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A NEW METHOD FOR ASSESSMENT OF THE RED LIST THREAT STATUS OF MICROALGAE

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Abstract. Although the IUCN Red List Categories and Criteria is a widely internationally used system for classifying species at high risk of extinction, the micro-organisms are still practically excluded from the appropriately enlisted taxa. The present paper provides a method, which gives means to assess microalgae threat status much more objectively than it was possible before and in this way to achieve quite high degree of generalization in work with this peculiar group of organisms. The method described below uses the widely accepted standard IUCN Red List system of categories, but proposes their assignment on the basis of a complex application of seven criteria relevant to microalgae and classical data, available for them. These criteria can be interpreted in the same way for all taxonomic groups of algae and for all possible territorial levels (local, national, regional, global). The criteria are denominated with Latin capital letters A-G and each of them has a numerical expression with values (points) ranging between 4 and 1. The final assessment of the threat status is done on the basis of the total amount of points (T), which ranges between 7 and 28. In this way each alga is supplied with a formula (a combination of letters and numbers), which indicates its threat status and in the same time outlines its most critical, "weak spots" on which special attention has to be paid when conservation measures

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have to be proposed. As it is exemplified in detail in the paper, the formula could be expressed in a table or in a text format, in full or in a short version, depending on the needs of the relevant studies or proposals (e.g. *Anabaena lapponica* Borge [VU – A3 B4 C4 D2 E2 F2 G3], or *Anabaena lapponica* Borge [VU – A3 B4 C4 D2 E2 F2 G3 T20], or *Anabaena lapponica* Borge [VU – T20]), or *Anabaena lapponica* Borge [VU]).

Key words: threat categories, algae, conservation status

INTRODUCTION

The IUCN Red List Categories and Criteria is a widely internationally used system for classifying species or taxonomic units below the species level at high risk of extinction. Since its first adoption by IUCN Council in 1994, this system underwent some revisions which lead to its essential improvement: 1) better possibilities for application of categories and criteria to different taxonomic groups and assessment of an increasingly more diverse range of taxa occurring in a wide variety of habitats; 2) appearance of more and more successful applications of Red List categories and criteria at regional, national or local levels.

However, according to the Second Edition of Version 3.1 of The IUCN Red List Categories and Criteria (IUCN 2012) the micro-organisms are still practically excluded from the appropriately enlisted taxa. The reason lies in the obstacles in applying the accepted criteria to different types of micro-organisms, including prokaryotic and eukaryotic microscopic algae. In spite of the fact that "ongoing technological advances continue to provide more scope of improving data analysis" (op. cit.), it is practically impossible to use for microalgae the standard IUCN criteria related with number of mature individuals, real area of occupancy, population size, *etc*. The reason is not only in the fact that "different from *lovely or charismatic wildlife*, such as vertebrates, beetles, butterflies, and flowering plants, algae have not received extensive attention" (Watanabe 2005), but lies also in the uneven state of knowledge of algal groups in different countries, as well as the uneven studies of different algal groups in a given country and, in addition, often there is a lack of recent studies in places, which have been visited by phycologists of previous generations. Nevertheless some national or regional Red Lists of microalgae (or including microalgae) have been created, as separate lists or as parts of Red Data Books (*e.g.* Siemińska 1986, 1992, 2006; Gutowski & Mollenhauer 1996; Lange-Bertalot & Steindorf 1996; Palamar-Mordvintseva et al. 1998; Lenzenweger 1999; Environmental Agency, Japan 2000; Németh 2005; algal lists in regional Red Data Books of Moscow District, Leningrad District, Kirov District, Kamchatka District, Vologda District, Nizhegorod District, Nenets Autonomic Region, of Tatarstan Republik and of Komi Republic – all cit. acc. to Komulainen 2009). Most of them do not provide a clear indication of the reasons for assigning a certain category to given species and it is obvious that they are based only on the personal expertise of the authors and more rare the methodological approaches and criteria used are clearly defined (*e.g.* Németh 2005; Watanabe 2005). The lack of commonly accepted methodology leads to the application of different approaches for evaluation of taxa from different taxonomic groups of algae even in the same country or region, and to an assignment of different threat categories, ranging around those proposed in the global IUCN system (*e.g.* potentially threatened, rare, indeterminate) or using only some of the IUCN categories (*e.g.* Vulnerable, Endangered and Critically Endangered). This results in difficulties for further comparisons between the different Red Lists and taxa status, as well as in the lack of a stable basis for creation of microalgal Red Lists in other regions and countries, in spite of the clear recognition of their necessity due to loss of habitats and biodiversity in many regions of the world. Most of these problems (often related also to Red Data Books) have been recognized and discussed from different aspects by other authors (*e.g.* Palamar-Mordvintseva et al. 1998; Denys 2000; Kondratieva 2003; Siemińska 2006; Németh 2005; Ellis 2008) and it was even proposed to exclude microalgae from such lists due to recent lack of objective criteria and sufficient knowledge for their assessment (*e.g.* Komulainen 2009).

The aim of the present paper is to provide a method, which will give means to assess microalgae threat status much more objectively than it was possible before and in this way to achieve quite high degree of generalization in work with this peculiar group of organisms. The method described below uses the widely accepted standard IUCN Red List system of categories, but proposes their assignment on the basis of criteria relevant to microalgae and classical data, available for them. These criteria can be interpreted in the same way for all taxonomic groups of algae and for all possible territorial levels (local, national, regional, global). We strongly believe that the chosen criteria correspond well with the general ideas, lying behind the already accepted IUCN Red List criteria and that in the proposed combination they represent the minimum necessary information for the species assessment. We approbated the proposed method using all available data on microalgal biodiversity in Bulgaria, provided over a century in more than 300 publications. The results obtained corresponded strongly with our personal expert assignment of threat status to a given alga. In this way the first Red List of Bulgarian microalgae was prepared (Stoyneva-Gärtner et al., this volume) as a first practical application of the method proposed in the present paper and therefore the exemplification in the text below is based on Bulgarian cases.

Description of the proposed *Method for assessment of the Red List threat status of microalgae*

The method proposed in this paper is **aimed at objective assessment of the threat status of prokaryotic and eukaryotic microscopic algae**. It is based on a **complex application of seven criteria, denominated with Latin capital letters**

A–G, organized in alphabetical order. The criteria, described in details below in the text, are of equal importance for assessment, and their alphabetical order should not be accepted as an importance weight. For example, criterion E is not less important than criterion B, or criterion A is not more important than criterion B. **Each of the criteria A-G has a numerical expression with values (points) ranging between 4 and 1.** The lowest optional value 1 practically reflects all cases, which do not fit to the descriptions relevant to values 4, 3 and 2. The unification of the range and the usage of the same step (4 levels in descending way of importance) in combination with alphabetical denomination of criteria was done with the idea for obtaining an elegant and cozy for work system, the steps of which are quite easy to remember.

The final assessment of the threat status has to be done on the basis of the total amount of points (sum of the points for all seven criteria), which ranges between 7 and 28. The range of points for each threat category is provided in the text below. **The threat category follows the standard IUCN Red List categories and their standard denominations**: EX – Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, LR – Low Risk (with the subcategories NT – Near Threatened, LC – Least Concern and DD – Data Deficient), NE – Not Evaluated. On conformity with the standard IUCN Guidelines (2012), "listing in the categories of Not Evaluated and Data Deficient indicates that no assessment of extinction risk has been made, though for different reasons ... Taxa listed in these categories should not be treated as if they were non-threatened and it may be appropriate (especially for Data Deficient forms) to give them the same degree of attention as threatened taxa, at least until their status can be properly assessed". Therefore algae in both NE and DD categories should not be supplied with numerical values for any of the seven proposed by us criteria. In our opinion, in cases of microalgae the category Extinct should be assigned with a high degree of circumspection, since these organisms often are capable to develop resting stages of long surveillance and it is extremely difficult to prove the death of the last individual.

