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Flora of springs in the Polish Tatra Mountains – habitat and phytosociological characteristics of crenophiles

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Abstract: The flora of 179 springs in Tatra National Park was studied between 2003-2006. These springs represent complete diversity in the region with respect to altitude (from 900 to 1960 m a.s.l.), kind of bedrock (on siliceous and carbonate bedrock) and spring discharge (from 0.1 to >3500 l/s), and they also represent various ecomorphological types (mainly rheo- and helocrenes). In the springs, 239 plant taxa were recorded (60 mosses, 51 liverworts and 128 taxa of vascular plants). Among these species, 13 taxa (*Arabis soyeri* subsp. *subcoriacea, Bryum schleicheri, Cardamine amara, Dichodontium palustre, Epilobium alsinifolium, E. anagallidifolium, Heliosperma quadridentatum, Palustriella commutata, Philonotis calcarea, P. seriata, Rhizomnium magnifolium, Scapania paludosa, S. uliginosa)* had an ecological optimum in crenic habitats (crenophiles). Ecological and phytosociological characteristics of these species, as well as their distribution in the investigated springs, were shown.

Key words: crenic flora, water-springs flora, spring ecosystem, *Montio-Cardaminetea*, Tatra Mountains, Tatra National Park

1. Introduction

Springs are usually small dimension habitats which are strongly related to groundwater outflow. Particular habitat conditions, mainly low and constant water temperature and high air humidity throughout the year, determine their peculiar floristic composition (Zechmeister 1993; Valachovič 2001). Springs focus taxa which are found only in crenic habitats (crenobionts) or have their favourite habitat there (crenophiles) (Hadač 1983; Zechmeister & Mucina 1994; Cantonati *et al.* 2006).

Crenic flora is highly diverse. Plants associated mainly with rush and sedge vegetation (class *Phragmitetea*), spring vegetation (*Montio-Cardaminetea),* wet meadows (*Molinio-Arrhenatheretea*) and swamps (*Alnetea glutinosae*) dominate on lowlands (Wołejko 2000a, 2000b, 2000c, 2000d; Gawenda 2001; Kucharski 2007; Osadowski 2010). In the montane regions, species connected with the *Montio-Cardaminetea*, *Scheuchzerio-Caricetea fuscae, Mulgedio-Aconitetea* classes play the main role (Stuchlik 1968; Mamcarz 1978; Krause & Wika 2009).

The flora of springs, especially in the mountains, is one of the less known types of biocenosis in our country, also in the Polish part of the Tatra Mountains, even though they are one of the most important crenal regions in Poland. The only information about this subject comes from the interwar period (Szafer *et al.* 1923; Szafer & Sokołowski 1927; Pawłowski *et al.* 1928) and from 1980s. (Balcerkiewicz 1984). This knowledge is incomplete, describes only single, partly characterized plant communities, does not reflect the existing diversity of crenic flora, and does not explain its circumstances. Spring vegetation in the Slovakian part of the Tatras is much better known (Hadač 1956; Šoltes 1989; Valachovič 2001).

The aim of this study is to present ecological and phytosociological characteristics of the crenophiles – rare and endangered plant species which have their favourite habitat in springs. Additionally a short characteristic of the whole spring flora diversity is presented to provide background for a detailed study of 13 identified species of crenophiles in springs in the Polish Tatra Mountains.

2. Study area

The research was conducted in the Polish Tatra Mts. within boundaries of Tatra National Park (TNP) (21164

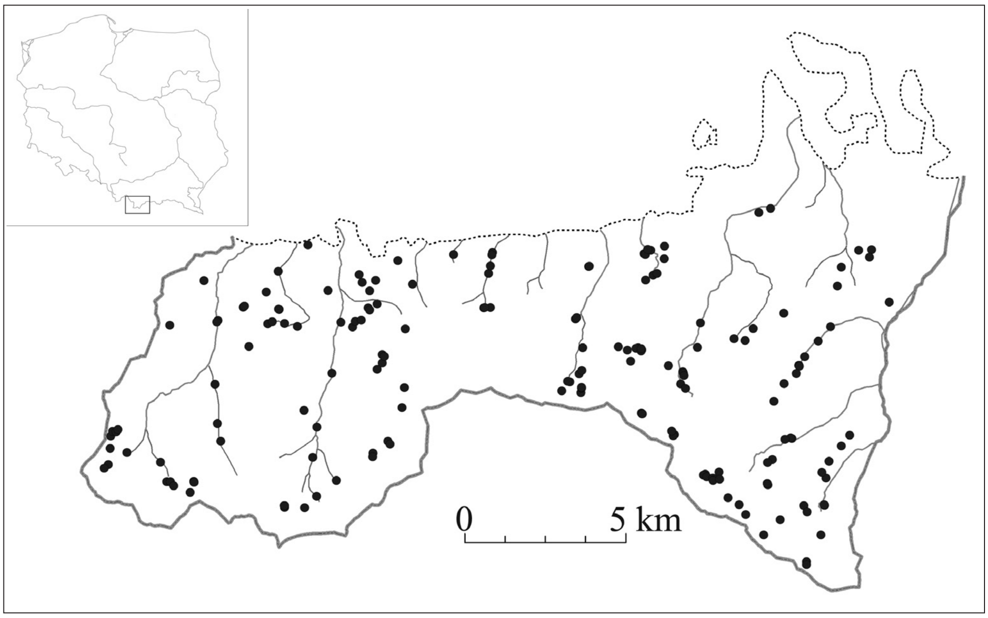

Fig. 1. Location of 179 springs investigated in the Tatra National Park

ha) (Fig. 1). The Tatra Mts. belong to regions with the greatest diversity and highest concentrations of groundwater outflows in Poland (Wit-Jóźwik 1974; Dynowska 1987). Water outflows are irregularly distributed because of different geological and morphological conditions. Most of the springs are focused on the crystalline basement, and fewest are located in the upper karst (Łajczak 1996). Spring distribution along the elevation gradient is closely related to geological structure. Almost all water outflows occur in the lower montane belt on calcareous substrates. In other altitude ranges, outflows are mainly fed by water coming from crystalline rocks.

3. Material and methods

The results presented in this paper are part of a larger study which focused on the diversity of spring flora and vegetation and was conducted during years 2003-2006 in the Tatra National Park (Smieja 2009). Springs are defined here as areas under the direct influence of groundwater coming to the surface (crenal), i.e. the zone where the groundwater comes to the surface (euctenal), with the run off zone immediately adjacent to it (hypocrenal), until the stream forms or the water is lost.

Plant species compositions and basic environmental variables were recorded within the springs. The altitude of each springs was obtained using a topographic map 1:10 000 (Zarząd Topograficzny Sztabu Generalnego WP 1992). Water temperature and pH were measured in situ using portable instruments (mercurial thermometer with 0.1°C resolution, pH-meter Elmetron CP-104). The bedrock (calcareous or siliceous) was identified in the field with the help of geologic maps 1: 10 000 (Gózik & Sokołowski 1958-1980).

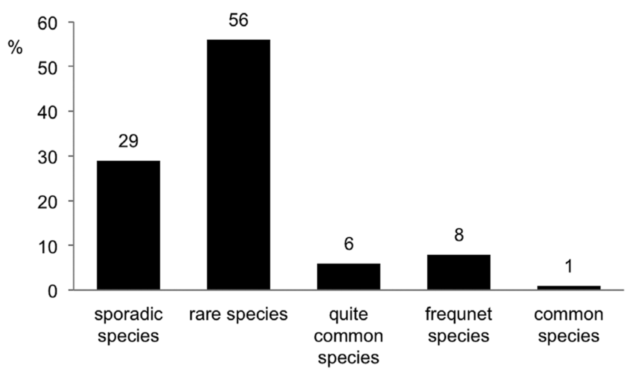

Fig. 2. Percentage participation of species noted in springs in the frequency classes
Explanations: sporadic species <1.0%, rare 1.0-10.0%, quite common 10.1-20.0%, frequent 20.1-50.0%, common >50.0%)

