Acta Mycologica

DOI: 10.5586/am.1057

Publication history
Received: 2015-04-15
Accepted: 2015-06-23
Published: 2015-08-05

Handling editor
Maria Rudawska, Institute of Dendrology of the Polish Academy of Sciences, Poland

Authors' contributions
NM: field research and draft of the manuscript; BK: species identification and critical revising; BK, NM: final writing of the manuscript

Funding
The study was supported by the National Science Centre, grant No. N N304 170539 and from the W. Szafer Institute of Botany, Polish Academy of Sciences through its statutory funds.

Competing interests
No competing interests have been declared.

Citation
Matura N, Krzewicka B. *Verrucaria* species and other rare amphibious lichens in the Beskid Sądecki Mts. Acta Mycol. 2015;50(1):1057. http://dx.doi.org/10.5586/am.1057

ORIGINAL RESEARCH PAPER

Verrucaria species and other rare amphibious lichens in the Beskid Sądecki Mts

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Abstract
Ten freshwater lichen species from the Beskid Sądecki Mts are presented. Seven of them: *Hydropunctaria rheitrophila*, *Thelidium aquaticum*, *T. minutulum*, *T. zwackhii*, *Verrucaria dolosa*, *V. elaeomelaena* and *V. submersella*, are new to the region. Three species: *Verrucaria elaeina*, *V. hydrophila* and *V. latebrosa*, were previously known from single localities.

Keywords
freshwater lichens; lichenized fungi; Verrucariaceae; Carpathian Mts

This issue of Acta Mycologica is dedicated to Professor Maria Lisiewska and Professor Anna Bujakiewicz on the occasion of their 80th and 75th birthday, respectively.

Introduction

Lichenized fungi occurring in freshwater ecosystems comprise a small (about 5% of the world's population) and poorly known group of organisms compared to the terrestrial lichens. They are restricted to submerged or partially inundated rocks, such as in springs, rivers, and lakes. Because of their biology, aquatic and semi-aquatic lichens constitute a very interesting ecological group of fungi. In freshwater habitats, species distribution is known to be affected by several ecological factors related to the length of submergence, shading, substrate (lithology, stability), water chemistry, speed and transportation [1–3]. Freshwater lichens belong to a few genera, the most representative being *Verrucaria*. Species of the family Verrucariaceae occur in nearly all European freshwater lichen communities, being often the dominant or the only family occurring in the permanently submerged zone [4].

Lichenological research in the Beskid Sądecki Mts was initiated by Rehman [5] and Boberski [6] at the end of the 19th century. The first records regarding aquatic species were reported by Olech [7,8], who conducted a comprehensive survey of the lichen biota of the area and recognized five aquatic taxa: *Bacidina inundata* (Fr.) Vězda, *Verrucaria aquatilis* Mudd, *V. denudata* Zschacke (at present *V. hydrophila* Orange), *V. guestphalica* Servít (at present *V. elaeina* Borrer) and *V. laevata* Körb. [at present *V. praetermissa* (Trevisan) Anzi]. A comparative survey was conducted by Śliwa [9] in the Beskid Sądecki Mts in the late 1990s in order to determine the impact of human

activity on the diversity and distribution of lichens. Śliwa [9] confirmed the occurrence of two freshwater taxa (*B. inundata* and *V. praetermissa*) reported previously. Additionally, she reported one more species, that is *Verrucaria anziana* Garov. (at present *V. latebrosa* Körb.). Furthermore, a few new localities of lichens associated with freshwater habitats were reported from the Żebracze nature reserve by Czarnota [10]. However, permanently and periodically submerged habitats were not of special concern in the studies mentioned above.

In 2013, a lichenological survey focused on the lichen biota of freshwater habitats was carried out by us in the Beskid Sądecki Mts. A considerable collection of lichens associated with such habitats was obtained in the survey. Many interesting species, including new regional records, were identified in the material collected.

