

Reported and potential bioluminescent species in Lithuania

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Bioluminescent species are those producing and emitting light by chemical reactions and using it for a wide range of functions important for survival, hunting, camouflage, mating, recognition, and communication. Studies on Lithuanian bioluminescent species biodiversity are scarce. The aim of this study was to review available information about reported and potential (found near the borders of the neighbouring countries) bioluminescent (fireflies, fungi, centipedes, springtails), and luminescent (mosses) species in Lithuania. Available sources of literature on the diversity of Lithuanian, Latvian, Polish, and Belarusian bioluminescent species were studied, and folklore and verbal evidence of seen bioluminescent species were analysed as well. All collected information was generalized and presented as a list of Lithuanian bioluminescent species. The results showed that representatives of 26 different bioluminescent and one luminescent species may glow in the dark in Lithuania depending on the season, temperature, humidity, pH and oxygen presence in their environment: two reported and one potential (immigrating from Poland and Belarus) species of fireflies; recently reported one species of bioluminescent centipedes from the family of *Geophilus*; one potential species of bioluminescent springtail (reported in Latvia and Poland); 21 reported species of bioluminescent fungi; one reported species of luminescent moss. Glowing must be confirmed for two fungi species mentioned in folklore, also one species is found that does not glow in Lithuania but is bioluminescent in North America. Specimens of *Chlorociboria* sp. and *Xylaria hypoxylon* found in the Botanical Garden of Vytautas Magnus University did not glow, while *Armillaria mellea* glowed brightly emitting green light.

Keywords: bioluminescent, firefly, centipede, springtail, fungus, moss

INTRODUCTION

Although the best known terrestrial luminescent organisms are firefly, glow-worm, and certain

click-beetles, most of other examples are in the sea (McCapra, 1976). In general, bioluminescence is produced through chemical reactions in which substrates, called luciferins, and enzymes, called luciferases, are involved in the production of light (Shimomura, 2006). Luminescence provides a selective advantage mediated through its detection

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and responses by other organisms; its functions may be classed as defensive, offensive, or communicative (Woodland Hastings, 2011). While in nature plants do not use chemical reactions to produce light, scientists have already tried to reconstruct complex metabolic pathways of prokaryotes and force them to function in plant chloroplasts, leading to emission of light visible to the naked eye in the dark (Krichevsky et al., 2010).

Recent research on the behaviour and the ecology of European bioluminescent species seems to lag behind compared to other continents (De Cock, 2009). There may be several reasons for European fireflies being less studied: European fireflies are less eye-catching and of lower biodiversity of species compared to other continents. Firefly displays are only seen late at night, but the high degree of urbanisation, industrialisation and intensive agriculture disturb their observation (De Cock, 2009). New studies on the application of bioluminescence give hope that this natural phenomenon will be a great tool for creating more sustainable urban spaces in future: with glowing street trees (Dr. Alexander Krichevsky's research group at the State University of New York, later at "Gleaux" or former "Bioglow", US), plants shining as desk lamps for reading books (Prof. Michael Strano's research group at Massachusetts Institute of Technology), and glowing facades of buildings (Sandra Rey's research group at "Glowee" in France).

Studies on the biodiversity of Lithuanian bioluminescent species are scarce, while the general

public is usually aware only of the glowing firefly (*Lampyrus nocticula* and *Phosphaenus hemipterus*) and sometimes fungi (mostly *Armillaria mellea*) species. The aim of this study was to review the available information about reported and potential (found near the border of the neighbouring countries and having the potential of migrating to Lithuania) bioluminescent (fireflies, fungi, centipedes, springtails), and luminescent (mosses) species in Lithuania.

MATERIALS AND METHODS

This paper is an overview of available information about all the bioluminescent species found, seen, and reported in scientific works or the media, mentioned in Lithuanian folklore, or having the potential of migrating to Lithuania from the neighbouring countries (Latvia, Poland, Kaliningrad region, or Belarus). Verbal confirmation of seen bioluminescent species, which had not been reported before, were also collected if possible. Usually the Lithuanian public are not aware of other bioluminescent species, except the fireflies (*Lampyrus nocticula* and *Phosphaenus hemipterus*) and, in rare cases, fungi (mostly *Armillaria mellea*). It is hard to confirm if the species reported or mentioned in folklore actually glow in Lithuania during a certain season and under environmental conditions as there is very little photographic evidence published. All collected information was generalized, concentrated, and presented as a list (in Table 1).