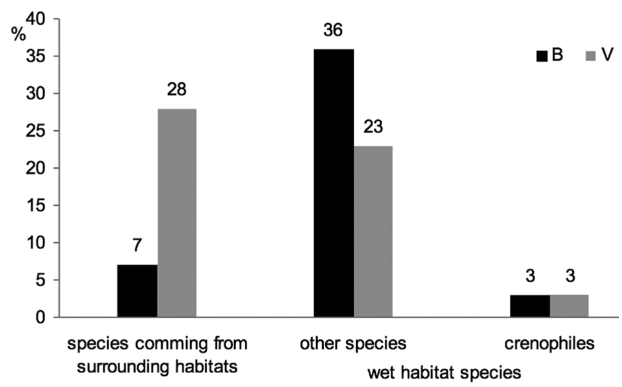

Fig. 3. Habitat distribution of spring flora
Explanations: B – bryophytes, V – vascular plants

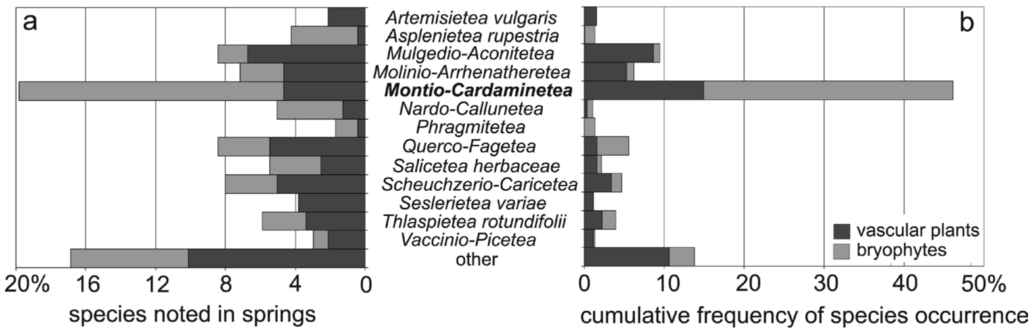

Fig. 4. Phytosociological affinity of species noted in the studied springs (a) and their cumulative frequency of occurrence (b) (according to Matuszkiewicz 2005; Dierssen 2001; Kliment *et al.* 2007)

Samples were taken from 179 springs which represent complete diversity in the region with respect to altitude (from 900 to 1960 m a.s.l.), kind of bedrock (on siliceous and carbonate bedrock) and spring discharge (from 0.1 to >3500 l/s). They also represent various ecomorphological types (mainly rheo- and helocrenes). Environmental descriptions of all investigated springs are available in Smieja (2009). Nomenclature of taxa follows Mirek *et al.* (2002), Ochyra *et al.* (2003), and Klama (2006).

Habitat conditions and distributions of the crenofiles were presented on ecodiagrams against the background of all investigated springs.

4. Results

In the investigated springs, a total of 239 plant taxa were recorded: 60 mosses, 51 liverworts and 128 taxa of vascular plants (Appendix 1). In crenic flora, plants found in springs with low frequency (below 10%) dominate (Fig. 2). These are mainly highly specialized wet habitat species (e.g. high-mountain calcifugous or mountain calciphilous plants). A high number of taxa are also species characteristic of other types of habitats (e.g. *Prenanthes purpurea, Thuidium tamariscinum*) and enter the crenon of the surroundings because of their small size.

Plants occurring in springs with frequencies above 10% are rare. These are wide ecological amplitude species growing in a variety of wet habitats, for example *Brachythecium rivulare, Deschampsia caespitosa, Viola biflora* and species peculiar to spring habitats (e.g. *Cardamine amara, Palustriella commutata, Philonotis seriata*). Only two taxa, *Viola bliflora* and *Palustriella commutata*, are common in springs (with a frequency of over 50%).

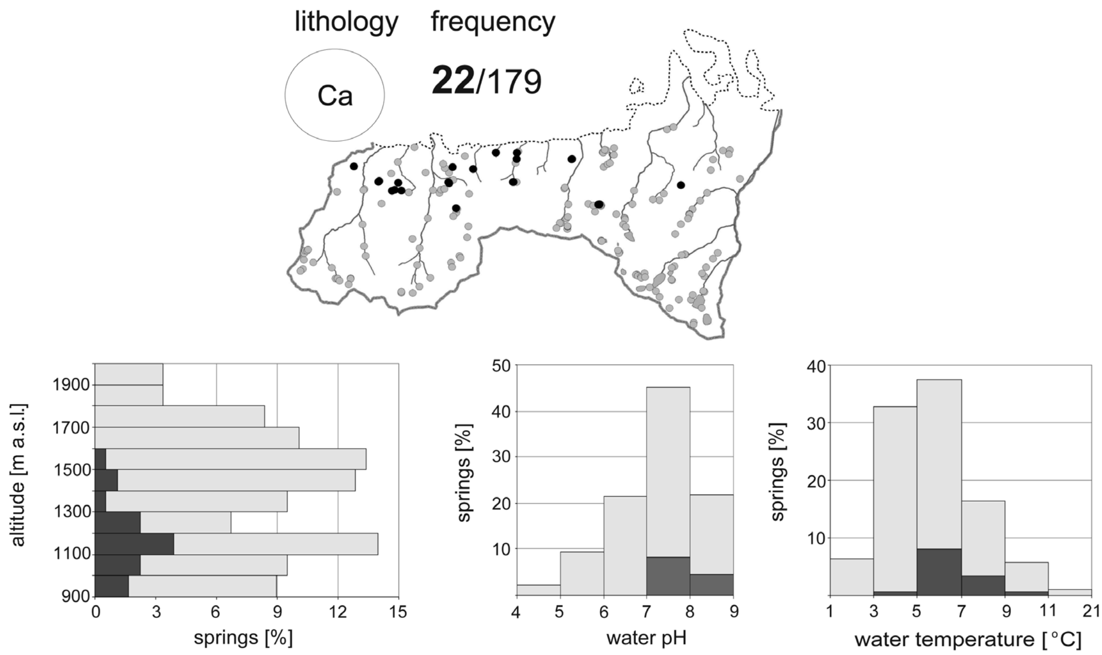

Fig. 5. The distribution and habitat range of *Arabis soyeri* Reut. & A. Huet subsp. *subcoriacea* (Gren.) Breistr in the Tatra National Park springs (Ca – calcareous substrata). This species is restricted to the calcareous substrate, and therefore most of its localities occur in the lower montane belt in the Western Tatras

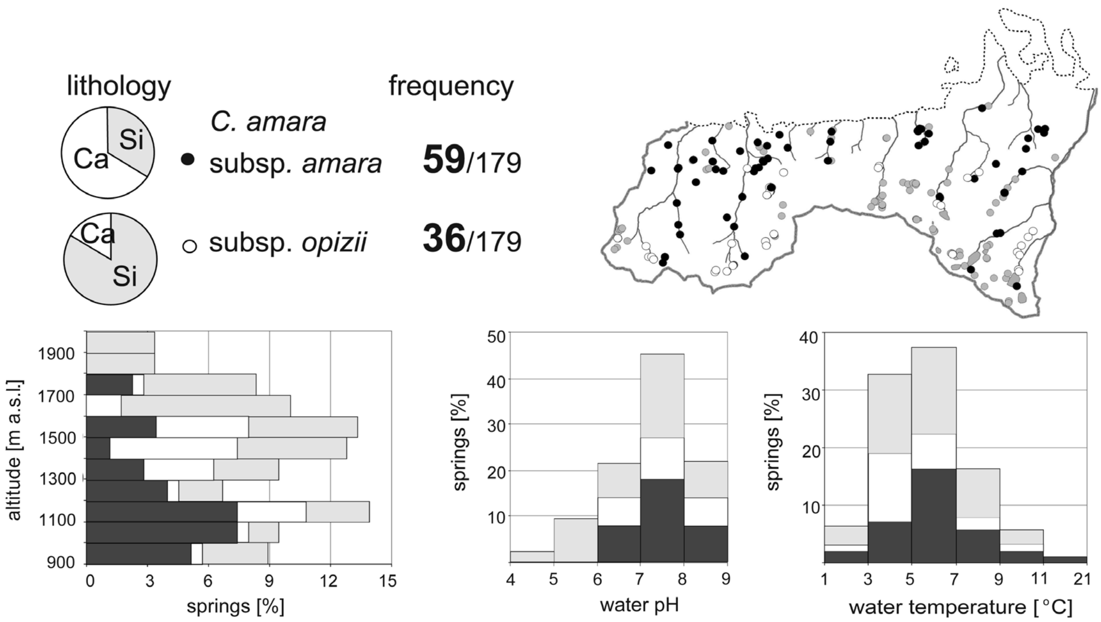

Fig. 6. The distribution and habitat range of *Cardamine amara* L. subsp. *amara* and *C. amara* L. subsp. *opizii* (J. Presl & C. Presl) Čelak in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). The species is characteristic of crenal communities of the *Montio-Cardaminetea* class. In the Tatra springs, two subspecies, altitudinally differentiated, are distinguished. *C. amara* subsp. *amara* is restricted to the lower montane belt, while *C. amara* subsp. *opizii* is restricted to the upper montane and subalpine belt. In some springs, there are intermediate forms between these subspecies, which are difficult to classify because of mixed traits

Plants connected with permanently wet habitats dominate in crenic flora, and about 6% of them are crenophiles. Other plants, even those occurring in the investigated objects with high constancy, are species coming from surrounding habitats (Fig. 3). In springs, they usually grow singly, reveal a reduced viability, and their species composition depends on the surrounding vegetation. Vascular plants dominate in this group (e.g. *Oxalis acetosella, Picea abies, Soldanella carpatica)*.