Material and methods

Field work was carried out by the first author in the Beskid Sądecki Mts in 2013. The following streams were included in the study: Baraniecki stream, Czaczowiec stream, Szczawniczek stream, Uhryński Potok stream, Wierchomlanka stream and Wojkowski stream. The lichen material was analyzed with standard morphological and anatomical methods using microscopic techniques. Voucher specimens are available in the herbarium of the W. Szafer Institute of Botany, Polish Academy of Sciences (KRAM).

Results and discussion

Ten freshwater lichen species were recorded by us in the Beskid Sądecki Mts. Seven of them are new to the region (*Hydropunctaria rheitrophila*, *Thelidium aquaticum*, *T. minutulum*, *T. zwackhii*, *Verrucaria dolosa*, *V. elaeomelaena*, *V. submersella*). Three species (*Verrucaria elaeina*, *V. hydrophila* and *V. latebrosa*) were known in the study area only from single localities.

Hydropunctaria rheitrophila (Zschacke) Keller, Gueidan & Thüs
Verrucaria rheitrophila Zschacke

It is characterized by completely immersed perithecia visible as black dots on the upper surface of the thallus and by a greenish thallus with black punctae giving a spotted and weakly roughened appearance on the upper surface. Black punctae are well visible in thinner thalli; however, they are sometimes completely immersed in the thicker ones and then the upper surface is even. Ascospores are simple, colorless and ellipsoid reaching up to 10–12(–15) × 4.5–7 µm.

Hydropunctaria scabra is another freshwater species with black punctae in the thallus but it differs in the larger perithecia forming projecting mounds, larger ascospores 14–17 × 7.5–9 µm, and the presence of a greenish black to black thallus with a continuous black basal layer.

Hydropunctaria rheitrophila occurs on submerged siliceous or calcareous rocks and pebbles in sunny places.

This species is reported from the Beskid Sądecki Mts for the first time. It was found in the Szczawniczek stream on submerged stones in a sunny place at an altitude of 900 m. It is widespread in the mountainous regions of southern Poland, where it has many localities, especially in the Western Carpathians, where it occurs in nearly all mountain ranges [11]. This species was also recorded from lower altitudes at scattered localities in central and northern Poland [11,12]. In Europe, it is widespread from sea level to alpine areas [9].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Szczawniczek stream, on left side of road, before turning

onto the trail towards the Runek Peak, 49°25′385″ N, 20°52′476″ E, alt. 945 m, on submerged stone in sunny place, 5 September 2013, leg. N. Matura (KRAM).

Thelidium aquaticum Servít

It is characterized by a superficial, thin, dark olive greenish to brownish thallus which is continuous or with small cracks. Perithecia are initially completely immersed in the thallus, their upper half becoming exposed later. The involucrellum is absent. The exciple is brown-black above and colorless to pale brown at base, reaching up to 80–115 µm in diameter. Ascospores are 3-septate, reaching up to 16–27 × 5–8 µm.

Thelidium zwackhii also has 3-septate ascospores but differs in the bigger exciple reaching up to 140–300 µm wide.

Thelidium aquaticum is an amphibious species occurring on siliceous substrate in streams.

This species is reported from the Beskid Sądecki Mts for the first time. It was found in the Czaczowiec stream on inundated rocks in sunny places, at an altitude of 430 m. In Poland, it is known from scattered localities in the Carpathian Mts [13] and from a few sites in central Poland [14]. This species is poorly known in Europe and outside Poland it has so far been reported only from the type locality [4].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Czaczowiec stream, near bus stop in Izgierkówka village, 49°31′960″ N, 20°48′464″ E, alt. 434 m, on rock often inundated with water in sunny place, 27 July 2013, leg. N. Matura (KRAM).

Thelidium minutulum Körb.
Thelidium acrotellum Arnold

This species has a thin, superficial, pale grey-green to dark brown thallus. It is continuous, usually not cracked or forms numerous small patches. Perithecia are prominent, without an involucrellum. They are very prominent or up to half-immersed in the thallus, with an inconspicuous ostiole. The exciple is brown above and usually colorless at base, reaching up to 80–240 µm in diameter. Ascospores are 1-septate, reaching up to 13–32 × 4–15 µm.