Table 1. List of reported and potential bioluminescent species in Lithuania

Bioluminescent species	Reported in Lithuania	Potential of migrating to Lithuania	Bioluminescent features
Firefly			
<i>Lampyrus nocticula</i>	Yes		Females glow (underside of their last three abdominal segments) and do not fly
<i>Phosphaenus hemipterus</i>	Yes		Both females and males are feebly bioluminescent (glowing underside of their last two abdominal segments in response to disturbance) and do not fly

Table 1. (continued)

<i>Phausis splendidula</i> or syn. <i>Lamprohiza splendidula</i>	Verbal confirmation by six different unrelated persons. Flying fireflies, glow in green, spotted in the western and southern regions of Lithuania	Reported in Poland and Belarus	Females glow, but do not fly, males fly and glow
Centipedes (<i>Geophilus</i>)			
<i>Geophilus</i> sp.	Yes. Reported in 2012 in the residential area of Antakalnis, Vilnius; another verbal confirmation received in 2018, to the effect that it was spotted in the residential area of Karoliniškės, Vilnius. In September 2018, one glowing specimen was caught in Vilnius Belmontas district and was brought for analysis to Vytautas Magnus University (VMU)		The underside of its body glowed, leaving green slime when touched. The glowing specimen from Vilnius Belmontas district was described by Ingrida Šatkauskienė (Assoc. Prof., VMU) as one of the two possible species: <i>Geophilus easoni</i> or <i>Geophilus carpohagus</i>
Springtails (<i>Collembola</i>)			
<i>Anurida granaria</i>		A species widespread in the Northern hemisphere. Reported in Latvia and Poland	Whole body emits light
Fungi			
<i>Armillaria cepistipes</i>	Yes. Research on more detailed identification is needed		Glowing young mycelium
<i>Armillaria gallica</i>	Yes. Research on more detailed identification is needed		Glowing young mycelium
<i>Armillaria mellea</i>	Yes		Glowing young mycelium
<i>Armillaria ostoyae</i>	Yes. Research on more detailed identification is needed		Glowing young mycelium
<i>Armillaria tabescens</i>		Reported in Estonia and Germany	Glowing young mycelium
<i>Chlorociboria aeruginascens</i>	Yes. Reported in some references		Glowing young mycelium
<i>Clavaria botrytis</i> or syn. <i>Ramaria botrytis</i> ?	In folklore it was called “naktižibas, naktižibis”, meaning “shining at night”		Glowing fruiting bodies? Bioluminescence of this species is not confirmed by visual evidence
<i>Collybia tuberosa</i>	Yes		Glowing young mycelium
<i>Collybia radicata</i> or syn. <i>Xerula radicata</i>	Yes		Glowing young mycelium
<i>Mycena epipterygia</i>	Yes		Glowing young mycelium

Table 1. (continued)

<i>Mycena haematopus</i>	Yes	Glowing young mycelium and fruiting bodies
<i>Mycena inclinata</i>	Yes	Glowing young mycelium
<i>Mycena maculata</i>	Yes	Glowing young mycelium
<i>Mycena polygramma</i>	Yes	Glowing young mycelium
<i>Mycena pura</i>	Yes	Glowing young mycelium
<i>Mycena rosea</i>	Yes	Glowing young mycelium
<i>Mycena sanguinolenta</i>	Yes	Glowing young mycelium
<i>Mycena stylobates</i>	Yes	Glowing young mycelium
<i>Mycena zephrus</i>	Yes	Glowing young mycelium
<i>Omphalotus olearius</i>	Yes. Very rare, only one habitat known	Glowing mycelium and fruiting body
<i>Panellus stipticus</i>	The species is found in Lithuania, but it is not bioluminescent here	Does not glow in Lithuania, but is bioluminescent in North America
<i>Suillus bovinus?</i>	Yes. In folklore it was called “nakcižieda”, meaning “blooming at night”, <i>naktižibas</i> , <i>naktižibis</i> , <i>žibanaktis</i> , meaning “shining at night”	Glowing fruiting bodies? Bioluminescence of this species is not confirmed by visual evidence
<i>Tricholoma sciodes</i>	Yes	Glowing young mycelium
<i>Xylaria hypoxylon</i>	The species is found in Lithuania, although there is no confirmation about its bioluminescence	Glowing reported in European countries, though not yet confirmed by visual evidence in Lithuania
Mosses		
Not bioluminescent (does not use chemical reaction for glowing), but luminous (reflects light) moss, capable of glowing in the dark	Yes. Very rare. One habitat registered in Biržai in 1998 (on spruce tree windfall roots in a dense fir grove)	Tiny clear spherical protone-mal cells reflect light to give off a greenish-golden color
<i>Schistostega pennata</i>		

Note: the luminescence of species not in bold type is not confirmed by visual evidence or it does not glow in Lithuania.