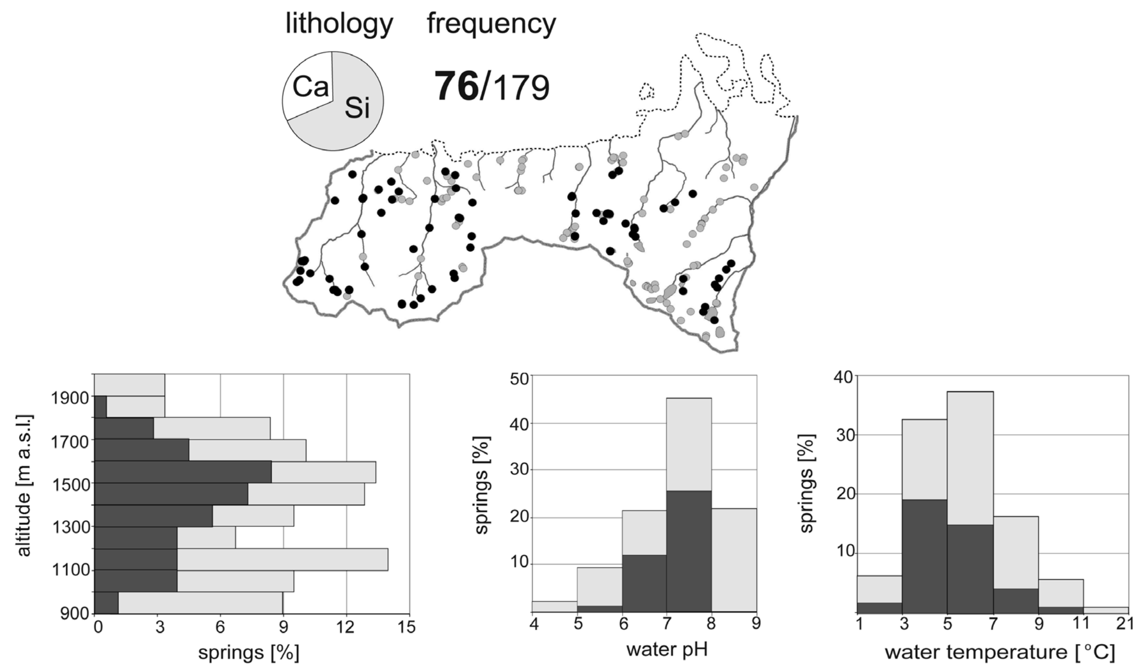

Fig. 7. The distribution and habitat range of *Epilobium alsinifolium* Vill. in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). The species characteristic of the order *Montio-Cardaminetalia* (high altitude crenal communities). In springs, it is interspersed on the moss layer and its cover value is low,. *E. alsinifolium* shows high diversity in respect to altitude, but prefers the upper montane and subalpine belt. In the lower montane belt, the taxon was noted in springs with low water temperature (the average – 6 °C)

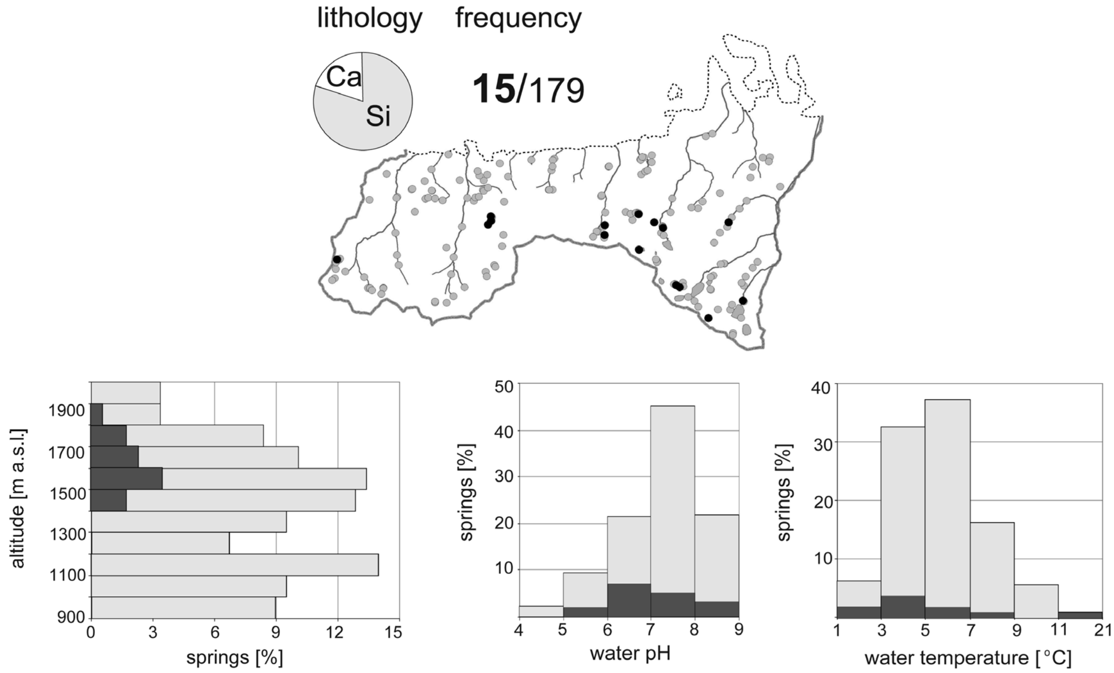

Fig. 8. The distribution and habitat range of *Epilobium anagallidifolium* Lam. in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). The species characteristic of the *Montio-Cardaminetalia* order, rare in the studied springs, where it grows singly. The species occurs mainly in the upper montane and subalpine belt, irrespective of bedrock substrates and water pH

In a phytosociological sense, in terms of the total number of taxa and their frequency, the carstic flora is dominated by characteristic and differential species of the *Montio-Cardaminetea* class. Species of montane tall-herb vegetation (*Mulgedio-Aconitetea)* are also numerous (Fig. 4).

Among the taxa found in the investigated springs, 13 species have an ecological optimum in crenal habitats: 5 taxa of vascular plants, and 8 species of bryophytes. Below, the general ecological and phytosociological characteristics of the crenophiles are