Below are enlisted the **seven proposed criteria and their numerical values (points)** with relevant explanations and denominations (in all cases when "species" is used below, it has to be read as "species or taxonomic units below the species level"). It has to be boldly underlined that their scope is dependent on the area, country, or region for which the Red List is created:

A. Number of localities in which the species was found (number of all known localities for a given species, regardless of the period and frequency of its finding):

4 – 1 locality
3 – 2–5 localities
2 – 6–10 localities
1 – ≥11 localities

B. Species affiliation to differen number of habitats and threat habitat

categories listed in relevant Red Data Book/Red List[1]:

- **4** – species affiliation to one or more than one habitat, all of which are assigned with the threat status of Critically Endangered and/or Endangered according to the relevant Red Data Book of Habitats/Red List of Habitats, *e.g.* for Bulgaria here and below we consider the Bulgarian Red Data Book of Natural Habitats (Biserkov et al. 2015)
- **3** – species affiliation to one, or more than one habitat, all of which are assigned with the threat status of Vulnerable and/or Potentially Endangered according to the relevant Red Data Book of Habitats/Red List of Habitats
- **2** – species affiliation to two or more habitats, which are with a significant difference in their threat status according to the relevant Red Data Book of Habitats/Red List of Habitats (*e.g.* CR and VU) or, among which are habitats not assigned with any threat status in relevant Red Data Book of Habitats/Red List of Habitats
- **1** – species affiliation only to habitats without threat status in the relevant Red Data Book of Habitats/Red List of Habitats.

C. Affiliation of the species to a certain number of main ecological groups (hydrophyton, thermophyton, cryophyton, edaphophyton, aerophyton, spelaeophyton, symbiotic algae, parasitic algae)

- **4** – species affiliation to a single ecological group (*e.g.* only to hydrophyton, regardless if the species is planktonic or benthic)
- **3** – species affiliation to two ecological groups (*e.g.* hydrophyton and aerophyton)
- **2** – species affiliation to three ecological groups
- **1** – species affiliation to 4–8 ecological groups

D. Affiliation of the species to a conservationally important area[2]:

- **4** – species found only in one protected area of highest possible category relevant to the territory in consideration for a given Red List (*e.g.* for Bulgaria it should be read as "taxon found only in a Reserve (regardless of its type) or only in a National Park")
- **3** – species found only in one territory with lower national nature conservation status, or another conservation status/value (*e.g.* for Bulgaria it should be read as "species found in a Protected locality, in a Nature monument, etc.

[1] When this method is applied in countries without a Red Data Book or a Red List of Habitats, it is suggested to replace this criterion with the following one**: B*. Affiliation of the species to a number of habitats (or habitat types): 4** – species is known from only one habitat; **3** – species is known from 2 habitats; **2** – species is known from 3–5 habitats, and **1** – species is known from ≥ 6 habitats. In case of such replacement, it is strongly recommended to use the criterion B with an asterisk, as it is shown above.

[2] if the territory has more than one conservational status, in this assessment the highest one has to be taken into account (*e.g.* if a given locality is situated in a Reserve and has been declared as a Ramsar site, the criterion D should get 4 points)

or in a Natura 2000 site, or in a wetland from the Red List of Bulgarian wetlands (regardless of its category; MICHEV & STOYNEVA 2007), or in a Ramsar site, or in Corine site, or in other area with national or international conservational importance and status (UNESCO site, Monument of World Cultural and Natural Heritage, *etc.*)

2 – species found in two or more territories, among which at least one is of conservational importance (according to their enlistment above for values 4 and 3)

1 – species found only in area/areas without conservational importance

***E. Species endemism*:**

4 – local endemic (*e.g.* Rila endemic), declared as an endemic species by its author, or afterwards by other author(s), or a species which have not been reported as endemic, but has been described from a given country (*e.g.* Bulgaria) and have been found only in one of its floristic regions

3 – national endemic (*e.g.* Bulgarian endemic), declared as an endemic species by its author, or afterwards by other authors, or species which has not been reported as endemic, but has been described from the country (*e.g.* Bulgaria) and has been found in more than one of its floristic regions

2 – regional endemic (*e.g.* Balkan endemic) or continental endemic (*e.g.* European endemic, Australian endemic)

1 – non-endemic species

***F. Species areal*:**

4 – globally rare species (*e.g.* found in small number of localities/countries (≤10) or no more than 3 continents)

3 – continentally rare species (*e.g.* found in a limited number of localities/countries (≤5) of Europe or another continent, relevant for the country for which the Red List is prepared)

2 – locally rare species (*e.g.* rare for Bulgaria, found in ≤5 (–10) localities in the relevant country)

1 – species with another distribution (*e.g.* cosmopolitan and found in 12 localities in Bulgaria)

G. Expert weight. This is an expert and in some way "subjective" addition of points to the species assessment, strongly based on the personal knowledge and experience of the phycologists, who make the assessment. It is recommended values 4, 3 or 2 to be applied when at least one of the following cases concerns the species under assessment: **a)** the species is typical inhabitant of an important for algae habitat to which lower status is assigned in relevant Red Data Lists/Books of Habitats, or the habitat still has not any status, or the species belongs to a territory with a potential conservation value; **b)** there are historical data which prove or strongly suggest the decline in species areal (decrease of number of localities, incl. destruction of some of the localities), decline in the number of habitats, loss of habitats or decline in species numbers (for the period of at least 20 years calculated back from the assessment time); **c)** expert opinion about the unique character of the species in terms of distribution or its potential endemism (*e.g.* species described from a given country which during more than 10 years after the description has not been found anywhere else), or its stenobiont character, *etc.*; **d)** another expert reason or reasons (with a strong recommendation for its /their argumentation in the relevant proposal or publication):

4 – high expert weight
3 – mean expert weight
2 – low expert weight
1 – no need to apply additional expert weight because the other points describe well enough the species status or because it is possible to suggest that the species has not been reported due to lack of investigations and not because of its real extinction from the wild

The scale of compliance between total counted points and threat status is as follows (it is strongly suggested not to include in Red Lists species with a total of 7 points only):

28–25 – CR
24–21 – EN
20–17 – VU
16–13 – NT
12–8 (7) – LC

Additional considerations which have to be taken into account when the proposed method is applied: species which are taxonomically unclear, species which are subjects of occasional transport, saprobionts or other species typical for strongly polluted habitats should be excluded from the Red List proposals. The proposals should be based on published data, which could be checked by readers and, when necessary, changed after obtaining of new data. For special considerations concerning criteria B and D, readers are kindly invited to check the footnotes to this paper.

When all the steps described above are properly followed, then **each alga is supplied with a formula** (a combination of letters and numbers), **which indicates its threat status** and in the same time **outlines its most critical, "weak spots" on which special attention has to be paid when conservation measures have to be proposed**. For example, if alga has A4 in the formula where other values are 1, the weak point is its occurrence in only one locality, or if the formula is expressed as A3B1C1D1E1F4G4, then it is to be seen that it is a globally rare species with a declining population and occurs/or occurred in 3–5 localities only to which special attention in further conservation measures has to be paid.

An advantage of the proposed method is that the **formula for each taxon can be expressed in different ways**, depending on the necessity in a given publication or report, either as data in a table or as a simple text. An example of table format is given below (***Example 1***). In this format, cozy applicable to more taxa, the values

(4 to 1) of each criterion (A-G) and their total (T) for a given taxon are easily seen. For a better and immediate orientation, the first column following the taxa names shows the assigned IUCN threat status.