In addition, samples of three species of bioluminescent fungi (*Armillaria mellea*, *Chlorociboria* sp., and *Xylaria hypoxylon*) growing in the Botanical Garden of Vytautas Magnus University were collected to test and prove their glowing features in Lithuania. Infected wood specimens were taken from growing trees and were transported to a room where the temperature was around 21°C. The specimens were moistened with tap water and left in the dark. The glowing

feature was tested every hour after the specimens were brought to room temperature.

RESULTS AND DISCUSSION

Fireflies

Two species of fireflies have long been known in Lithuania (Pileckis, Monsevičius, 1995; Ferenc, 2004; Tamutis et al., 2011; Kazantsev, 2012): *Lampyrus nocticula* and *Phosphaenus*

hemipterus. Female individuals of both species glow but do not fly, males fly but do not glow (*Lampyrus nocticula*) or do not fly but glow (*Phosphaenus hemipterus*) (Telnov 2004; Novak, 2008; Majka, MacIvor, 2009; Hopkins et al., 2015). Verbal confirmation of at least 6 different unrelated persons, that glowing flying fireflies have been already spotted in western and southern Lithuanian regions, indicate that probably the third species of fireflies is already migrating from Poland (Novak, 2018; Kubisz et al., 2000; De Cock, 2009) and Belarus (Aleksandrovich et al., 1996). *Phauisis splendidula* or *Lamprohiza splendidula* is found in those countries. The male individuals of the species fly and glow in the dark (females glow, but do not fly).

Centipede

Glowing centipedes (*Geophilus* sp.) were reported to be found in the residential area of Antakalnis in Vilnius in October 2012 (in an urban deciduous tree forest), but exact species was not identified. The finder (Liudas Aidietis) sent some two individuals to the Lithuanian Institute of Ecology of the Nature Research Centre for species recognition, but the species was not identified (<http://kauno.diena.lt/<...>>, 2012). Centipedes left green slime on a palm when a closer look was taken. Centipede *Orphaneus brevilabiatus*, common in tropical forests in Asia and Africa, produces light from the secretions of two luminous patches near the ends of

each segment of its body; the source of light is beneath the body of the insect and can be made out through its exterior. It is also capable of secreting bioluminescent slime, and the emission spectrum of this luminescence was found to have the maximum of about 510 and 480 nm (Anderson, 2008). Another verbal confirmation of glowing centipedes was received in 2018, the finder claimed he had seen a spotted glowing centipedes in the residential area of Karoliniškės in Vilnius. In September of 2018 one glowing specimen was caught in Vilnius Belmontas district by Kristina Girčytė and was brought to Vytautas Magnus University for identification. Assoc. Prof. Ingrida Šatkauskienė identified the specimen (Fig. 1) as *Geophilus carpophagus* or *G. easoni* (further research is planned to identify the species finally).

Springtail

Bioluminescent springtails (*Collembola*) are reported to be found in soils all around the globe: for example, *Anurida granaria* and *Onychiurus* sp. are widespread, while *Lobella* sp. is present in Japan (Oba, Branham, 2011; Herring, 1987). In Lithuania, around 120 species of springtails are found, although their bioluminescent features have not been traced yet (Sukackienė, 2015). The bioluminescent species *Anurida granaria* has been reported in Latvia (Grinbergs, 1956; 1960) and Poland (Skarzynski, 2001), which strongly implies that probably they live in Lithuania as well.



Fig. 1. Specimen of *Geophilus*, which was caught in Vilnius Belmontas district in 2018 by Kristina Girčytė and identified as *G. carpophagus* or *G. easoni* by Ingrida Šatkauskienė, Assoc. Prof. at Vytautas Magnus University