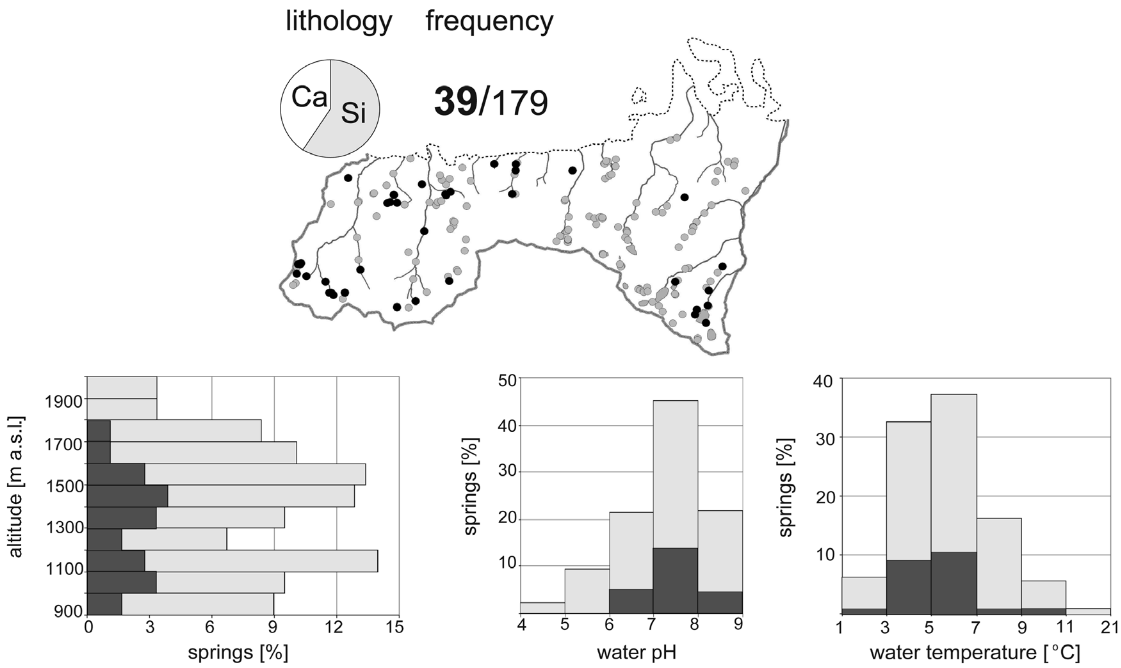

Fig. 9. The distribution and habitat range of *Heliosperma quadridentatum* (Murray) Schinz & Thell. in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). The species, characteristic of the *Cratoneuretum falcati* association, is common in springs, where it forms tufts or small patches. It occurs in sunny spaces in springs from the lower montane belt up to the subalpine belt. *H. quadridentatum* reaches its optimum development in springs on calcareous bedrock or/and with high water pH

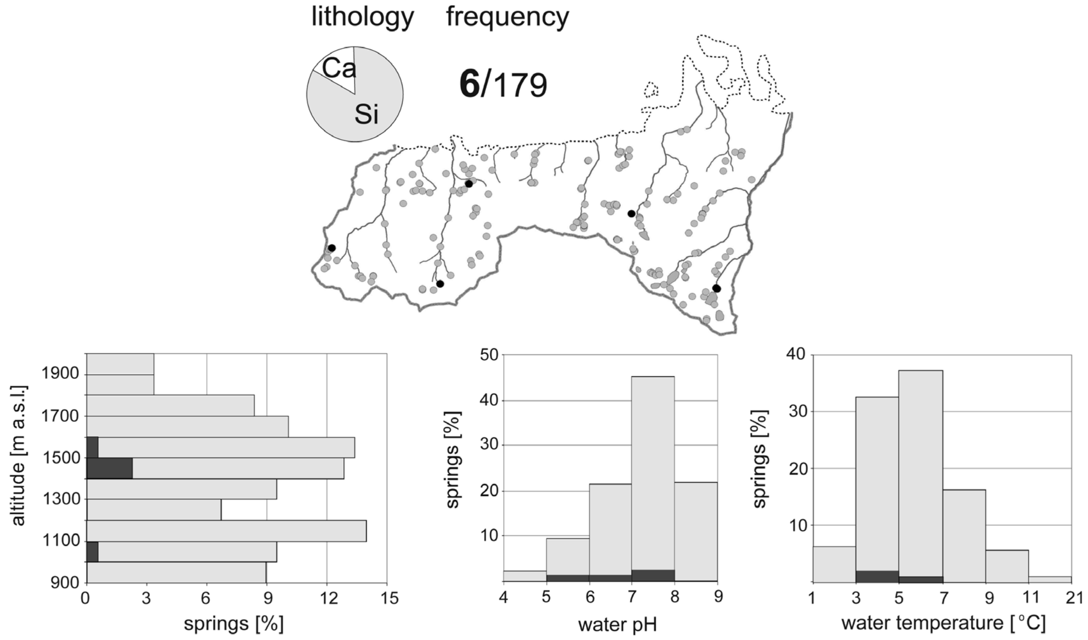

Fig. 10. The distribution and habitat range of *Bryum schleicheri* Schwägr. in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). A moss characteristic of the *Montio-Cardaminetea* class. It forms small patches in springs located in the upper montane belt on siliceous substrates, and in one spring on calcareous substrates in the lower montane belt

presented, as well as their distribution in TNP (Figs. 5-17).

5. Discussion

In the spring flora, species primarily connected with the crenal habitat are particularly valuable. Because spring habitats are uncommon in the landscape and are often destroyed by human activity, crenophiles are rare and endangered species. Among plants, there are no crenobiotic taxa, which are represented only by animals (Cantonati *et al.* 2006).

Investigations of 179 springs in TNP show that, although individual springs are small in size and are

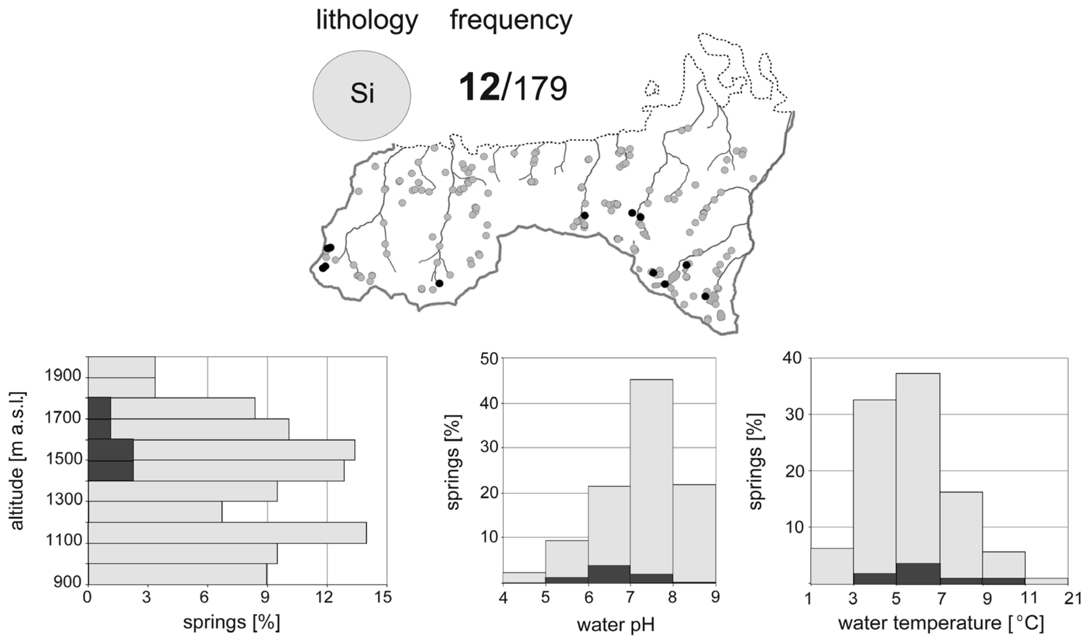

Fig. 11. The distribution and habitat range of *Dichodontium palustre* (Dics) M. Stech in the Tatra National Park springs (Si – siliceous substrata). A moss characteristic of the *Caltho-Dicranelletum squarrosae* association. Rare in springs. The species usually forms dense patches in crenons situated in the upper montane and subalpine belt in the crystalline part of TNP