Example 1: Presentation of a Red List with the formula for each species in a table format.

Taxon/Conservation status (CS), criteria (A-G) values and their total points (T)	**CS**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**T**
***Achnanthidium temniskovae* Ivanov et Ector**	**CR**	**3**	**4**	**4**	**3**	**4**	**4**	**4**	**26**
***Actinotaenium crassiusculum* (De Bary) Teiling**	**EN**	**4**	**4**	**4**	**4**	**1**	**4**	**2**	**23**
***Anabaena lapponica* Borge**	**VU**	**3**	**4**	**4**	**2**	**2**	**2**	**3**	**20**
***Trachydiscus minutus* (Bourrelly) Fott**	**NT**	**4**	**1**	**4**	**1**	**1**	**4**	**1**	**16**
***Trachelomonas pseudobulla* Svirenko**	**LC**	**4**	**1**	**1**	**1**	**1**	**2**	**1**	**11**
***Oedogonium jordanovii* Vodenicharov**	**DD**	–	–	–	–	–	–	–	–

In case when a single species or a small group of species are discussed or cited, it is recommended to express the formula as a text, as it is shown in ***Example 2:*** *Anabaena lapponica* Borge [VU - A3 B4 C4 D2 E2 F2 G3], or *Anabaena lapponica* Borge [VU – A3 B4 C4 D2 E2 F2 G3 T20]. Depending on the need, the formula can also be used in shortened versions, for instance providing a combination of the threat status and the total counts for a given taxon (***Example 3:*** *Anabaena lapponica* Borge [VU – T20]), or providing only the species threat status ***(Example 4:*** *Anabaena lapponica* Borge [VU]). It has to be underlined that in the last cases, it would be impossible to compare the exact level of threat for two species, which belong to the same category and have equal totals, but have different distribution of the points in the seven criteria (***Example 5:*** *Ophiocytium arbuscula* (A. Braun) Rabenhorst [VU – A4 B4 C4 D2 E1 F1 G3 T19] and *Ophiocytium lagerheimii* Lemmermann [VU – A3 B4 C4 D2 E1 F4 G1 T19]), or for species, which belong to the same threat category but have different total points (***Example 6:*** *Goniochloris triradiata* Pascher [VU – A4 B4 C4 D2 E1 F4 G1 T20] and *Mischococcus sphaerocephalus* Vischer [VU – A3 B2 C4 D2 E1 F4 G1 T17]). In case of different total points, when a comparison is necessary to be done, the species with higher total should be considered as more threatened. In all other cases it is obvious that future conservation measures should take into account exactly the "weak points" of a given taxon.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article. It was written after the propsal of the first author and all the other authors contributed equally to the discussions of the text.

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RED LIST OF BULGARIAN ALGAE. II. MICROALGAE.

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Abstract. The Red List presented in this paper is focused on Bulgarian non-marine microalgae which face a risk of extinction. The assignment to each IUCN Red List category is according to the seven specific criteria and their relative values in the new method for evaluation of the threatened status of microalgae (Stoyneva-Gärtner et al., this volume). The list contains 756 taxa (613 species, 82 varieties and 61 forms) from 7 divisions, classified in six IUCN categories and shows that threatened microalgae represent 14% the total algal biodiversity of Bulgaria.

Key words: algae, Bulgaria, Red List, threatened species

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In spite of having no legal definition, Red Lists are world-wide accepted valuable sozological tools for designating the threatened status of organisms, which face an extinction risk and for raising the public awareness for their conservation as well. However, algae, most probably due to their general belonging to the invisible with the *naked eye* microscopic world, have been rarely considered as threatened (*e.g.* Krause 1984; Rassi & Väisänen 1987; Gutowski & Mollenhauer 1996; Knappe et al. 1996; Kusel-Fetzmann 1999; Lange-Bertalot & Steindorf 1996; Lenzenweger 1999; Mollenhauer & Kristensen 1996; Environmental Agency, Japan 2000; Palamar-Mordvintseva & Tsarenko 2004; Németh 2005; Blaženčić et al. 2006; Siemińska 2006) and only 92 taxa, mainly marine macroalgae, have been included in The IUCN Red List of Threatened Species,Version 2015–4.

In Bulgaria, the first Red List of macroalgae, based on standard IUCN criteria and categories, was published as a first part of general Red List of Bulgarian algae (Temniskova et al. 2008). The paper title (*Red List of Bulgarian Algae. I. Macroalgae*) clearly indicates the wish to create a second part oriented towards country's microscopic algae due to the recognition of their biodiversity and conservation importance. The task was extremely difficult because of the obstacles in applying the standard IUCN criteria to the microalgal taxa, using the recent knowledge on their distribution and taxonomy. Therefore the efforts of the author's team were devoted firstly towards the development of a new method for an objective evaluation of the threatened status of the microalgae (Stoyneva-Gärtner et al., this volume). The Red List of microalgae presented in this paper is based on this method and was compiled after critical reading of all the references on their distribution in non-marine habitats of Bulgaria.

The Red List provided below is organized in a table format in the following way: *1)* algal taxa in main taxonomic groups (after Temniskova & Stoyneva 2011a,b), enlisted in alphabetical order according to their recently accepted taxonomic name (mainly after Guiry & Guiry 2016); *2)* assigned IUCN threat category based on *3)* the relative value of each of the seven criteria (A-G) fixed by Stoyneva-Gärtner et al. (this volume), which practically gives the exact formula for each algal taxon and *4)* its total counts (T). As it is proposed in the method description, in further publications or reports such formula could be used separately for each taxon: *e.g. Anabaena pirinica* Petkoff [CR – A3 B3 C4 D4 E4 F4 G4]. In case of special insistence on the level of the importance of the species due to its total counts, the formula could be expressed as *Anabaena pirinica* Petkoff [CR – A3 B3 C4 D4 E4 F4 G4 T25], or could be used in its short versions (*e.g. Anabaena pirinica* Petkoff [CR – T25], or *Anabaena pirinica* Petkoff [CR]).

According to the IUCN recommendations in the Guidelines for Application of IUCN Red List Criteria at Regional Levels (Versions 3.0, 2007 and 4.0., 2012) we avoided the general categories 'Extinct' and 'Extinct in the Wild'. Taking into account the lack of recent investigations in some of the localities, we decided to avoid also the category 'Regional Extinct' even for species, which have not been confirmed for the territory of Bulgaria during the last five (or more) decades. The other categories (Critically Endangered, Endangered, Vulnerable, Low Risk /Near Threatened, Least Concern/ and Data Deficient) were designated according to the total counts for each species, obtained after applying the seven criteria and their relative values proposed by Stoyneva-Gärtner et al. (this volume). Due to the restricted volume of the paper, the synonyms are provided only for a few taxa, described from Bulgaria and references concerning the distribution of the included algae are enlisted only in the end of the paper. A special note has to be made for some *mesoalgae*, which could be visible macroscopically, but could not be identified even on generic level without a light microscope (*e.g. Oedogonium*, *Mougeotia*, *Zygnema*). Their representatives are included in the present list with one exception – *Spirogyra rhodopea* Petkoff, which has been enlisted as a Data Deficient species in Temniskova et al. (2008).

