galium saxatile*, *Vaccinium myrtillus*, *Luzula multiflora*, *Carex pilulifera*, *Veronica officinalis*, *Caluna vulgaris*, *Potentilla erecta*, *Euphrasia rostkoviana* or also *E. stricta* are among species present in almost all Czech localities of *Diphasiastrum* species; *Chamerion angustifolium*, *Juncus squarrosus*, *Carex ovalis*, *Rhodococcus vitis-idaea*, *Pyrola minor* and *Orthilia secunda* are usually also present. From a phytosociological point of view, these communities can be classified as the association *Calluno-Vaccinietum* Büker 1942 (alliance *Genistion* Böcher 1943).

Woody species are usually completely missing from the localities of *Diphasiastrum* species in initial stages of succession, or, if present, only young trees or shrubs can be found. In more advanced successional stages, provided that succession is not blocked by regular human interventions (e. g. on ski slopes or on regularly mown grassy margins of forest roads), dispersed spruce, fir, birch trees and/or exceptionally juniper shrubs occur (e.g. on former pastures of the Bohemian Forest). If a locality is shaded by shrub or tree layer, the *Diphasiastrum* species at first cease to be fertile, and later their growth slows down remarkably until they finally die out. This is how a rich locality of *D. tristachyum* at Slučí tah in the Bohemian Forest ceased to exist a long time ago (Procházka 1965). Another locality of this species, with a very abundant population still existing in the 1960s, near Chrbonín in the Českomoravská vrchovina hills (Kaisler 1964) has also almost disappeared. Former clearing in a fir stand was reforested by spruce; consequently the original large population of fertile individuals declined to mere 2 m<sup>2</sup> of sterile individuals several years ago, and the last shoots, completely shaded, are doomed to extinction from the locality.

The occurrence of all *Diphasiastrum* species in particular localities is only temporary. They can persist for a period from several years to several decades (although stands whose age is estimated at more than 100 years are exceptionally reported from western and northern Europe – cf. Horn 1997b), depending on the duration of successional stages in which their sporophytes can occur. This statement has a limited validity only for *D. alpinum* in alpine communities and for *D. complanatum*, a species which best of all congeners tolerates complete shade and can thus survive relatively longer in shaded forest, though under such conditions it is almost always sterile. Temporary character of *Diphasiastrum* localities can be documented by the analysis of the history of occurrence of *D. tristachyum* in the Czech Republic, based both on data collected by Kubát (1974) and data presented in this study. Another published distribution map of this species (Slavík 1986: 28) was also taken into account. However, some localities in this map have been erroneously recorded – the one in the Rokytnice v Orlických horách was assigned to the phytogeographical mapping square no. 5764 (should be correctly 5864) and another one in Říčky in the Orlické hory Mts was assigned to the square no. 5765 (correctly 5865). The data show that in 1950 (cf. Kubát 1974: 315) none of the four documented localities, discovered since the beginning of the floristic research in the Czech Lands up to then, existed. In 1950–1968, eight new localities were found; of these only one existed in 1990 (Chrbonín in the region of Tábor). On the other hand, four new localities were recorded after 1990 so that five in total have been

known at present. Obviously, localities of *Diphasiastrum* species disappear after some time but new originates in other sites, often located in very distant regions where no occurrence had been recorded before (Fig. 3).

In the Orlické hory Mts, all *Diphasiastrum* species had been missing for three decades; according to the present knowledge, three species currently occur there one of which was discovered in these mountains for the first time. In the Krkonoše Mts, there was no record of *Diphasiastrum* for more than 30 years (with an exception of *D. alpinum* and partly *D. complanatum*), whereas all six European species grow there nowadays. This indicates that even in areas from which *Diphasiastrum* species completely disappeared, they can appear again after several decades on different places with suitable ecological conditions.