Thelidium zahlbruckneri Servít also has 1-septate ascospores but differs in the dark brown exciple reaching up to 100–150 µm in diameter and smaller ascospores 10–15 × 4–7 µm. *Thelidium zwackhii* and *T. aquaticum* differs in the 3-septate ascospores.

Thelidium minutulum occurs mainly in non-aquatic (terrestrial) habitats on both calcareous and non-calcareous substrates or rarely on soil, in moist and shady places but it is also often found on small stones beside streams in the splash zone.

This species was not previously reported from the Beskid Sądecki Mts. It was found at scattered localities in the Czaczowiec stream, the Uhryński Potok stream and the Wojkowski stream. The species occurred on splashed or inundated substrates, in both sun-exposed and shaded places. In Poland, it is known mainly from terrestrial populations from scattered localities in mountains and lowlands [13,15]. Amphibious populations are often overlooked. The species is widespread in Europe [4].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Czaczowiec stream, near bus stop in Czaczów village, 49°30′499″ N, 20°47′119″ E, alt. 562 m, on rock often inundated with water, 27 July 2013, leg. N. Matura (KRAM); Czaczowiec stream, near bus stop in Izgierkówka village, 49°31′960″ N, 20°48′464″ E, alt. 434 m, on rock often inundated with water in sunny place, 27 July 2013, leg. N. Matura (KRAM); Uhryński Potok stream, near shrine in Uhryń village, 49°30′217″ N, 20°51′647″ E, alt. 539 m, on splashed rock in shaded place, 24 August 2013, leg. N. Matura (KRAM); Góry Leluchowskie Mts: Wojkowski stream, a few hundred meters beyond the asphalt road, near clearing in Wojkowa village, 49°20′227″ N, 20°59′368″ E, alt. 689 m, on splashed rock, 4 September 2013, leg. N. Matura (KRAM).

Thelidium zwackhii (Hepp) A. Massal.

This species is characterized by a thin, superficial, grey-green to dark brown, scattered thallus, in small flecks or forming a continuous or slightly cracked crust. Perithecia are prominent, without an involucrellum, sessile or half-immersed in the thallus. The exciple is 140–300 µm wide, brown above and usually colorless at base. Ascospores are 3-septate, reaching up to 25–32 × 10–12 µm.

Thelidium aquaticum also has 3-septate ascospores but differs in the smaller exciple reaching up to 80–150 µm in diameter and smaller ascospores 16–27 × 5–8 µm.

Thelidium zwackhii occurs mainly in non-aquatic (terrestrial) habitats but its amphibious populations are often noted by streams.

This species is reported from the Beskid Sądecki Mts for the first time. It was found in the Uhryński Potok stream on inundated rocks in sunny places, at 500 m. In Poland, it is rather rare species [15,16]. In Europe it is rarely recorded but presumably widely distributed [4].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts. Pasmo Jaworzyny Krynickiej range: Uhryński Potok stream, on the geological trail, 49°30′809″ N, 20°51′898″ E, on rock often inundated with water in sunny place, alt. 500 m, 24 August 2013, leg. N. Matura (KRAM).

Verrucaria dolosa Hepp

This species is characterized by an almost absent or thinly superficial thallus which is non-gelatinous, 25–50 µm thick, green to olive-brown, more or less smooth, glossy, continuous and never areolate, only sometimes with a few cracks. Perithecia form low to moderate projections 100–150(–180) µm wide; they are semi-immersed to prominent. They often are covered by the thallus in the lower part. The involucrellum is present, more or less conical. Ascospores are simple, colorless, 15–17.5 × 6.5–8.5 µm.

Verrucaria maculiformis is similar in the presence of a thin thallus but differs in the larger perithecia forming moderate projections 150–250 µm in diam. and terrestrial habitat.

Verrucaria dolosa occurs on siliceous rocks, limestone and concrete, in moist habitats by freshwater watercourses, e.g., in the splash zone.