Since the recent algal biodiversity in Bulgaria is quite rich – ca. 5500 taxa (Stoyneva 2014), a preliminary screening of the species was done by the author's team in an effort to elucidate the most rarely reported algae in Bulgarian phycological literature since the first publications by Istvánffi (1890) and Petkoff (1898a-c) till nowadays. Afterwards the chosen algae were evaluated according to the method of Stoyneva-Gärtner et al. (this volume). Therefore it is possible to expect that further checking could outline more threatened microalgae in the country.

The proposed Red List of threatened Bulgarian non-marine microalgae contains 757 taxa (613 species, 83 varieties and 61 forms) from 7 divisions classified in six IUCN categories and the number of the threatened taxa in these categories and main taxonomic groups is shown below (**Tables 1-2)**.

The number of threatened species, varieties and forms of microalgae in the present Red List shows that they comprise 14% of the total algal biodiversity of Bulgaria, and together with the 88 threatened macroalgae enlisted in Temniskova et al. (2008), they constitute 15% of all algae reported for the country.

Table 1. Distribution of threatened Bulgarian microalgae in taxonomic divisions and IUCN categories (CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern and DD – Data Deficient).

IUCN category	Cyano prokaryota	Eugleno phyta	Pyrrho phyta	Ochro-phyta	Hapto-phyta	Chloro-phyta	Strepto-phyta	Total
CR	4 sp., 2 f.	1 sp.	–	10 sp., 2 var.	–	18 sp., 1 var., 3 f.	5 sp., 18 var., 17 f.	38 sp., 21 var., 22 f.
EN	24 sp., 1 var.	8 sp., 4 var., 4 f.	2 sp.	77 sp., 8 var., 1 f.	1 sp.	47 sp., 2 var., 1 f.	22 sp., 6 var., 2 f.	181 sp., 21 var., 8 f.
VU	20 sp.	10 sp.	–	114 sp., 8 var.	–	64 sp., 2 var.	49 sp., 8 var., 1 f.	257 sp., 18 var., 1 f.
NT	14 sp.	12 sp., 2 var.	2 sp.	31 sp.	–	25 sp., 1 var.	24 sp., 2 var.	108 sp., 5 var.
LC	1 sp.	1 sp.	–	1 sp.	–	–	–	3 sp.
DD	– – 1 f.	3 sp.	–	14 sp., 6 var.	–	5 sp., 5 var., 4 f.	4 sp., 6 var., 25 f.	26 sp., 17 var., 30 f.
Total	63 sp., 1 var., 3 f.	35 sp., 6 var., 4 f.	4 sp.	247 sp., 24 var., 1 f.	1 sp.	159 sp., 11 var., 8 f.	104 sp., 40 var., 45 f.	613 sp., 82 var., 61 f.

Table 2. Red List of Bulgarian microalgae: CS – conservation status (CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatend, LC – Least Concern, DD – Data Defficient); A–G – criteria in 1–4 categories (described in details in Stoyneva-Gärtner et al., this volume), where: A – number of localities, B – affiliations to protected habitats of Bulgaria, C – affiliation to ecological category, D – affiliation to protected territories, E – endemism, F – general geographic distribution, G – expert weight and T – total counts. In quotes are given the original writting-outs of DD infraspecific taxa, which belong to species which have been taxonomically transferred, or taxa with author names which have been not found by the authors of this paper in the available taxonomic literature.