Particular *Diphasiastrum* species appear on suitable sites gradually, as indicated by a long-term annual monitoring of the above mentioned localities in the Bohemian Forest at Kvilda (for years, only *D. issleri* had been known from there, then *D. alpinum* appeared) and Bučina (first *D. alpinum*, later *D. issleri*). Štursová (1998) reports that usual annual increments in shoot length in *D. alpinum* and *D. issleri* in the Krkonoše Mts range from 10 to 30 cm; this is in accordance with our observation of these two and other species carried out in the Bohemian Forest. Provided that the growth rate of particular species is comparable (as indicated by our observations), temporal sequence of particular species' arrival to the locality can be reconstructed by comparing the size of individual clones. This was made on the above mentioned locality in the Jihlavské vrchy hills. The following sequence was derived from the size of the sporophytes of species present in the locality: *D. complanatum* – *D. tristachyum* – *D. zeilleri* – *D. alpinum* (Procházka et al. 1988: 285).

Due to insufficient knowledge of the duration of non-green saprophytic haploid gametophyte (prothallus), maturing possibly as late as after 12–15 years (Novák 1972: 114), the time of arrival of particular species to a given locality cannot be dated precisely only from the size of diploid sporophytes. Regardless of the presumably long-time survival of spores in the soil, observations from the localities studied in the present paper indicate that prothalli must have been present prior to the principal changes resulting in the present state of vegetation in which the sporophytes grow. Wire blocks of the “iron curtain” in the Bohemian Forest were removed in 1990 and since then, older or younger stages of sporophytes of different *Diphasiastrum* species have appeared in those places. These plants could not have developed during mere 9 years from gametophytes germinated from spores arrived to these localities as late as after the cessation of vegetation removal. The situation on the Černá sjezdovka ski slope in Špindlerův Mlýn is rather different. This place came to full use as late as in 1979, although its lower part has been used for skiing and other sport events since the beginning of 1970s (M. Kociánová, personal communication) so that deforestation took place here at the end of 1960s the latest. Hence there were more than 20 years between the deforestation and the first records of *Diphasiastrum* species on the locality, and the sporophytes were at least five-years old at the time of their first discovery. Grass mixture (of exclusively local provenance) has been originally sown on the ski slope, which was maintained daily by snow trucks during the winter season and since 1996 it has been mown 1–2 times a year. The pattern of colonization of new localities by the representatives of the genus *Diphasiastrum* and the duration of their ontogenetical development can be clarified only by a long-term monitoring of those sites for which the temporal development of terrain and vegetation is dated and on which young sporophyte stages appeared later.

Clearly, species of the genus *Diphasiastrum* most frequently appear in certain stage of succession following complete removal or heavy disturbance of vegetation. Such a stage obviously provides soil fungi with optimum condition; presence of these fungi is necessary for the development of endotrophic mycorrhiza, conditioning the existence of saprophytic gametophyte. Absence of scrub and tree layers along with a low cover of herbs makes a subsequent existence of green saprophytes possible. Along with progressive successional development, *Diphasiastrum* species gradually decline. The first decrease in their abundance is associated with an increase in cover of the herb layer because other species, especially tuft grasses, are much stronger competitors. For this reason, mere mowing without spatial disturbance of vegetation, which would lead to creation of initial successional stages with mosses and low grass cover, is ineffective.

It appears that apart from the gradual decline of *Diphasiastrum* species due to successional development, whole populations can disappear for other reasons during a short time. This is documented by the history of a rich locality of *D. alpinum* at Horní Blatná in the western part of the Ore Mts (heath above a railway, 300–500 m SE of the Horní Blatná railway station, left of the railway in direction to Pernink, altitude 875 m a. s. l.). The locality was known since 30 August 1990 (leg. P. Kulíšek, det. J. Michálek, 3 October 1990, leg. J. Michálek). J. Michálek reported:

“Until 1993, it used to be the most amazing locality of this kind I had ever seen. Numerous fertile populations created almost carpets in places and grew through heather on more than hundred-meter section of a skelet-like plateau over a deep cutting of the railway. The locality was shaded by birch trees only to a limited extent and seemed to be very perspective until 1993 (the occurrence was documented by specimens collected on 5 August). When I organized the floristic summer school of the Czech Botanical Society in Nejděk in 1994, I directed some excursions also to this locality. These, however, confirmed a sudden decline of most of the populations. I visited the locality as well and, to my surprise, there was no sign of the majority of plants! Since that time, *D. alpinum* has occurred here only sporadically.“

We can only speculate about ecological causes leading to such a heavy stress that a rich population almost disappears in a short time.