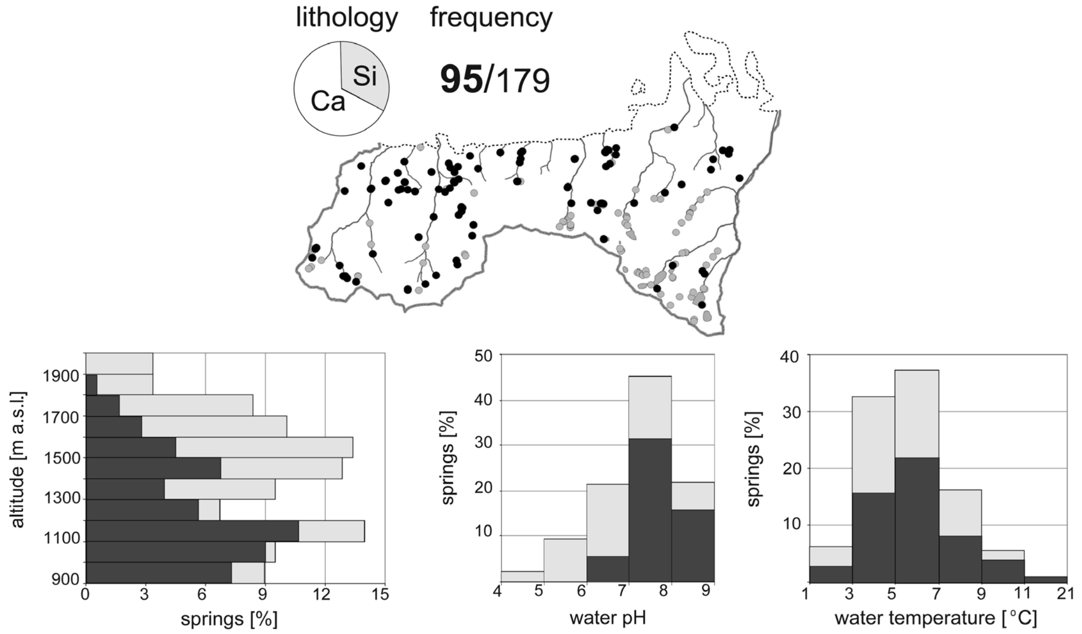

Fig. 12. The distribution and habitat range of *Palustriella commutata* (Hedw.) Ochyra in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). The species, characteristic of the *Cratoneurion commutati* alliance (montane and alti-montane crenal communities of calcareous substrates). It forms extensive patches, and often overgrows the whole spring's area (especially in helocrenes). This is a calcicole moss, even though it also occurs in the crystalline part of TNP, and always in springs with high water pH. This species shows a wide altitudinal distribution

species poor (average 15 species) (Smieja 2009), they create a type of habitat gathering a high number of species. In comparison with the species richness of the Polish Tatras, the species noted in springs (239 taxon) make up about: 13% of mosses flora (Ochyra 1996), 25% of liverworts flora (Szweykowski 1996), and 13% of the flora of vascular plants (Mirek & Piękoś-Mirkowa 1996). The high taxa richness of crenic flora is due to the high diversity of the crenic habitat in the Tatara Mts., and absence of numerous species with wide ecological

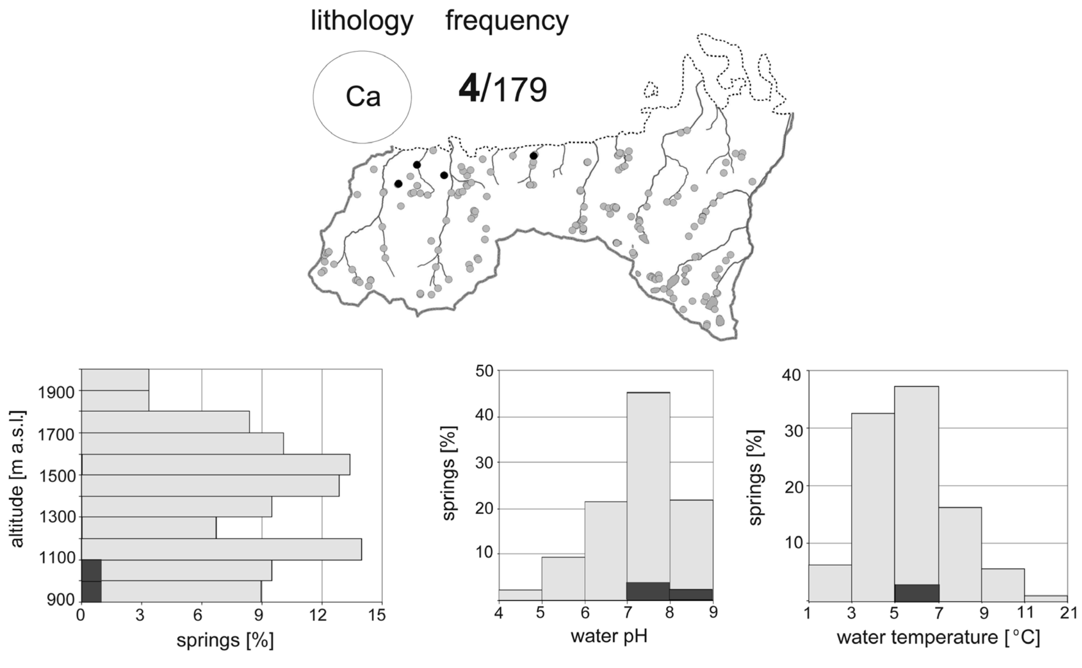

Fig. 13. The distribution and habitat range of *Philonotis calcarea* (Bruch & Schimp.) Schimp. in the Tatra National Park springs (Ca – calcareous). A moss characteristic of the *Cratoneuretum falcati* association, is rare in investigated springs. It forms small tufts in springs on calcareous bedrock in the lower montane belt of the Western Tatras

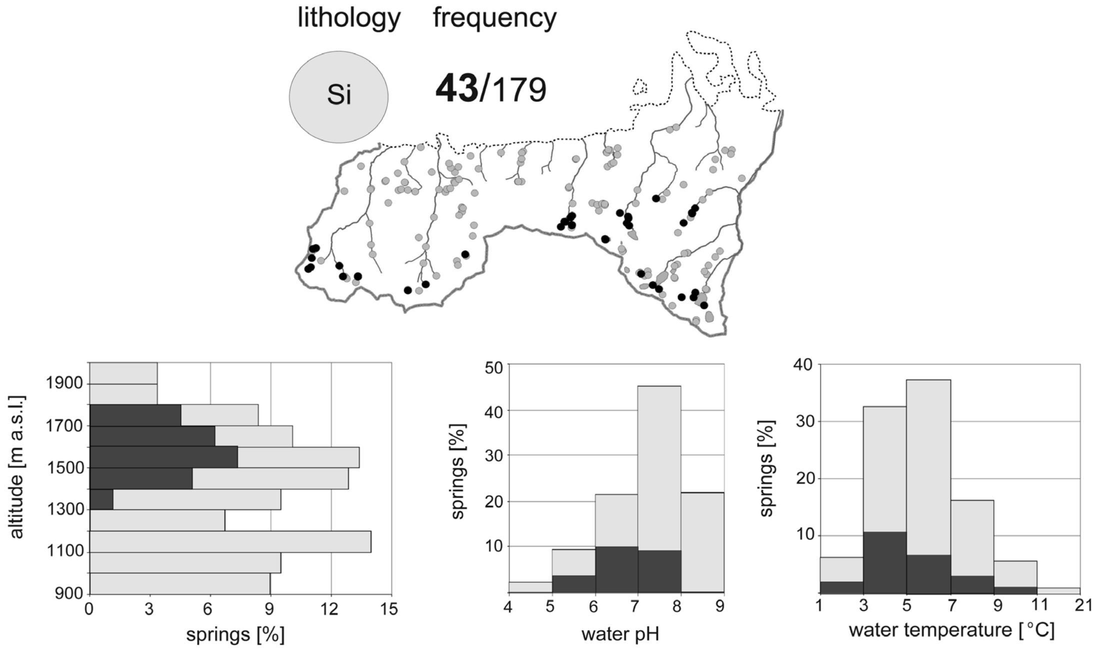

Fig. 14. The distribution and habitat range of *Philonotis seriata* Mitt. in the Tatra National Park springs (Si – siliceous substrata). A moss characteristic of the *Philonotidion seriatae* alliance (alpine moss-rich crenal communities on siliceous substrates). It forms extensive patches in springs on siliceous bedrock in the upper montane belt and the subalpine belt

amplitude. A numerous group of plants in crenic flora comprises species not connected with wet habitat, but which came to the crenal from the surrounding plant communities.