Taxon/Conservation status and criteria	**CS**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**T**
CYANOPROKARYOTA									
„*Anabaena affinis* forma Petkoff“	**DD**	–	–	–	–	–	–	–	–
***Anabaena lapponica* Borge**	**VU**	3	4	4	2	2	2	3	**20**
***Anabaena oscillarioides* f. *intermedia* Petkoff**	**CR**	4	4	4	4	4	4	4	**28**
***Anabaena pirinica* Petkoff**	**CR**	3	3	4	4	4	4	4	**26**
***Aphanocapsa testacea* Nägeli**	**EN**	3	4	4	4	1	4	4	**24**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Aphanothece nidulans Richter	EN	3	4	4	4	1	2	3	**21**
Aulosira valkanovii Draganov	EN	3	2	4	2	4	4	4	**23**
Calothrix hollerbachii Draganov	EN	4	1	4	1	4	4	4	**22**
Calothrix thermalis Hansgirg ex Bornet et Flahault	EN	4	3	4	3	1	4	4	**23**
Chroococcus cohaerens (Brébisson) Nägeli	NT	3	2	4	1	1	2	1	**14**
Chroococcus helveticus Nägeli	VU	4	1	4	3	1	4	1	**18**
Chroococcus membraninus (Meneghini) Nägeli	NT	4	3	4	1	1	2	1	**16**
Chondrocystis dermochroa (Nägeli) Komárek et Anagnostidis	VU	4	3	4	3	1	3	1	**19**
Chroococcus westii Boye-Petersen	EN	4	4	4	3	1	4	1	**21**
Coleodesmium sagarmathae Komárek et Watanabe	EN	3	4	4	4	1	4	3	**23**
Coleodesmium wrangelii ([Agardh] Bornet et Flahault) Borzi ex Geitler	VU	3	4	4	2	1	2	1	**17**
Coelosphaerium aerugineum Lemmermann	EN	4	4	4	3	1	2	4	**22**
Cyanobacterium diachloros (Skuja) Komárek, Kopecký et Cepák	EN	4	4	4	3	1	4	1	**21**
Cylindrospermum alatosporum Fritsch	EN	4	4	4	3	1	3	2	**21**
Cylindrospermum dobrudjense Draganov	EN	3	1	4	2	4	4	4	**22**
Cylindrospermum marchicum (Lemmermann) Lemmermann	VU	4	1	4	1	1	3	4	**18**
Cylindrospermum urumoffii Petkoff	CR	3	3	4	4	4	4	4	**26**
Cylindrospermum voukii Pevalek	NT	4	1	4	1	1	4	1	**16**
Eucapsis minor (Skuja) Elenkin	EN	3	4	4	2	1	4	4	**22**
Eucapsis minuta Fritsch	EN	3	4	4	2	1	4	3	**21**
Gloeocapsa alpina Nägeli	LC	1	1	2	2	1	1	1	**9**
Gloeocapsa gelatinosa Kützing	VU	4	3	4	3	1	2	1	**18**
Gloeocapsa granosa (Berkeley) Kützing	NT	4	1	4	1	1	4	1	**16**
Gloeocapsa haematodes (Kützing) Kützing	EN	3	4	4	4	1	4	1	**21**
Gloeocapsopsis crepidinum (Thuret) Geitler ex Komárek	NT	4	1	4	1	1	2	1	**14**
Gloeothece fuscolutea (Nägeli ex Kützing) Nägeli	NT	3	2	4	2	1	3	1	**16**
Gomphosphaeria virieuxii Komárek et Hindák	VU	3	2	3	4	1	3	2	**18**
Hapalosiphon fontinalis Bornet	VU	4	4	4	3	1	2	1	**19**
Jaaginema geminatum (Meneghini ex Gomont) Anagnostidis et Komárek	NT	3	4	3	2	1	1	1	**15**
Lemmermanniella pallida (Lemmermann) Geitler	EN	4	4	4	4	1	3	2	**22**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Lyngbya lutea Gomont ex Gomont	VU	3	2	4	3	1	2	4	**19**
Lyngbya martensiana var. *mendenhalliana* Kol	EN	4	1	4	4	1	4	4	**22**
Mastigocladus laminosus Cohn ex Kirchner	VU	2	3	4	3	1	2	4	**19**
Mastigocladus testarum Lagerheim ex Bornet et Flahault	NT	4	1	4	1	1	2	1	**14**
Merismopedia elegans A. Braun	VU	3	4	4	2	1	2	3	**19**
Merismopedia affixa Richter	EN	3	4	4	4	1	3	4	**23**
Merismopedia convoluta Brébisson ex Kützing	NT	3	1	4	1	1	2	4	**16**
Merismopedia insignis Škorbatov	EN	3	2	4	4	1	4	3	**21**
Merismopedia mediterranea Nägeli	VU	3	1	4	1	1	3	4	**17**
Microchaete grisea Thuret ex Bornet et Flahault	NT	4	1	4	1	1	2	1	**14**
Microcoleus anguiformis Harvey ex Kirchner	VU	4	1	4	1	1	4	4	**19**
Nostoc caeruleum Lyngbye ex Bornet et Flahault	VU	4	1	4	1	1	3	4	**18**
Nostoc carneum (Lyngbye) Agardh ex Bornet et Flahault	NT	3	2	3	2	1	1	2	**14**
Nostoc disciforme Fritsch	EN	4	4	3	3	1	4	4	**23**
Nostoc zetterstedtii Areschoug	CR	4	4	4	4	1	4	4	**25**
Oscillatoria formosa f. *nalbanthis* Petkoff	CR	4	4	4	4	4	4	4	**28**
Oscillatoria annae Van Goor	VU	3	4	4	2	1	2	2	**18**
Oscillatoria dzeman-sor Woronichin	NT	4	1	4	1	1	4	1	**16**
Phormidium bulgaricum (Komárek) Anagnostidis et Komárek	EN	3	4	4	2	1	4	4	**22**
Phormidium molischii (Vouk) Anagnostidis et Komárek	EN	4	3	4	1	1	4	4	**21**
Phormidium willei (Gardner) Anagnostidis et Komárek	NT	3	1	4	2	1	2	1	**14**
Rivularia rufescens Nägeli ex Bornet et Flahault	EN	4	4	4	3	1	4	4	**24**
Romeria alascensis (Hortobágyi et Hilliard) Komárek	VU	3	2	4	2	1	4	1	**17**
Scytonema bewsii Fritsch et Rich	VU	4	4	4	1	1	4	1	**19**
Scytonema cincinatum (Kützing) Thuret ex Bornet et Flahault	EN	4	3	4	3	1	2	4	**21**
Scytonema mirabile [Dillwyn] Bornet	NT	2	2	4	2	1	3	1	**15**
Stigonema mamillosum (Lyngbye) Agardh et Bornet et Flahault	VU	4	1	4	4	1	2	1	**17**
Scytonematopsis starmachii Kovácik et Komárek	CR	4	4	4	4	1	4	4	**25**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Stigonema turfaceum Cooke ex Bornet et Flahault	VU	4	3	4	1	1	3	2	18
Symploca thermalis Gomont	EN	4	3	4	3	1	4	4	23
Tolypothrix calcarata Schmidle	VU	4	4	3	1	1	4	3	20
Tolypothrix saviczii Kossinskaja	EN	3	4	4	2	1	4	4	22
EUGLENOPHYTA									
Astasia bulgarica Mihajlow	DD	–	–	–	–	–	–	–	–
Astasia sophiensis Mihajlow	DD	–	–	–	–	–	–	–	–
Phacus abrupta Korshikov	VU	4	4	4	1	1	4	1	19
Phacus angustus Drezepolski	VU	4	4	4	1	1	4	1	19
Phacus anomalus Fritsch et Rich	NT	4	1	4	1	1	3	1	15
Phacus curvicauda f. *robusta* Allorge et Lefèvre	EN	4	4	4	4	1	4	1	22
Phacus ichthydion Pochmann	EN	4	4	4	4	1	3	1	21
Phacus inconspicuus Deflandre	VU	3	4	4	2	1	2	1	17
Phacus inflexus (Kisselev) Pochmann	NT	4	1	4	1	1	3	1	15
Phacus janiczakii Stawinski	EN	4	4	4	4	1	4	1	22
Phacus monilatus var. *suecicus* Lemmermann	NT	3	2	4	2	1	1	1	14
Phacus onyx Pochmann	VU	4	4	4	4	1	2	1	20
Phacus oscillans Klebs	VU	4	1	4	1	1	3	4	18
Phacus pleuronectes f. *gigas* (Da Cunha) Popova	EN	4	4	4	4	1	3	1	21
Phacus polytrophos Pochmann	NT	3	1	4	1	1	3	1	14
Phacus pomiformis (Conrad) Pochmann	EN	4	4	4	3	1	4	3	23
Phacus swirenkoi Skvortzov	NT	4	1	4	1	1	4	1	16
Strombomonas asymmetrica (Roll) Popova	NT	3	2	4	2	1	2	1	15
Strombomonas balvayi Bourrelly et Couté	NT	3	1	4	1	1	4	1	15
Strombomonas jaculata (Palmer) Deflandre	NT	3	1	4	1	1	4	1	15
Strombomonas morenensis Balech et Dastugue	VU	3	2	4	2	1	4	1	17
Strombomonas praeliaris var. *amphora* Kirjakov	EN	4	1	4	1	4	4	4	22
Strombomonas vermontii f. *commune* Popova	EN	4	4	4	1	1	4	4	22
Strombomonas vodenicarovii Kirjakov	EN	4	1	4	1	4	4	4	22
Trachelomonas acanthophora var. *speciosa* (Deflandre) Balech	EN	4	4	4	4	1	3	1	21
Trachelomonas acanthostoma var. *europaea* Drezepolski	NT	4	1	4	1	1	4	1	16
Trachelomonas alisoviana Skvortzov	NT	4	1	4	1	1	4	1	16
Trachelomonas elegans Conrad	EN	4	4	4	4	1	4	1	22