## Conclusions

1. Since the second half of the eighties, but namely after 1990, altogether 10 localities harbouring three and more species of the genus *Diphasiastrum* were registered in the Czech Republic. One of them, Špindlerův Mlýn in the Krkonoše Mts, harbours all six European representatives of the genus including *D. oelgaardii*, a species missing from the Czech flora up to then. As the species of this genus are obligatorily acidophilous and occur mostly on very acid soils, there might be a possible association with general increase in soil acidity due to the long-term large-scale impact of imissions. This could also explain the fact that in the last ten years, the altitudinal minimum of the distribution of *D. alpinum* shifted remarkably to lower altitudes. This species can be nowadays found in phytogeographical regions in which it had been never recorded before, i. e. not only in the districts of the Oreophyticum from where it used to be exclusively reported (Kubát 1988: 200) but also in the Mesophyticum (Tepelské vrchy hills: Toužimská vrchovina).
2. As the Czech species of the genus (to a certain extent except for *D. complanatum*) are markedly heliophilous and grow only on sites where the competition from other

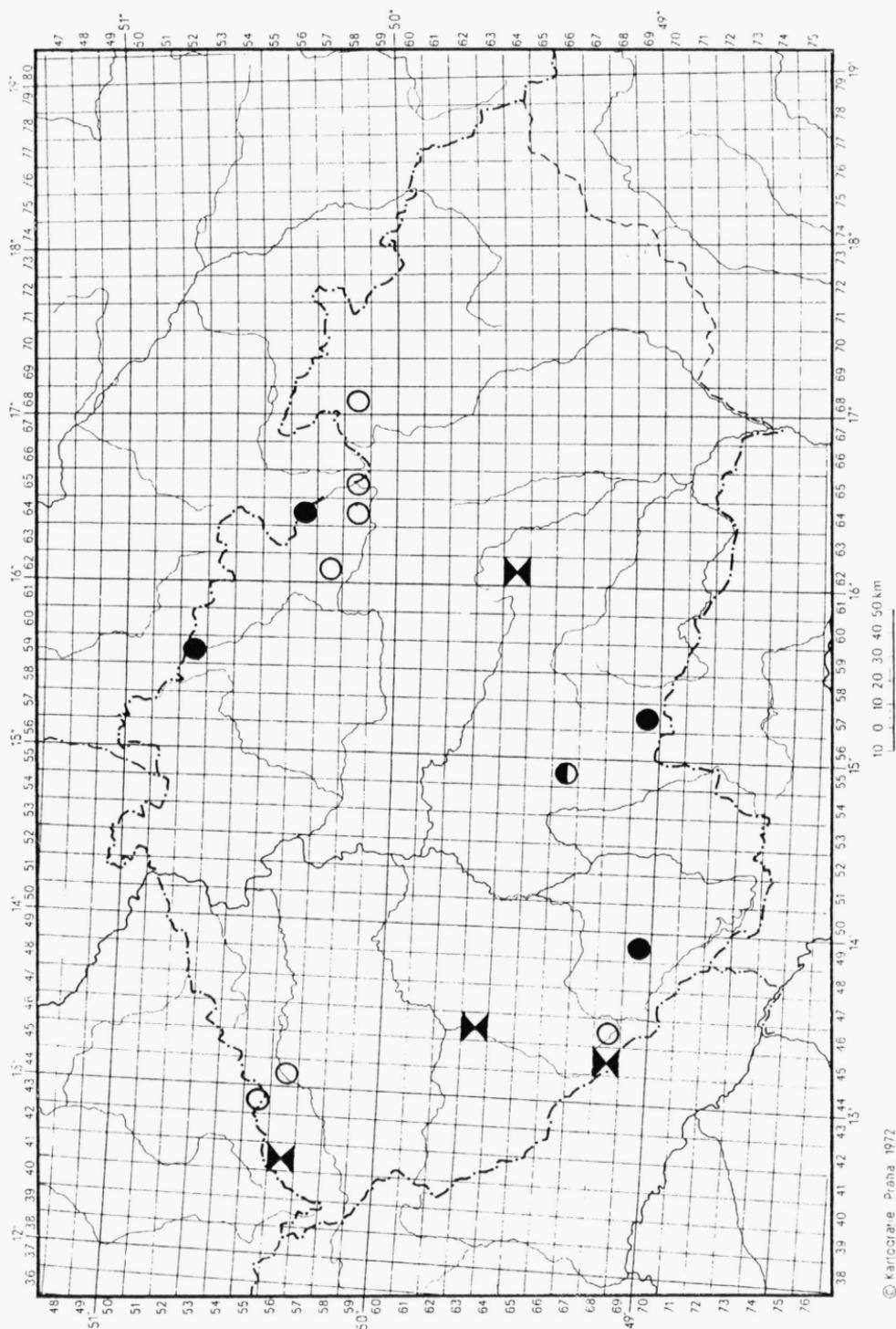


Fig. 3. – Historical and present distribution of *Diphysastrum tristachyum* in the Czech Republic. X = 1850–1950, O = 1951–1990, ◐ = 1951–1998, ● = 1990–1998

vegetation is reduced (apart from moss layer), they occur mostly in sites strongly influenced by human activities from where the vegetation was completely removed or is periodically disturbed.

3. The occurrence of more *Diphasiastrum* species in one locality is not an unusual phenomenon. Particular species can possibly arrive to the new localities more or less at the same time but in most cases they appear successively.
4. On joint localities of more species of the genus *Diphasiastrum*, other representatives of the order *Lycopodiales* usually occur. *Lycopodium clavatum* is practically always present.
5. *Diphasiastrum* species persist in particular localities always for a short time. Whereas the species disappear from individual localities, new localities appear in other areas with temporary favourable ecological conditions.