This species is reported from the Beskid Sądecki Mts for the first time. It was found in the Baraniecki and Szczawniczek streams on rocks in the splash zone, at altitudes of ca. 500 and 1000 m. The species occurs at scattered localities in the Polish Carpathian Mts and in northern and central Poland [11]. This species is widespread in Europe [11].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Baraniecki stream, 49°24′914″ N, 20°48′058″ E, alt. 508 m, in splash zone on rock, 7 July 2013, leg. N. Matura (KRAM); Szczawniczek stream, on left side of road, before turning onto the trail towards Runek Peak, 49°25′385″ N, 20°52′476″ E, alt. 945 m, on submerged stone in sunny place, 5 September 2013, leg. N. Matura (KRAM).

Verrucaria elaeina Borrer
Verrucaria guestphalica auct.

This species is characterized by a whitish or grey-green rimose thallus with perithecia one-quarter to three-quarters immersed, rarely completely immersed in the thallus. Perithecia usually vary in the same specimen, forming moderate projections 220–400 µm in diam. The involucrellum is well-developed, darkly pigmented, weaker colored in basal parts, conical-hemispherical to conical, usually more or less spreading from the exciple below. Ascospores are simple, colorless, ellipsoid to narrowly ellipsoid or oblong-ellipsoid, 18–22(–24) × 7–9 µm.

Verrucaria praetermissa differs in the more immersed perithecia, slightly larger ascospores and the presence of a black basal layer. *Verrucaria submersella* differs in the larger ascospores (up to 20–32 µm long), and *V. sublobulata* has smaller perithecia forming low projections 80–120 µm in diam., and a greenish thallus.

Verrucaria elaeina is a facultatively amphibious species occurring on a variety of substrates such as limestone, sandstone, and concrete. It occurs in shady places both in moist and dryer habitats but never at sunny and xerothermic sites.

In the Beskid Sądecki Mts, this species was previously reported by Olech [8] at one locality in a stream in the Jaworzyna Krynicka range. It was found in our study at scattered localities in all the streams examined, mainly in the splash zone, at altitudes ranging from 500 to 600 m. The species is very common in the Polish Carpathians, where it was recorded in most of the ranges [11]. Known in Europe from scattered localities [11].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Baraniecki stream, 49°25′283″ N, 20°47′523″ E, alt. 514 m, on rock often inundated with water in sunny place, 12 July 2013, leg. N. Matura (KRAM); Czaczowiec stream, in Barnowiec village, beyond barrier and behind sharp bend in asphalt road, 49°29′592″ N, 20°46′730″ E, alt. 647 m, on rock often inundated with water in sunny place, 27 July 2013, leg. N. Matura (KRAM); Czaczowiec stream, near bus stop in Czaczów village, 49°30′499″ N, 20°47′119″ E, alt. 562 m, on splashed rock, 27 July 2013, leg. N. Matura (KRAM); Uhryński Potok stream, in Uhryń village, at the level of the nature trail, 49°29′740″ N, 20°51′641″ E, alt. 576 m, on splashed rock in sunny place, 24 August 2013, leg. N. Matura (KRAM); Wierchomlanka stream, in Wierchomla Mała village, about 500 m behind last house on the road, 49°25′398″ N, 20°49′269″ E, alt. 612 m, on big stone often inundated in sunny place, 2 September 2013, leg. N. Matura (KRAM); Góry Leluchowskie Mts: Wojkowski stream, a few hundred meters beyond asphalt road, near clearing in Wojkowa village, 49°20′227″ N, 20°59′368″ E, alt. 689 m, on rock often inundated with water, 4 September 2013, leg. N. Matura (KRAM); Wojkowski stream, in Wojkowa village, near historic Orthodox Church and bus stop, 49°20′758″ N, 20°59′778″ E, alt. 620 m, on splashed rock, 4 September 2013, leg. N. Matura (KRAM).

Verrucaria elaeomelaena (A. Massal.) Arnold

This species has a light brownish green to mid-brown subgelatinous thallus with perithecia at first completely covered by the thallus layer but becoming erumpent in thalline warts later. The apex is often somewhat exposed and blackish. The involucrellum is black, variable, conical, present in the upper half of the exciple or reaching to the base of the thallus. Ascospores are simple, colorless, broadly ellipsoid to ovoid, rounded at both ends, 22–30 × 12–16 µm.