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Trachelomonas formosa (Skvortzov) Deflandre	EN	4	4	4	4	1	4	1	**22**
Trachelomonas laticollis Kotlar	EN	4	4	4	4	1	4	1	**22**
Trachelomonas obtusa Palmer	NT	3	1	4	1	1	3	1	**14**
Trachelomonas ovoides Conrad	VU	4	1	4	1	1	4	4	**19**
Trachelomonas mirabilis var. *helvetica* Huber-Pestalozzi	EN	4	4	4	4	1	4	1	**22**
Trachelomonas pascherii Valkanov	DD	–	–	–	–	–	–	–	–
Trachelomonas perforata Averintsev	NT	4	1	4	1	1	4	1	**16**
Trachelomonas pseudobulla Svirenko	LC	4	1	1	1	1	2	1	**11**
Trachelomonas rhodopensis Valkanov	CR	4	4	4	4	4	4	4	**28**
Trachelomonas rugulosa Stein	NT	3	2	4	2	1	2	1	**15**
Trachelomonas scabra var. *ovata* Playfair	EN	4	4	4	4	1	3	1	**21**
Trachelomonas stokesiana Palmer	VU	3	4	4	2	1	2	1	**17**
Trachelomonas szabadosiana Huber-Pestalozzi	NT	4	1	4	1	1	4	1	**16**
Trachelomonas vas Deflandre	EN	4	4	4	4	1	3	1	**21**
Trachelomonas verrucosa f. *sparseornata* Deflandre	EN	4	4	4	4	1	4	1	**22**
Trachelomonas woycickii Kosczwara	VU	3	4	4	2	1	2	1	**17**
Trachelomonas zorensis Deflandre	VU	4	4	4	1	1	4	1	**19**
PYRRHOPHYTA									
Cystodinium cornifax (Schilling) Klebs	NT	3	2	4	2	1	2	1	**15**
Katodinium planum (Fott) Loeblich III	EN	4	4	4	4	1	3	1	**21**
Tetradinium intermedium Geitler	EN	4	4	4	3	1	4	3	**23**
Hemidinium nasutum Stein	NT	3	2	4	2	1	2	1	**15**
OCHROPHYTA									
BACILLARIOPHYCEAE									
Achnanthidium caledonicum (Lange-Bertalot) Lange-Bertalot	EN	4	3	4	4	1	2	3	**21**
Achnanthidium daonense (Lange-Bertalot) Lange-Bertalot, Monnier et Ector	NT	2	2	4	3	1	1	2	**15**
Achnanthidium helveticum (Hustedt) Monnier, Lange-Bertalot et Ector	NT	2	2	4	3	1	1	1	**14**
Achnanthidium kranzii (Lange-Bertalot) Round et Bukhtiyarova	EN	4	3	4	4	1	2	3	**21**
Achnanthidium kryophila (Petersen) Bukhtiyarova	EN	3	3	4	4	1	2	4	**21**
Achnanthidium lineare W. Smith	NT	2	2	4	2	1	1	1	**13**
Achnanthidium subatomoides (Hustedt) Monnier, Lange-Bertalot et Ector	NT	2	2	4	2	1	1	1	**13**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Achnanthidium subatomus (Hustedt) Lange-Bertalot	NT	2	2	4	2	1	1	2	14
Achnanthidium temniskovae Ivanov et Ector	CR	3	4	4	3	4	4	4	26
Achnanthidium ventralis (Krasske) Haworth et Kelly	EN	4	3	4	4	1	2	3	21
Adlafia bryophila (Petersen) Moser, Lange-Bertalot et Metzeltin	VU	3	3	4	4	1	2	2	19
Adlafia suchlandtii (Hustedt) Lange-Bertalot	EN	4	3	4	4	1	2	3	21
Amphora eximia Carter	VU	3	3	4	3	1	2	3	19
Aneumastus stroesei (Østrup) Mann et Stickle	VU	4	3	4	3	1	2	2	19
Aulacoseira alpigena (Grunow) Krammer	VU	2	3	4	4	1	2	2	18
Aulacoseira distans (Ehrenberg) Simonsen	EN	4	3	4	4	1	2	3	21
Aulacoseira pfaffiana (Reinsch) Krammer	VU	3	3	4	4	1	2	3	20
Aulacoseira valida (Grunow) Krammer	EN	4	3	4	4	1	2	4	22
Boreozonacola hustedtii Lange-Bertalot, Kulikovskiy et Witkowski	EN	3	3	4	4	1	2	4	21
Brachysira neoexilis Lange-Bertalot	VU	3	3	4	4	1	2	2	19
Brachysira styriaca (Grunow) Ross	VU	4	3	4	3	1	2	3	20
Caloneis dubia Krammer	VU	4	3	4	3	1	2	3	20
Caloneis lauta Carter et Bailey-Watts	EN	4	3	4	4	1	2	3	21
Caloneis schumanniana (Grunow) Cleve	EN	4	3	4	4	1	2	3	21
Caloneis tenuis (Gregory) Krammer	VU	3	3	4	3	1	1	2	17
Campylodiscus hibernicus Ehrenberg	DD	–	–	–	–	–	–	–	–
Cavinula cocconeiformis (Gregory) Mann et Stickle	VU	3	3	4	4	1	2	3	20
Cavinula lapidosa (Krasske) Lange-Bertalot	VU	3	3	4	4	1	2	3	20
Cavinula pseudoscutiformis (Hustedt) Mann et Stickle	VU	3	3	4	3	1	2	3	19
Cavinula variostriata (Krasske) Mann et Stickle	VU	3	3	4	3	1	2	2	18
Cavinula weinzierlii (Schimanski) Czarnecki	CR	4	4	4	4	1	4	4	25
Chamaepinnularia schauppiana Lange-Bertalot et Metzeltin	EN	4	4	4	4	1	2	3	22
Chamaepinnularia soehrensis var. *hassica* (Krasske) Lange-Bertalot	EN	4	4	4	4	1	2	3	22
Cocconeis disculus (Schumann) Cleve	VU	3	3	4	3	1	2	3	19
Cocconeis neodiminuta Krammer	VU	3	3	4	3	1	2	1	17
Ctenophora pulchella var. *lacerata* (Hustedt) Bukhtiyarova	DD	–	–	–	–	–	–	–	–
Ctenophora pulchella var. *lanceolata* (O'Meara) Bukhtiyarova	DD	–	–	–	–	–	–	–	–