6. The most frequent cause of the decline of *Diphasiastrum* species is successional development during which a closed herb layer formed by competitively stronger species is gradually built, and locality is shaded by tree species. Under such conditions, populations of *Diphasiastrum* species gradually die off. Complete sudden extinctions or remarkable reductions of *Diphasiastrum* populations were also reported. The reasons for such events are not quite clear.

The following unambiguous conclusions can be drawn from the present paper and used in the nature conservation practical management:

1. Conservation of the species of the genus *Diphasiastrum* without directed human interventions is completely ineffective in the long-term horizon.
2. As many aspects needed for active protection remain unknown, it is necessary to monitor the localities regularly and carry out detailed studies on the ecology of particular *Diphasiastrum* species. For example, the knowledge of the ecology of gametophytes is quite insufficient.
3. On localities with *Diphasiastrum*, it is necessary to keep succession permanently blocked and, at the same time, ensure that neighbouring plots are disturbed or the vegetation is removed completely so that initial successional stages originate and representatives of the genus *Diphasiastrum* can migrate there from a close vicinity.

#### **Addendum: Remarks on the determination**

Determination of individual species of the genus *Diphasiastrum* is sometimes complicated as documented by a number of specimens in herbaria which have been either misidentified by the collector or not determined at all. Even in scientific literature, erroneously described illustrations can be found. Jirásek's photograph identified as *D. complanatum* from the Bohemian Forest (Novák 1972: 118) which certainly does not show *D. complanatum* but *D. tristachyum* or *D. zeilleri* (closer determination is not possible on the basis of the photograph) can serve as an example. However, determination of well developed fertile *Diphasiastrum* plants should not be problematic, the only possible exception being the pair *D. complanatum* – *D. zeilleri*. Basically the same holds for well developed, sufficiently grown up sterile plants. It is necessary to stress that, with an exception of *D. alpinum* and *D. tristachyum* which do not have sterile branches dorsiventrally flattened, the characters given in determination keys for ventral sides of the sterile flat-