Fungi

Several fungi species found in Lithuania have been mentioned as bioluminescent by different sources (Urbonas, 1997a; Urbonas, 1997b; Liubienė, 2015; Isokas, 2016): *Armillaria mellea*, *Collybia tuberosa*, *Collybia radicata*, *Chlorociboria aeruginascens*, *Tricholoma sciodes* (glowing mycelium), and some species of the genus *Mycena* (glowing fruiting bodies). *Marasmius*, *Mycena*, and *Collybia* are surface forest litter (small branches, leaves, cones, needles, and other) decomposing fungi, while *Tricholoma* decompose the middle (deeper) layer of forest litter (Urbonas, 1997a). Some species are mentioned in folklore as glowing: *nakcižibiai*, *žibanakčiai*, *naktižieda* meaning “shining at night” (Liubienė, 2015): *Suillus bovinus*, *Clavaria botrytis* or *Ramaria botrytis*. According to the meaning, the fruiting bodies should glow, but there is no written or photographed evidence; moreover, these species are not included in the global list of bioluminescent fungi species (bioluminescence of these species must be proved). Some bioluminescent fungi species that have been reported in other countries (mostly in north-eastern America and some European countries) are also found in Lithuania: *Xylaria hypoxylon* (until now no evidence of glowing in Lithuania has been reported), *Panellus stipticus* (not glowing in Lithuania).

Armillaria mellea is a parasitic fungus attacking around 200 different species of plants (Urbonas, 1997a). Six species of *Armillaria* are found in Northern European countries (Finland, Sweden, Norway, Denmark, Holand), while four species (*Armillaria borealis*, *A. os-*

toyae, *A. gallica* and *A. cepistipes*) are still described as one (*Armillaria mellea*) in Lithuania (Urbonas, 1997b). *A. tabescens* should grow in Lithuania too as it is found in Estonia and Germany (Urbonas, 1997b). Mycelium of *A. gallica*, *A. tabescens* (Mihail, Bruhn, 2007), *A. os-toyae* (Rishbeth, 1986), and *A. cepistipes* (Mihail, 2015) are also bioluminescent.

Fungi of *Mycena* genus, which grow in Lithuania (Urbonas, 1997b), are reported as bioluminescent in other countries: *Mycena epipterygia*, *M. sanquinolenta*, *M. stylobates*, (Bothe, 1931), *M. haematopus*, *M. zephrus*, *M. polygramma* (Treu, Agerer, 1990; Bermudes et al., 1992), *M. pura*, *M. rosea*, *M. maculata* (Treu, Agerer, 1990), *M. inclinata* (Wassink, 1948), *M. tintinnabulum* (Bothe, 1930).

Bioluminescent *Tricholoma margarita* (previously known as *Mycena margarita*) (Desjardin, 2010), which emits yellowish green light in all parts of the basidiome or nonluminescent fruiting body in some populations, does not glow in Lithuania, but there are some reports that mycelium of *T. sciodes* (Urbonas, 1997a) glows at night. There is one habitat of *Omphalotus olearius* known in Lithuania (Urbonas, 1997b), while glowing features of its mycelium and fruiting body have been reported in other countries (Wassink, 1948).

Specimens of wood infected with *Armillaria mellea* found in the Botanical Garden of Vytautas Magnus University (Kaunas district) started glowing four hours after the specimens were brought into room temperature and oxidation of luciferin started. The infected pieces of wood emitted bright green light (Fig. 2) for

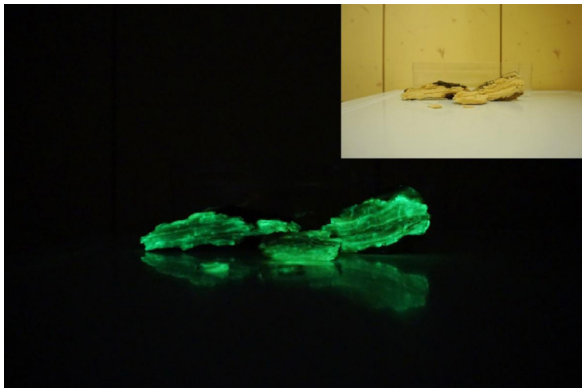


Fig. 2. Specimen of wood infected with *Armillaria mellea*, found at the Botanical Garden of Vytautas Magnus University

two nights, later the glowing gradually reduced. A new cutting of the same sample wood initiated glowing after four hours. Irrigation and cutting new layers let the same piece of wood glow for one and a half months until it became infected with mould, which killed the bioluminescent fungus inside.

Xylaria hypoxylon is attributed to bioluminescent species, although its luminescence might require association with photogenic bacteria or other light-emitting microorganisms (Murrill, 1915). Evidence on the glowing of *Chlorociboria aeruginascens* is scarce, but there are some reports even in Lithuania (Isokas, 2016). Specimens of *Xylaria hypoxylon* (Fig. 3) and *Chlorociboria* sp. (Fig. 4) found in the Botanical Garden of Vytautas Magnus University did not glow even after two days in a humid and warm environment.