It is distinguished from *V. funckii*, a species similar in appearance, by a thicker and paler thallus and larger, broadly ellipsoid ascospores (*V. funckii* has ascospores ellipsoid to narrowly ellipsoid, rounded at apices 18–25 × 6–10 µm, and occurs exclusively on siliceous rocks).

Verrucaria elaeomelaena is an amphibious species occurring on calcareous rocks, or rarely on sandstone or rarely on siliceous rocks submerged in calcareous water (with pH > 7), on inundated or submerged rocks and pebbles in streams mainly in lowlands and uplands, less frequently in mountains.

This species is reported from the Beskid Sądecki Mts for the first time. It was found in the Czaczowiec and Wojkowski streams on submerged stones in sunny places at an altitude of ca. 600 m. The species occurs at scattered localities in the Polish Carpathian Mts and in northern and central Poland [11]. In Europe it is widespread but rare [4].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Czaczowiec stream, in Barnowiec village, beyond barrier and behind sharp bend in asphalt road, 49°29′592″ N, 20°46′730″ E, alt. 647 m, on rock often inundated with water in sunny place, 27 July 2013, leg. N. Matura (KRAM);

Góry Leluchowskie: Wojkowski stream, in the central part of Wojkowa village, sunny place near the road, 49°21′802″ N, 20°58′935″ E, alt. 555 m, on submerged stone, 4 September 2013, leg. N. Matura (KRAM).

Verrucaria hydrophila Orange
Verrucaria denudata Zschacke nom. illeg., non Nyl. (1858)
Verrucaria hydrela auct., non Ach. (1814)

The species is distinguished by a smooth uncracked, continuous, subgelatinous thallus without a black basal layer, perithecia covered by a layer of thallus, and a conical involucrellum reaching the base – on dry thalli visible as black points, on wet thalli visible as a black disc within the transparent thallus. Ascospores are simple, colorless, ellipsoid, reaching up to 20–25(–26) × 10–12(–15) µm.

Initially this taxon was mistakenly reported as *Verrucaria hydrela* Ach. in Poland. However, *V. hydrela* described by Acharius [17] differs in the presence of an uneven, non-gelatinous thallus with a few cracks. For this reason, the specimens with a smooth, uncracked and subgelatinous thallus and with perithecia with a conical involucrellum covered by a layer of thallus were recognized by Krzewicka [11] as *V. denudata* Zschacke. Unfortunately, this name was illegitimate therefore Orange [18] described this taxon as *V. hydrophila*.

Verrucaria hydrophila is a freshwater species occurring on permanently submerged siliceous rocks, in sunny places.

In the Beskid Sądecki Mts, this species was previously reported at two localities from the Pasmo Radziejowej range [7] and at one locality from the Pasmo Jaworzyny Krynickiej range [10]. In our study, this species was found on scattered localities in the Baraniecki, Czaczowiec and Uhryński Potok streams on submerged or often inundated stones, at altitudes ranging from 500 to 650 m. This species has many localities in mountainous regions of Poland. It is widespread in the Carpathian Mts but also occurs in the Sudeten Mts, central and northern Poland [11]. In Europe, it is widespread but known as *V. hydrela* [11].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Baraniecki stream, 49°24′914″ N, 20°48′058″ E, alt. 508 m, in the splash zone on rock, 7 July 2013, leg. N. Matura (KRAM); Czaczowiec stream, in Barnowiec village, about 100 m beyond barrier, 49°29′372″ N, 20°46′672″ E, alt. 785 m, on rock often inundated with water in sunny place, 24 July 2013, leg. N. Matura (KRAM); Czaczowiec stream, near bus stop in Izgierkówka village, 49°31′960″ N, 20°48′464″ E, alt. 434 m, on rock often inundated with water in sunny place, 27 July 2013, leg. N. Matura (KRAM); Uhryński Potok stream, in central part of Uhryń village, sunny place near asphalt road and human settlements, 49°28′604″ N, 20°51′580″ E, alt. 641 m, on submerged stone in sunny place, 23 August 2013, leg. N. Matura (KRAM); Uhryński Potok stream, in Uhryń village, at the level of the nature trail, 49°29′740″ N, 20°51′641″ E, alt. 576 m, on submerged stone in sunny place, 24 August 2013, leg. N. Matura (KRAM).