Species described in this work as crenophiles are mainly mountain plants also distrubuted in habitats with similar environmental conditions, for example: along flushes and rills, in bogs, and on wet rock ledges (Thiebaut *et al.* 1998; Hájková *et al.* 2006). The main ecological factors investigated in this work influencing Tatra crenophile distribution are: altitude, type of bedrock (siliceous/ carbonate bedrock) and pH of

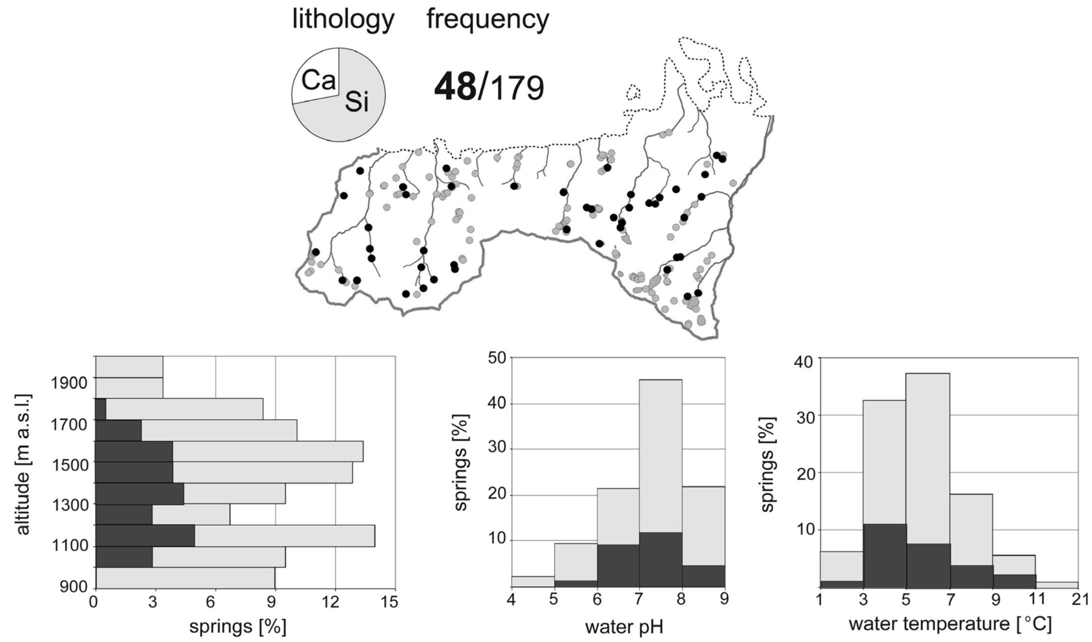

Fig. 15. The distribution and habitat range of *Rhizomnium magnifolium* (Horik.) T. J. Kop in the Tatra National Park springs (Ca – calcareous, Si – siliceous substrata). A moss characteristic of the *Montio-Cardaminetea* class. In springs, it mainly occurs as small tufts in places not flooded directly. This species shows a wide ecological amplitude. It is distributed from the lower montane belt up to the subalpine belt, regardless of the geological basement

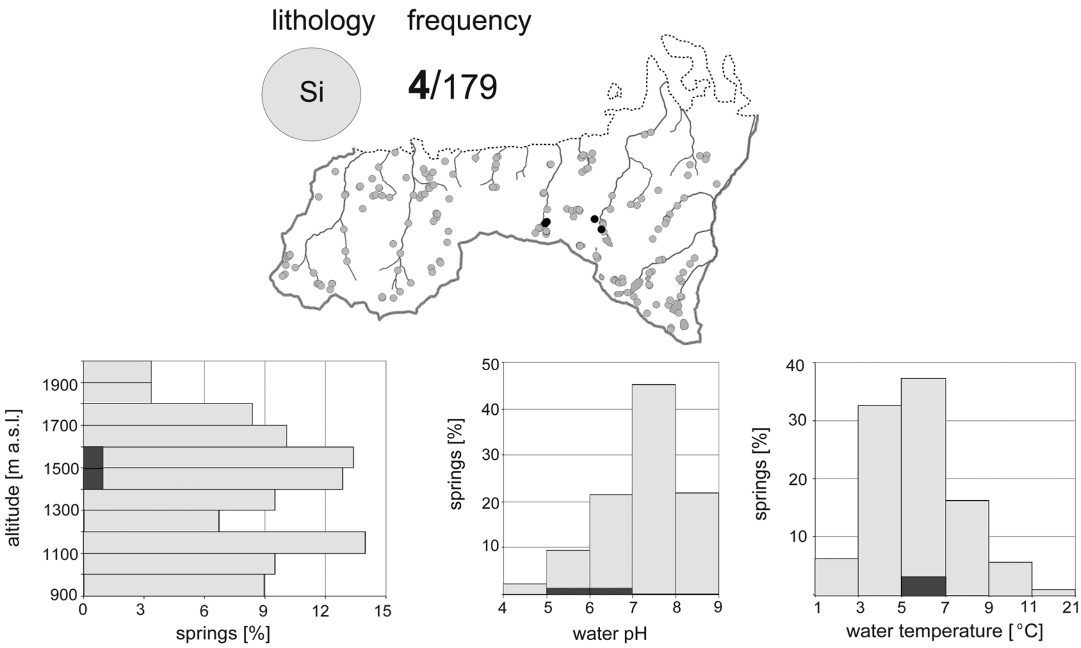

Fig. 16. The distribution and habitat range of *Scapania paludosa* (Müll. Frib.) Müll. Frib. in the Tatra National Park springs (Si – siliceous substrata). This liverwort, characteristic of the *Philonotidion seriatae* alliance, is entirely restricted to bryophyte-dominated springs, where it forms extensive, swollen turfs. This species was noted in springs in the upper montane belt in the crystalline part of TNP

water. The connection between the investigated factors is very important in the study area. The occurrence of calcareous springs mainly of the lower montane belt and siliceous springs up to the upper montane belt causes a reduction in the altitudinal ranges of calcicole species (*Arabis soyeri* subsp. *subcoriacea, Philonotis calcarea*) and an increased range of "granitic" species (*Scapania uliginosa*).

The occurrence of *Palustriella commutata* is interesting. This species, described as a typically calcicole moss (Bain & Proctor 1980), occurs also in the crystalline Tatras on siliceous bedrock. There the *Palustriella*

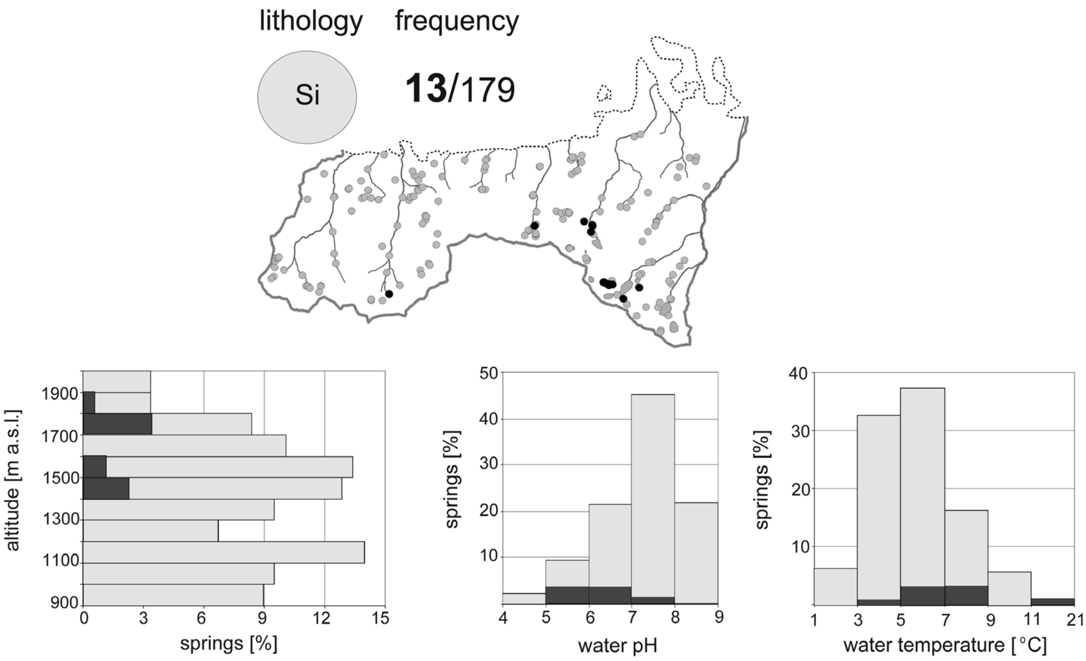

Fig. 17. The distribution and habitat range of *Scapana uliginosa* (Sw. ex Lindenb.) Dumort. in the Tatra National Park springs (Si – siliceous substrata). A liverwort characteristic of the *Scapanietum uliginosae* association. It forms an almost homogeneous layer covering large parts of springs. This species is related to groundwater outflow on siliceous bedrock up to the timberline. Localities were noted within springs with relatively high water temperature during the day

commutata is probably associated with groundwater draining the calcareous rocks and outflowing in the crystalline area. One such interpretation of the occurrence of these species supports a higher than expected value of water pH. In the case of bryophytes growing in water, or flooded, water chemistry is more important than the type of substrate (Hájková & Hájek 2003). The springs with water mineralization substantially different from the surrounding rocks were mentioned by Oleksynowa & Komornicki (1996).