Luminescent moss

A rare species of luminescent moss *Schistostega pennata* was reported to be found in Lithuania in Biržai in 1998 (it was found on spruce tree windfall roots in a dense fir grove) (Lietuvos Raudonoji knyga, 2007). It was included in the Red Book of Lithuania in 2000. This moss does not use chemicals to emit light. The ephemeral protonemal mat is composed of filamentous strands of tiny clear spherical cells that reflect light to give off a greenish-golden



Fig. 3. Specimen of wood infected with *Xylaria hypoxylon*, found at the Botanical Garden of Vytautas Magnus University

colour and chloroplasts move within the spherical cells to maximize their ability to collect the reflected light (Harpel, Helliwell, 2005). The plants are not contorted when dry.

Results showed that representatives of 26 different bioluminescent and one luminescent species may glow in the dark in Lithuania depending on the season, temperature, humidity, pH, and the presence of oxygen in their environment. Two reported and one potential of immigrating (from Poland and Belarus) species of fireflies; recently reported one unidentified species of bioluminescent centipedes from the family of *Geophilus* (in 2018 one caught specimen was described as *Geophilus easoni* or *G. carpophagus*); one potential species of bioluminescent springtail (reported in Latvia and Poland); reported 21 species (confirmation of glowing features still needed for some species) of bioluminescent fungi; and one reported species of luminescent moss. Bioluminescent features of *Suillus bovinus* and *Clavaria botrytis*



Fig. 4. Specimen of wood infected with *Chlorociboria* sp., found at the Botanical Garden of Vytautas Magnus University

must be yet confirmed by visual evidence (these two species were mentioned in folklore as shining at night). Also, one species of fungi (*Panel-lus stipticus*), which is bioluminescent in North America, is found in Lithuania, but it does not glow here. Specimens of *Chlorociboria* sp. and *Xylaria hypoxylon* found in the Botanical Garden of Vytautas Magnus University at the beginning of December did not glow, while *Armillaria mellea* (found at the end of November) glowed brightly with green light.

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Asta Malakauskienė

RASTOS IR POTENCIALIOS BIOLIUMINESCENCINĖS RŪŠYS LIETUVOJE

Santrauka

Bioluminescencinės rūšys, dėl cheminių reakcijų sugebančios skleisti šviesą, švytėjimą naudoja daugybei išlikimui svarbių funkcijų: medžioklei, kamufliažui, poravimuisi, atpažinimui, bendravimui bei kitoms. Lietuvos bioluminescencinių rūšių įvairovės tyrimai kol kas yra negausūs. Šio tyrimo tikslas buvo apžvelgti informaciją pasiekiamuose literatūros šaltiniuose apie rastas Lietuvoje ir potencialias (randamas Latvijoje, Lenkijoje, Baltarusijoje)

bioluminescencines (jonvabalių, grybų, šimtakojų, kolembolų) ir liuminescencines (samanų) rūšis. Taip pat buvo atsižvelgiama į tautosakos ir dabartinius žodinius liudijimus apie bioluminescencines rūšis. Visa surinkta informacija apibendrinta ir pateikta kaip Lietuvos bioluminescencinių rūšių sąrašas. Rezultatai rodo, kad Lietuvoje galima pamatyti tamsoje švytinčias 26 skirtingas bioluminescencines ir vieną liuminescencinę rūšis priklausomai nuo metų sezono, oro temperatūros, drėgmės, terpės pH ir deguonies patekimo į augimo aplinką: dvi randamas ir vieną potencialią (imigruojanti iš Lenkijos ir Baltarusijos) jonvabalių rūšis; neseniai rastą ir

detaliai neidentifikuotą žemlindų rūšį iš *Geophilus* šeimos; vieną potencialią kolembolų rūšį (randama Latvijoje ir Lenkijoje); 21 randamą bioluminescencinę grybų rūšį; vieną liuminescencinę samanų rūšį. Dviejų grybų rūšių, paminėtų Lietuvos tautosakoje, švytėjimo savybes dar reikia patvirtinti. Rasta viena grybų rūšis, kuri nešvyti Lietuvoje, tačiau švyti Šiaurės Amerikoje. *Chlorociboria* sp. ir *Xylaria hypoxylon* mėginiai iš Vytauto Didžiojo universiteto botanikos sodo tamsoje nešvytėjo, o *Armillaria mellea* švytėjo ryškiai žalia šviesa.

Raktažodžiai: bioluminescencinis, jonvabalis, šimtakojis, kolembola, grybas, samana