tened branches hold only for their middle parts where the leaves are opposite and decussate, markedly anisophilous (lateral leaves are well developed whereas leaves on the upper and inner sides are comparatively smaller; moreover, the dorsal leaves differ from the ventral ones in size and shape). Other above-ground parts of plants, e.g. on stems under sporangia spikes, possess leaves of the same shape (isophilous) arranged in a spiral and hence they cannot be used for determination. The most important features are not well developed on very young dwarf shoots of sterile plants which are therefore difficult or even impossible to determine. This holds also for sterile plants from strongly waterlogged sites (e.g. sterile shoots almost entirely overgrown by mosses).

Whereas determination of plants (even of sterile ones) on the locality is not difficult for an experienced person, wrongly collected plants (or their parts) can be determined in herbaria only with difficulties and in some cases the reliable determination is not possible.

Both in the wild and in herbaria, well developed (even fertile) plants can be sometimes found, being morphologically more or less intermediate between two species so that assigning such individuals to one or another species is not quite reliable (e. g. *D. complanatum* – *D. zeileri* on more sites in the Ore Mts, *D. oellgaardii* – *D. tristachyum* at Dívčí lávky in the Krkonoše Mts or *D. complanatum* – *D. issleri* on the right bank of the Lipno reservoir in the Bohemian Forest). Such plants require further detailed study. It is possible that they represent  $F_1$  hybrids between hybridogeneous *Diphasiastrum* species and their original parents; considering close affinity and equal number of chromosomes  $2n = 46$ , such a possibility cannot be excluded. Attempts to interpret the origin of such “transitional” types by means of hybridization have been already published. On one locality in the Appalachian Mts (North Vermont, USA) plants were discovered and described by Gilman (1994) as *D. digitatum* × *D. /×/ sabinifolium*. In 1997, the same author collected in the same area also plants which he preliminarily classified as a hybrid combination *D. /×/ sabinifolium* × *D. tristachyum* (Gilman, in litt.). Had the existence of such hybrids been proved by e. g. isozyme analysis, their description would considerably simplify the taxonomical study of the whole genus *Diphasiastrum* and consequently made their determination easier.

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## Souhrn

Před rokem 1986 byla v České republice známa jen jediná lokalita (PR Pod Popelní horou na Šumavě) se společným výskytem více než dvou druhů plavuníků. Později, zejména však po roce 1990, bylo při floristickém výzkumu objeveno v různých územích Čech dalších 9 nalezišť, na nichž rostou 3 a více druhů rodu *Diphasiastrum* (obr. 1, tab. 3). Všech 6 středoevropských zástupců rodu (*D. alpinum*, *D. complanatum*, *D. issleri*, *D. oellgaardii*, *D. tristachyum* a *D. zeileri*) roste na ploše jen asi 4000 m<sup>2</sup> na lyžařské sjezdovce ve Špindlerově Mlýně v Krkonoších (podobně jako na sjezdovce na východním svahu Zwieselbergu na rakouské Šumavě). Plavuník *Oellgaardii*, před několika desetiletími doložený z české Šumavy, dnes v tomto území nezvěstný, se vyskytuje na Černé sjezdovce ve Špindlerově Mlýně na jediném známém existujícím nalezišti v ČR. Rada druhů byla v některých fy-

tachorionech zjištěna vůbec poprvé (*D. oellgaardii* v Krkonoších, *D. alpinum* a *D. tristachyum* v Jihlavských vrších, *D. alpinum* v Orlických horách, *D. alpinum* a *D. zeilleri* v Tepelských vrších). Jednotlivé druhy plavuníků se neobjevují na společných lokalitách najednou, ale osídlují je postupně.