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Appendix 1. List and frequency of the taxa recorded in the investigated springs (crenophiles are marked in bold). Frequency in springs: number of occurrences, % occurrences

Vascular plants

Abies alba Mill. 7, 3.9; *Acer pseudoplatanus* L. 1, 0.6; *Aconitum firmum* Rchb. 54, 30.2; *Agrostis stolonifera* L. 3, 1.7; *Alchemilla glabra* Neygenf. 10, 5.6; *A. monticola* Opiz 1, 0.6; *A. xanthochlora* Rothm. 2, 1.1; *Alchemilla* sp. 2, 1.1; *Arabis alpina* L. 24, 13.4; ***A. soyeri*** Reut. & A. Huet **subsp. *subcoriacea*** (Gren.) Breistr. 22, 12.3; *Asplenium viride* Huds. 1, 0.6; *Athyrium distentifolium* Tausch ex Opiz 1, 0.6; *A. filix-femina* (L.) Roth 1, 0.6; *Bellidiastrum michelii* Cass. 8, 4.5; *Calamagrostis arundinacea* (L.) Roth 3, 1.7; *C. varia* (Schrad.) Host 2, 1.1; *C. villosa* (Chaix) J. F. Gmel. 2, 1.1; *Caltha laeta* Schott, Nyman & Kotschy 57, 31.8; *Campanula polymorpha* Witasek 2, 1.1; ***Cardamine amara*** L. subsp. ***amara*** 59, 33.0; ***C. amara*** L. **subsp. *opizii*** (J. Presl & C. Presl) Čelak. 36, 20.1; *C. flexuosa* With. 8, 4.5; *C. trifolia* L. 1, 0.6; *Cardaminopsis arenosa* (L.) Hayek 1, 0.6; *C. neglecta* (Schult.) Hayek 1, 0.6; *Carex brachystachys* Schrank & K. Moll 1, 0.6; *C. echinata* Murray 1, 0.6; *C. flava* L. 3, 1.7; *C. lepidocarpa* Tausch 5, 2.8; *C. nigra* Reichard 4, 2.2; *C. sempervirens* Vill. 3, 1.7; *C. sylvatica* Huds. 5, 2.8; *Cerastium cerastoides* (L.) Britton 8, 4.5; *C. fontanum* Baumg. s. str. 6, 3.4; *C. tatrae* Borbás 8, 4.5; *Chaerophyllum hirsutum* L. 65, 36.3; *Chrysosplenium alternifolium* L. 54 30.2; *Cirsium palustre* (L.) Scop. 1, 0.6; *Coeloglossum viride* (L.) Hartm. 1, 0.6; *Crepis paludosa* (L.) Moench 36, 20.1; *Cystopteris fragilis* (L.) Bernh. 3, 1.7; *C. montana* (Lam.) Desv. 13, 7.3; *Dactylorhiza majalis* (Rchb.) P. F. Hunt & Summerh. 1, 0.6; *Dentaria glandulosa* Waldst. & Kit. 9, 5.0; *Deschampsia caespitosa* (L.) P. Beauv. 80, 44.7; *D. flexuosa* (L.) Trin. 2, 1.1; ***Epilobium alsinifolium*** Vill. 76, 42.5; ***E. anagallidifolium*** Lam. 15, 8.4; *E. montanum* L. 2, 1.1; *Equisetum palustre* L. 4, 2.2; *Eriophorum angustifolium* Honck. 5, 2.8; *Euphrasia salisburgensis* Hoppe 3, 1.7; *Fagus sylvatica* L. 3, 1.7; *Festuca carpatica* F. Dietr. 1, 0.6; *F. picta* Kit. 1, 0.6; *F. rubra* L. s. str. 1, 0.6; *Galeobdolon luteum* Huds. 3, 1.7; *Galium anisophyllon* Vill. 8, 4.5; *G. schultesii* Vest 1, 0.6; *Gentiana asclepiadea* L. 2, 1.1; *Geranium robertianum* L. 23, 12.8; *Geum urbanum* L. 5, 2.8; ***Heliosperma quadridentatum*** (Murray) Schinz & Thell. 39, 21.8; *Huperzia selago* (L.) Bernh. ex Schrank & Mart. 2, 1.1; *Impatiens noli-tangere* L. 3, 1.7; *Juncus filiformis* L. 2, 1.1;

J. triglumis L. 4, 2.2; *Leontodon pseudotaraxaci* Schur 1, 0.6; *Leucanthemum waldsteinii* (Sch. Bip.) Pouzar 26, 14.5; *Linum catharticum* L. 4, 2.2; *Listera ovata* (L.) R. Br. 1, 0.6; *Luzula alpino-pilosa* (Chaix) Breistr. 26, 14.5; *L. luzuloides* (Lam.) Dandy & Wilmott 1, 0.6; *L. sylvatica* (Huds.) Gaudin 6, 3.4; *Moneses uniflora* (L.) A. Gray 1, 0.6; *Mutellina purpurea* (Poir.) Thell. 18, 10.1; *Mycelis muralis* (L.) Dumort. 13, 7.3; *Myosotis decumbens* Host subsp. *variabilis* (Angelis) Grau 5, 2.8; *M. nemorosa* Besser 17, 9.5; *Nardus stricta* L. 8, 4.5; *Oxalis acetosella* L. 25, 14.0; *Parnassia palustris* L. 6, 3.4; *Pedicularis oederi* Vahl 1, 0.6; *P. verticillata* L. 2, 1.1; *Petasites albus* (L.) Gaertn. 42, 23.5; *Phyteuma orbiculare* L. 2, 1.1; *Ph. spicatum* L. 2, 1.1; *Picea abies* (L.) H. Karst. 19, 10.6; *Pinguicula alpina* L. 1, 0.6; *P. vulgaris* L. 7, 3.9; *Pinus mugo* Turra1, 0.6; *Poa alpina* L. 23, 12.8; *P. granitica* Braun-Blanq 2, 1.1; *P. nemoralis* L. 1, 0.6; *P. remota* Forselles 1, 0.6; *P. trivialis* L. 10, 5.6; *Polygonum bistorta* L. 1, 0.6; *P. viviparum* L. 2, 1.1; *Polygonatum verticillatum* (L.) All. 1, 0.6; *Potentilla erecta* (L.) Raeusch. 1, 0.6; *Prenanthes purpurea* L. 4, 2.2; *Ranunculus lanuginosus* L. 2, 1.1; *R. repens* L. 3, 1.7; *Salix reticulata* L. 1, 0.6; *Sanicula europaea* L. 1, 0.6; *Saxifraga aizoides* L. 7, 3.9; *S. androsacea* L. 1, 0.6; *S. carpathica* Rchb. 8, 4.5; *S. wahlenbergii* Ball 1, 0.6; *Sedum alpestre* Vill. 1, 0.6; *Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart. 1, 0.6; *Senecio ovatus* (P. Gaert., B. Mey. & Scherb.) Willd. 2, 1.1; *S. subalpinus* W. D. J. Koch 8, 4.5; *Sesleria tatrae* (Degen) Deyl 5, 2.8; *Soldanella carpatica* Vierh. 18, 10.1; *Solidago alpestris* Waldst. & Kit. 3, 1.7; *Stellaria nemorum* L. 83, 46.4; *Stellaria uliginosa* Murray 2, 1.1; *Swertia perennis* L. 10, 5.6; *Tofieldia calyculata* (L.) Wahlenb. 5, 2.8; *Trisetum fuscum* (Kit. ex Schult.) Roem. & Schult. 1, 0.6; *Tussilago farfara* L. 1, 0.6; *Urtica dioica* L. 7, 3.9; *Veratrum lobelianum* Bernh. 2, 1.1; *Veronica alpina* L. 2, 1.1; *V. beccabunga* L. 2, 1.1; *V. serpyllifolia* L. 1, 0.6; *Viola biflora* L. 116, 64.8.