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Cymbella aspera (Ehrenberg) Cleve	NT	2	2	4	2	1	1	1	**13**
Cymbella hustedtii Krasske	VU	3	3	4	3	1	2	2	**18**
Cymbella orientalis var. *delicatula* Stancheva et Ivanov	CR	4	4	4	3	4	4	4	**27**
Cymbopleura amphicephala (Nägeli) Krammer	NT	2	2	4	2	1	1	1	**13**
Cymbopleura anglica (Lagerstedt) Krammer	VU	3	3	4	3	1	2	2	**18**
Cymbopleura subaequalis (Grunow) Krammer	VU	3	3	4	4	1	2	3	**20**
Cymbopleura subaequalis var. *alpestris* Krammer	EN	4	3	4	4	1	2	3	**21**
Cymbopleura subcuspidata (Krammer) Krammer	VU	3	3	4	3	1	2	2	**18**
Decussata hexagona (Torka) Lange-Bertalot	CR	4	4	4	4	1	4	4	**25**
Diploneis fontium Reichardt et Lange-Bertalot	VU	4	3	4	3	1	2	2	**19**
Diploneis parma Cleve	VU	3	3	4	3	1	2	2	**18**
Encyonema brevicapitatum Krammer	EN	4	4	4	4	1	2	2	**21**
Encyonema gaeumannii (Meister) Krammer	NT	3	2	4	2	1	2	2	**16**
Encyonema hebridicum (Gregory) Grunow	EN	4	3	4	4	1	2	3	**21**
Encyonema mesianum (Cholnoky) Mann	NT	3	2	4	2	1	2	2	**16**
Encyonema neogracile Krammer	VU	2	3	4	3	1	2	2	**17**
Encyonema perpusillum (Cleve) Mann	VU	3	3	4	4	1	2	2	**19**
Encyonema reichardtii (Krammer) Mann	NT	3	3	4	3	1	1	1	**16**
Encyonema rostratum Krammer	EN	4	3	4	4	1	2	3	**21**
Encyonopsis falaisensis (Grunow) Krammer	NT	2	3	4	3	1	1	1	**15**
Encyonopsis krammeri Reichardt	EN	4	3	4	4	1	2	3	**21**
Encyonopsis naviculoides (Hustedt) Krammer	VU	4	3	4	3	1	2	2	**19**
Epithemia adnata var. *saxonica* (Kützing) Patrick	DD	–	–	–	–	–	–	–	–
Epithemia adnata var. *porcellus* (Kützing) Patrick	DD	–	–	–	–	–	–	–	–
Eucocconeis flexella (Kützing) Meister	VU	3	3	4	3	1	2	3	**19**
Eucocconeis quadratarea (Østrup) Lange-Bertalot	VU	3	3	4	4	1	2	3	**20**
Eunotia arculus (Grunow) Lange-Bertalot et Nörpel	VU	3	3	4	4	1	2	3	**20**
Eunotia arcus Ehrenberg	EN	4	3	4	4	1	2	4	**22**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Eunotia boreoalpina Lange-Bertalot et Nörpel-Schempp	VU	3	3	4	4	1	2	2	**19**
Eunotia diadema Ehrenberg	EN	3	3	4	3	1	4	4	**22**
Eunotia diodon Ehrenberg	EN	3	4	4	3	1	2	4	**21**
Eunotia faba (Ehrenberg) Grunow	EN	3	4	4	3	1	2	4	**21**
Eunotia flexuosa Kützing	VU	3	3	4	4	1	2	3	**20**
Eunotia flexuosa var. *rilensis* Kawecka	CR	4	4	4	4	4	4	4	**28**
Eunotia groenlandica (Grunow) Nörpel-Schempp et Lange-Bertalot	VU	3	3	3	3	1	2	2	**17**
Eunotia implicata Nörpel, Lange-Bertalot et Alles	VU	3	3	4	3	1	2	2	**18**
Eunotia inflata (Grunow) Norpel-Schempp et Lange-Bertalot	VU	3	3	4	4	1	2	2	**19**
Eunotia monodon Ehrenberg	VU	3	3	4	3	1	2	3	**19**
Eunotia mucophila (Lange-Bertalot, Nörpel et Alles) Lange-Bertalot	EN	3	3	4	4	1	2	4	**21**
Eunotia paludosa Grunow	VU	3	3	4	3	1	2	2	**18**
Eunotia pectinalis (Kützing) Rabenhorst	VU	3	3	4	3	1	2	2	**18**
Eunotia pseudopectinalis Hustedt	EN	3	3	4	4	1	4	4	**23**
Eunotia rhomboidea Hustedt	VU	3	3	4	4	1	2	3	**20**
Eunotia sudetica Müller	EN	4	4	4	3	1	2	3	**21**
Eunotia tenella (Grunow) Hustedt	VU	3	4	4	3	1	2	2	**19**
Eunotia triodon Ehrenberg	EN	3	3	4	4	1	2	4	**21**
Eunotia valida Hustedt	VU	3	4	4	3	1	2	2	**19**
Fragilaria alpestris Krasske	VU	3	4	4	3	1	2	2	**19**
Fragilaria amphicephaloides Lange-Bertalot	VU	3	3	4	3	1	2	2	**18**
Fragilaria tenera (Smith) Lange-Bertalot	VU	3	3	4	4	1	2	2	**19**
Frustulia crassinervia (Brébisson) Lange-Bertalot et Krammer	VU	3	3	4	3	1	2	3	**19**
Frustulia rhomboides (Ehrenberg) De Toni	VU	3	3	4	3	1	1	2	**17**
Frustulia saxonica Rabenhorst	VU	3	3	4	3	1	1	3	**18**
Genkalia boreoalpina Wojtal, Wetzel, Ector, Ognjanova-Rumenova et Buczkó	EN	4	3	4	4	1	2	3	**21**
Genkalia digitulus (Hustedt) Lange-Bertalot et Kulikovskiy	VU	3	3	4	3	1	2	3	**19**
Gomphonema acidoclinatum Lange-Bertalot et Reichardt	NT	2	2	4	3	1	1	1	**14**
Gomphonema amoenum Lange-Bertalot	VU	3	3	4	3	1	2	3	**19**
Gomphonema angustum Agardh	NT	3	3	4	2	1	1	1	**15**
Gomphonema carolinense Hagelstein	EN	4	3	4	3	1	4	3	**22**
Gomphonema exilissimum (Grunow) Lange-Bertalot et Reichardt	NT	2	2	4	2	1	1	1	**13**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Gomphonema gracile Ehrenberg	**VU**	2	3	4	3	1	2	2	**17**
Gomphonema hebridense Gregory	**VU**	3	3	4	4	1	2	2	**19**
Gomphonema intricatum Kützing	**VU**	3	3	4	3	1	2	2	**18**
Gomphonema lateripunctatum Reichardt et Lange-Bertalot	**VU**	3	3	4	3	1	2	2	**18**
Gomphonema neonasutum Lange-Bertalot et Reichardt	**VU**	4	3	4	3	1	2	3	**20**
Gomphonema parvulius (Lange-Bertalot et Reichardt) Lange-Bertalot et Reichardt	**EN**	4	3	4	4	1	2	3	**21**
Gomphonema productum (Grunow) Lange-Bertalot et Reichardt	**VU**	2	3	4	3	1	2	3	**18**
Gomphonema rhombicum Fricke	**LC**	1	2	4	2	1	1	1	**12**
Gomphonema sarcophagus Gregory	**VU**	3	3	4	3	1	2	2	**18**
Gomphonema subtile Ehrenberg	**EN**	4	3	4	4	1	2	3	**21**
Gomphonema utae Lange-Bertalot et Reichardt	**VU**	4	3	4	3	1	2	2	**19**
Hygropetra balfouriana (Grunow) Krammer et Lange-Bertalot	**VU**	4	3	4	3	1	2	3	**20**
Karayevia laterostrata (Hustedt) Round et Bukhtiyarova	**VU**	3	4	4	3	1	2	3	**20**
Karayevia suchlandtii (Hustedt) Buktiyarova	**EN**	4	3	4	4	1	2	3	**21**
Kobayasiella jaagii (Meister) Lange-Bertalot	**EN**	4	3	4	4	1	2	3	**21**
Kobayasiella parasubtilissima (Kobayasi et Nagumo) Lange-Bertalot	**VU**	3	3	4	3	1	2	2	**18**
Mastogloia smithii var. *lacustris* Grunow	**EN**	4	3	4	4	1	2	3	**21**
Melosira dickiei (Thwaites) Kützing	**DD**	–	–	–	–	–	–	–	–
Navicula angusta Grunow	**NT**	2	2	4	3	1	1	3	**16**
Navicula bremensis Hustedt	**EN**	4	3	4	4	1	2	3	**21**
Navicula concentrica Carter et Bailey-Watts	**EN**	3	4	4	3	1	2	4	**21**
Navicula detenta Hustedt	**EN**	3	3	4	3	1	3	4	**21**
Navicula medioconvexa Hustedt	**VU**	3	2	4	2	1	2	3	**17**
Navicula oligotraphenta Lange-Bertalot et Hofmann	**VU**	3	2	4	2	1	2	3	**17**