Všechny popisované lokality se nacházejí pouze v Čechách (na Moravě nebyla dosud zjištěna žádná) v submontánním až nižším montánním stupni v rozmezí nadmořských výšek od 620 do 1060 m, téměř výhradně na plochách silně ovlivněných lidskou činností, na nichž buď před časem došlo k úplné destrukci vegetace anebo kde probíhá její periodické narušování: pískovny a jiné materiálové jámy, důlní odvaly, náspy nedávno vybudovaných komunikací, lyžařské sjezdovky, plochy po odstraněných hraničních ženíjních zátarasech při západních hranicích státu atd. Společnými charakteristikami všech těchto ploch je buď úplná nebo téměř úplná absence dřevin, nízká pokryvnost bylinného patra a naopak velká pokryvnost patra mechového, v němž jsou zastoupeny především různé druhy rodu *Polytrichum*, z lišejníků pak zejména zástupci rodu *Cladonia*. Nezřídka se nacházejí na plochách s výsktem plavuníků i menší či větší plochy zcela bez vegetace.

Ve všech případech se na lokalitách více druhů rodu *Diphasiastrum* vyskytují další zástupci řádu *Lycopodiales*, vždy *Lycopodium clavatum* a buď *Huperzia selago* nebo *Lycopodium annotinum*, někdy i oba posledně jmenované druhy společně. Mimo podrobně popisované lokality, s výsktem více než 2 druhů plavuníků, byly v letech 1991–1998 ve zkoumaných územích objeveny i další nové lokality, na nichž rostou společně dva různé druhy rodu *Diphasiastrum*. Řadu nově zjištěných nalezišť s výsktem jen jediného druhu plavuníku v této práci neuvádíme.

Všechny plavuníky jsou druhy obligátně acidofilní, rostoucí na půdách silně až velmi silně kyselých (tab. 1, 2), takže nebyvalý nárůst počtu jejich lokalit je možné dávat do souvislosti s velkoplošným dlouhodobým působením imisí a v důsledku toho stoupající kyselostí půd. Tím je možné vysvětlit i skutečnost, že zatímco *D. alpinum* bylo až do velmi nedávné doby známo v ČR jen z nadmořských výšek nad 800 m, dnes známe výskyt už v 620 m a jmenovaný druh se objevil i v územích, odkud nikdy nebyl znám (Orlické hory, Jihlavské a Tepelské vrchy).

Jak vyplývá z analýzy historického a současného rozšíření *D. tristachyum* v ČR (obr. 2), jednotlivé lokality plavuníků nemají příliš dlouhé trvání. Po čase zanikají a jinde vznikají naleziště nová, což umožňuje tvorba obrovského množství lehkých spor a jejich velmi snadná šířitelnost vzduchem. Protože jsou plavuníky typickými druhy iniciačních fází sukcese, je hlavní příčinou jejich zániku sukcesní stárnutí vegetace (úplné zapojení bylinného patra konkurenčně zdatnějšími druhy, zastínění dřevinami).

Pasivní ochrana jednotlivých druhů rodu *Diphasiastrum* je z hlediska delšího časového horizontu neúčinná. Předpokladem účinné ochrany je pravidelný monitoring na lokalitách, studium ekologie jednotlivých druhů (nedostatečně znalosti jsou zejména o ekologii gametofytů a délce trvání jednotlivých stádií ontogenetického vývoje). V rámci managementu zaměřeného na dlouhodobější udržení výskytu plavuníků na jejich nalezištích je nutné trvale blokovat sukcesí a na sousedních plochách dostatečně narušovat nebo zcela odstraňovat vegetaci, aby znovu vznikala taková mladá sukcesní stadia, do nichž by se mohli zástupci rodu *Diphasiastrum* z těsného sousedství rozšiřovat.

Určování dospělých (plodných rostlin) by nemělo činit potíže a při určitých zkušenostech je poměrně snadná i determinace dobře vyvinutých sterilních rostlin. Potíže činí určování velmi mladých prýtlů, na nichž obvykle ještě nejsou dostatečně vyvinuté znaky nezbytné pro spolehlivou determinaci. Výjimečně mohou nastat problémy i s určováním některých dospělých, dobře vyvinutých (i plodných) rostlin, které by mohly být  $F_1$  hybridy. Takové rostliny, u nás sbírané kupř. na Šumavě, vyžadují další studium.

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