Verrucaria latebrosa Körb.

This species is distinguished by a non-subgelatinous, well-developed thallus with many cracks or regularly areolate and almost completely immersed perithecia. Perithecia form low to moderate projections, 250–500 µm in diam., mostly covered by the thallus except for the uppermost part with a black exposed convex ape. The involucrellum is well-developed (thick), present only around the apex or spreading outwards and downwards in the upper part. Ascospores are simple, colorless, ellipsoid, (18–)24–29(–36) × 8.5–12.5(–14) µm, with a halo in the fresh material.

Verrucaria submersella differs in the more prominent perithecia, half or three-quarters immersed in the thallus and forming shallow pits in the substrate, and the non-halonate ascospores. *Verrucaria cernaensis* differs in the well-developed involucrellum reaching to the base of the dark pigmented exciple, and smaller ascospores

[18–22(–25) × 8–14 µm]. *Verrucaria margacea* differs in the prominent perithecia forming moderate to distinct projections (280–)350–800 µm in diam., at first covered by the thallus and later partly exposed, and a conical involucrellum reaching to the base of the exciple.

Verrucaria latebrosa is an amphibious species occurring on siliceous rocks beside streams and lakes, often above the water level but in the splash zone, in sunny or partially shady places.

In the Beskid Sądecki this species was previously reported at one locality in a stream in the Pasmo Radziejowej range [9]. In our study, it was found at two localities in the Czaczowiec and Uhryński Potok streams in the splash zone. In Poland, it occurs in the southern part in the Sudeten Mts and the Carpathian Mts, mainly in the Tatra Mts [11]. In Europe, it has been reported only from Central Europe to date [19].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Pasmo Jaworzyny Krynickiej range: Czaczowiec stream, near bus stop in Czaczów village, 49°30′499″ N, 20°47′119″ E, alt. 562 m, in splash zone on rock, 27 July 2013, leg. N. Matura (KRAM); Uhryński Potok stream, near shrine in Uhryń village, 49°30′217″ N, 20°51′647″ E, alt. 539 m, on rock often inundated with water in shaded place, 24 August 2013, leg. N. Matura (KRAM).

Verrucaria submersella Servít

This species is characterized by a thin superficial to semi-endolithic dirty white to yellowish green cracked thallus without a black basal layer. Perithecia are half or three-quarters immersed in the thallus, forming moderate projections raised above the thallus, naked in the upper part, forming shallow pits in the substrate. The involucrellum is present in the upper half of the exciple, rarely reaching to the thallus base, appressed to the exciple or slightly laterally spreading into the thallus. The exciple is colorless to pale brown. Ascospores are ellipsoid, (20–)24–32 × 9–14 µm, without a halo.

Verrucaria praetermissa differs in the presence of a black basal layer. *Verrucaria sublobulata* is similar by the color of the thallus but differs in smaller and nearly immersed perithecia.

Verrucaria submersella occurs in the splash zone on limestone and dolomite mainly in shady places. It is also recorded on siliceous rocks and pebbles in streams with hard, well-buffered water [4].

This species is reported from the Beskid Sądecki Mts for the first time. It was found at one locality in the Wojkowski stream on rocks often inundated with water. It is poorly known in Poland, confirmed in the Carpathian Mts and in the central part of Poland in the Wyżyna Krakowsko-Wieluńska upland at scattered localities [11]. The species is reported from scattered localities in Central Europe from montane to subalpine areas [4].

Specimens examined. Poland. Western Carpathian Mts, Beskid Sądecki Mts, Góry Leluchowskie: Wojkowski stream, a few hundred meters beyond asphalt road, near clearing in Wojkowa village, 49°20′227″ N, 20°59′368″ E, alt. 689 m, on rock often inundated with water, 4 September 2013, leg. N. Matura (KRAM).

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