Bryophytes

Andreaea nivalis Hook. 2, 1.1; *Aneura pinguis* (L.) Dumort. 4, 2.2; *Anthelia juratzkana* (Limpr.) Trevis. 2, 1.1; *A. julacea* (L.) Dumort. 4, 2.2; *Barbilophozia floerkei* (F. Weber et D. Mohr) Loeske 4, 2.2; *Bazzania tricrenata* (Wahlenb.) Lindb. 1, 06; *Blepharostoma trichophyllum* (L.) Dumort. 1, 06; *Blindia acuta* (Hedw.) Bruch & Schimp. 5, 2.8; *Brachythecium rivulare* Schimp. 88, 49.2; *Bryum pseudotriquetrum* (Hedw.) P. Gaertn 79, 44.1; ***B. schleicheri*** Schwägr. 6, 3.4; *B. weigelii* Spreng. 7, 3.9; *Bucklandiella sudetica* (Funck) Bednarek-Ochyra & Ochyra 1, 06; *B. macounii* (Kindb.) Bednarek-Ochyra & Ochyra 2, 1.1; *B. microcarpa* (Hedw.) Bednarek-Ochyra & Ochyra 2, 1.1; *Calypogeia azurea* Stotler et Crotz 3, 1.7; *C. muelleriana* (Schiffn.) Müll. Frib. 1, 06; *Campylium stellatum* (Hedw.) Lange & C. E. O. Jensen 8, 4.5; *Cephalozia bicuspidata* (L.) Dumort. 8, 4.5; *C. lunulifolia* (Dumort.) Dumort. 1, 06; *Chiloscyphus pallescens* (Ehrh. ex Hoffm.) Dumort. 14, 7.8; *Ch. polyanthos* (L.) Corda 9, 5.0; *Cirriphyllum piliferum* (Hedw.) Grout 1, 06; *Climacium dendroides* (Hedw.) F. Weber & D. Mohr 2, 1.1; *Conocephalum conicum* (L.) Dumort. 1, 06; *C. salebrosum* Szweykowski, Buczkowska & Ochyra 16, 8.9; *Codriophorus acicularis* (Hedw.) P. Beauv. 4, 2.2; *Cratoneuron filicinum* (Hedw.) Spruce 30, 16.8; *Ctenidium molluscum* (Hedw.) Mitt. 2, 1.1; *Dichodontium pellucidum* (Hedw.) Schimp. 10, 5.6; ***Diobelonella palustris*** (Dicks.) Ochyra 12, 6.7; *Diplophyllum albicans* (L.) Dumort. 1, 06; *D. taxifolium* (Wahlenb.) Dumort. 1, 06; *Fissidens adianthoides* Hedw. 4, 2.2; *F. dubius* P. Beauv. 1, 06; *F. taxifolius* Hedw. 2, 1.1; *Fontinalis antipyretica* Hedw. 3, 1.7; *Harpanthus flotovianus* (Nees) Nees 3, 1.7; *Hygrohypnum cochlearifolium* (Venturi) Broth. 1, 06; *H. duriusculum* (De Not.) D. W. Jamieson 4, 2.2; *Hypnum cupressiforme* Hedw. 1, 06; *Jungermannia atrovirens* Dumort. 4, 2.2; *J. confertissima* Nees 1, 06; *J. obovata* Nees 13, 7.3; *J. pumila* With. 1, 06; *J. sphaerocarpa* Hook. 6, 3.4; *Kiaeria starkei* (F. Weber & D. Mohr) I. Hagen 1, 06; *Leiocolea bantriensis* (Hook.) Jörg. 2, 1.1; *Lepidozia reptans* (L.) Dumort. 3, 1.7; *Lophocolea bidentata* 1, 06; *Lophozia sudetica* (Nees ex Huebener) Grolle 6, 3.4; *L. ventricosa* (Dicks.) Dumort. 1, 06; *L. wenzelii* (Nees) Steph. 3, 1.7; *Marchantia polymorpha* L. subsp. *montivagans* Bischl. & Boisselier 22, 12,3; *M. polymorpha* L. subsp. *polymorpha* Bischl. & Boisselier 8, 4.5; *Marsupella emarginata* (Ehrh.) Dumort 2, 1.1; *M. sphacelata* (Gieseke ex Lindenb.) Dumort. 4, 2.2; *M. sprucei* (Limpr.) Bernet 1, 06; *Moerckia blyttii* (Moerch) Brockm. 1, 06; *Nardia scalaris* Gray 10, 5.6; *Oligotrichum hercynicum* (Hedw.) Lam. & DC. 11, 6.1; *Orthothecium intricatum* (Hartm.) Schimp. 1, 06; ***Palustriella commutata*** (Hedw.) Ochyra 95, 53.1; *P. decipiens* (De Not.) Ochyra 31, 17.3; *Pellia endiviifolia* (Dicks.) Dumort. 9, 5.0; *P. epiphylla* (L.) Corda 2, 1.1; *P. neesiana* (Gottsche) Limpr. 5, 2.8; *Pellia* sp. 25, 14.0; ***Philonotis calcarea*** (Bruch & Schimp.) Schimp. 4, 2.2; *Ph. fontana* (Hedw.) Brid. 5, 2.8; ***Ph. seriata*** Mitt. 43, 24.0; *Ph. tomentella* Molendo 3, 1.7; *Plagiochila asplenioides* (L. Mend. Taylor) Dumort. 10, 5.6; *P. porelloides* (Torrey ex Nees) Lindenb. 37, 20.7; *Plagiomnium affine* (Blandow ex Func) T. J. Kop. 3, 1.7; *P. elatum* (Bruch & Schimp.) T. J. Kop. 22, 12.3; *P. ellipticum* (Brid.) T. J. Kop. 2, 1.1; *P. medium* (Bruch & Schimp.) T. J Kop. 3, 1.7; *P. undulatum* (Hedw.) T. J. Kop. 15, 8.4; *Plagiothecium denticulatum* (Hedw.) Schimp. 2, 1.1; *P. platyphyllum* Mönk. 11, 6.1; *Platyhypnidium riparioides* (Hedw.) Dixon 6, 3.4; *Pleurocladula albescens* (Hook.) Grolle 1, 06; *Pohlia cruda* (Hedw.) Lindb. 1, 06; *P. wahlenbergii* (F. Weber & D. Mohr) A. L. Andrews 39, 21.8; *Polytrichastrum alpinum* (Hedw.) G. L. Sm. 2, 1.1; *P. formosum* (Hedw.) G. L. Sm. 1, 06; *Polytrichum commune* Hedw. 3, 1.7; *Porella cordaeana* (Huebener) Moore 5, 2.8; *Preissa quadrata* (Scop.) Nees 1, 06; *Radula lindenbergiana* Gottsche ex C. Hartm. 1, 06; *Rhizomnium punctatum* (Hedw.) T. J. Kop. 67, 37.4; ***Rh. magnifolium*** (Horik.) T. J. Kop. 48, 26.8; *Rhytidiadelphus squarrosus* (Hedw.) Warnst. 2, 1.1; *Sanionia uncinata* (Hedw.) Loesce 6, 3.4; *Scapania helvetica* Gottsche 2, 1.1; *S. irrigua* (Nees) Nees 4, 2.2; ***S. paludosa*** (Müll. Frib.) Müll. Frib. 4, 2.2; ***S. uliginosa*** (Sw. ex Lindenb.) Dumort. 13, 7.3; *S. undulata* (L.) Dumort. 71, 39.7; *S. subalpina* (Nees ex Lindenb.) Dumort. 17, 9.5; *Schistidium rivulare* (Brid.) Podp. 2, 1.1; *Sphagnum girgensohnii* Russow 1, 06; *Sph. palustre* L. 1, 06; *Sph. russowii* Warnst. 1, 06; *Sph. squarrosum* Crome 1, 06; *Straminergon stramineum* (Dicks. ex Brid.) Hedenäs 1, 06; *Tortella tortuosa* (Hedw.) Limpr. 3, 1.7; *Thuidium tamariscinum* (Hedw.) Schimp. 2, 1.1; *Warnstorfia exannulata* (Schimp.) Loeske 9, 5.0; *W. fluitans* (Hedw.) Loeske 3, 1.7.