Navicula porifera var. *opportuna* (Hustedt) Lange-Bertalot	**VU**	3	3	4	3	1	2	4	**20**
Navicula schmassmanii Hustedt	**EN**	3	3	4	4	1	2	4	**21**
Navicula striolata (Grunow) Lange-Bertalot	**VU**	4	3	4	3	1	2	3	**20**
Navicula tridentula Krasske	**EN**	3	3	4	4	1	2	4	**21**
Navicula utermoehlii Hustedt	**DD**	–	–	–	–	–	–	–	–
Navicula vulpina Kützing	**EN**	4	3	4	4	1	2	3	**21**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Neidiopsis levanderi (Hustedt) Lange-Bertalot et Metzeltin	EN	3	3	4	4	1	2	4	**21**
Neidium affine (Ehrenberg) Pfizer	VU	3	3	4	3	1	1	2	**17**
Neidium alpinum Hustedt	EN	4	3	4	4	1	2	3	**21**
Neidium ampliatum (Ehrenberg) Krammer	NT	3	3	4	3	1	1	1	**16**
Neidium bisulcatum (Lagerstedt) Cleve	VU	3	3	4	3	1	2	3	**19**
Neidium bisulcatum var. *subampliatum* Krammer	EN	4	3	4	3	1	2	4	**21**
Neidium hercynicum Mayer	EN	4	3	4	3	1	2	4	**21**
Neidium iridis (Ehrenberg) Cleve	VU	3	4	4	3	1	2	3	**20**
Nitzschia alpina Hustedt	VU	3	3	4	3	1	2	2	**18**
Nupela impexiformis Lange-Bertalot	EN	4	3	4	4	1	2	3	**21**
Nupela lapidosa (Krasske) Lange-Bertalot	VU	3	3	4	3	1	2	2	**18**
Nupela silvahercynia (Lange-Bertalot) Lange-Bertalot	EN	3	4	4	4	1	4	4	**24**
Orthoseira roeseana (Rabenhorst) O'Meara	VU	3	3	4	3	1	2	2	**18**
Pinnularia acutobrebissonii Kulikovskiy, Lange-Bertalot et Metzeltin	DD	–	–	–	–	–	–	–	–
Pinnularia angusta var. *rostrata* Krammer	EN	4	3	4	4	1	2	3	**21**
Pinnularia appendiculata (Agardh) Schaarschmidt	VU	3	3	4	3	1	2	2	**18**
Pinnularia bicapitata (Lagerstedt) Cleve	DD	–	–	–	–	–	–	–	–
Pinnularia biceps Gregory	VU	2	4	4	3	1	2	2	**18**
Pinnularia borealis var. *scalaris* (Ehrenberg) Rabenhorst	VU	3	3	4	3	1	2	3	**19**
Pinnularia brandelii Cleve	VU	4	3	4	3	1	2	3	**20**
Pinnularia braunii (Grunow) Cleve	VU	3	4	4	3	1	2	3	**20**
Pinnularia brevicostata Cleve	EN	3	3	4	4	1	2	4	**21**
Pinnularia crucifera Cleve	DD	–	–	–	–	–	–	–	–
Pinnularia divergens Smith	EN	4	3	4	4	1	2	3	**21**
Pinnularia divergentissima (Grunow) Cleve	EN	4	3	4	4	1	2	4	**22**
Pinnularia diversa Østrup	EN	4	3	4	4	1	2	4	**22**
Pinnularia eifeliana (Krammer) Krammer	VU	4	3	4	3	1	2	3	**20**
Pinnularia gentilis (Donkin) Cleve	DD	–	–	–	–	–	–	–	–
Pinnularia gigas Ehrenberg	DD	–	–	–	–	–	–	–	–
Pinnularia hemiptera (Kützing) Rabenhorst	VU	3	3	4	3	1	2	2	**18**
Pinnularia intermedia (Lagerstedt) Cleve	VU	3	4	4	3	1	2	2	**19**
Pinnularia isselana Krammer	VU	3	3	4	3	1	2	2	**18**
Pinnularia lata (Brébisson) Smith	VU	4	3	3	4	1	2	3	**20**
Pinnularia lundii Hustedt	VU	4	3	4	3	1	2	2	**19**
Pinnularia marchica Ilka Schönfelder	VU	4	3	4	3	1	2	2	**19**
Pinnularia mayeri Krammer	VU	3	3	4	3	1	2	2	**18**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Pinnularia microstauron var. *nonfasciata* Krammer	VU	3	3	4	3	1	2	2	**18**
Pinnularia neomajor var. *inflata* Krammer	VU	4	3	4	4	1	2	2	**20**
Pinnularia nobilis (Ehrenberg) Ehrenberg	DD	–	–	–	–	–	–	–	–
Pinnularia obscura Krasske	EN	4	3	4	4	1	2	3	**21**
Pinnularia platycephala (Ehrenberg) Cleve	EN	4	3	4	4	1	2	4	**22**
Pinnularia rabenhorstii (Grunow) Krammer	EN	4	3	4	4	1	2	3	**21**
Pinnularia rhombarea Krammer	EN	4	3	4	4	1	2	3	**21**
Pinnularia schoenfelderi Krammer	VU	3	3	3	3	1	2	3	**18**
Pinnularia schroederi (Hustedt) Cholnoky	VU	4	3	4	4	1	2	2	**20**
Pinnularia scotica Krammer	VU	4	3	4	3	1	2	3	**20**
Pinnularia stomatophora (Grunow) Cleve	VU	3	3	3	3	1	2	2	**17**
Pinnularia stomatophora var. *irregularis* Krammer	VU	4	3	4	4	1	2	2	**20**
Pinnularia subcommutata Krammer	VU	4	3	4	3	1	2	2	**19**
Pinnularia subrupestris var. *cuneata* Krammer	VU	4	3	4	3	1	2	3	**20**
Pinnularia sudetica (Hilse) Hilse	DD	–	–	–	–	–	–	–	–
Pinnularia tirolensis var. *julma* Krammer	VU	4	3	4	3	1	2	3	**20**
Placoneis abiskoensis (Hustedt) Lange-Bertalot et Metzeltin	VU	4	3	4	3	1	2	3	**20**
Placoneis ignorata (Schimanski) Lange-Bertalot	VU	3	3	4	3	1	2	2	**18**
Placoneis pseudanglica Cox	NT	3	2	4	2	1	2	1	**15**
Platessa rupestris (Krasske) Lange-Bertalot	EN	4	4	4	3	1	3	4	**23**
Psammothidium bioretii (Germain) Bukhtiyarova et Round	NT	1	3	4	2	1	1	2	**14**
Psammothidium curtissimum (Carter) Aboal	VU	3	3	4	4	1	2	3	**20**
Psammothidium didymum (Hustedt) Bukhtiyarova et Round	VU	3	3	4	4	1	2	3	**20**
Psammothidium marginulatum (Grunow) Bukhtiyarova et Round	VU	3	3	4	4	1	2	3	**20**
Psammothidium oblongellum (Østrup) Van de Vijver	VU	3	3	4	3	1	2	3	**19**
Psammothidium pseudoswazi (Carter) Bukhtiyarova et Round	VU	3	3	4	3	1	2	3	**19**
Psammothidium rechtense (Leclercq) Lange-Bertalot	VU	3	3	4	3	1	2	4	**20**
Psammothidium sacculum (Carter) Bukhtiyarova	VU	3	3	4	4	1	2	3	**20**
Pseudostaurosira pseudoconstruens (Marciniak) Williams et Round	NT	3	3	4	3	1	1	1	**16**
Rossithidium nodosum (Cleve) Aboal	EN	3	4	4	3	1	2	4	**21**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Rossithidium petersennii **(Hustedt) Round et Bukhtiyarova**	**VU**	3	3	4	3	1	2	2	**18**
Rossithidium pusillum **(Grunow) Round et Bukhtiyarova**	**VU**	3	3	4	4	1	2	2	**19**
Sellaphora americana **(Ehrenberg) Mann**	**DD**	–	–	–	–	–	–	–	–
Sellaphora disjuncta **(Hustedt) Mann**	**EN**	4	3	4	3	1	2	4	**21**
Sellaphora laevissima **(Kützing) Mann**	**VU**	3	3	4	3	1	2	3	**19**
Sellaphora perhibita **(Hustedt) Lange-Bertalot et Cantonati**	**EN**	4	3	4	4	1	2	3	**21**
Stauroneis acidoclinata **Lange-Bertalot et Werum**	**VU**	3	3	4	4	1	2	2	**19**
Stauroneis anceps **Ehrenberg**	**EN**	4	3	4	4	1	2	3	**21**
Stauroneis gracilis **Ehrenberg**	**VU**	3	4	4	3	1	2	2	**19**
Stauroneis kriegerii **Patrick**	**VU**	3	4	4	3	1	2	2	**19**
Stauroneis phoenicenteron **(Nitzsch) Ehrenberg**	**VU**	3	3	4	3	1	2	2	**18**
Stauroneis phoenicenteron **var. *lanceolata* (Kützing) Brun**	**DD**	–	–	–	–	–	–	–	–
Stauroneis siberica **(Grunow) Lange-Bertalot et Krammer**	**VU**	4	3	4	3	1	2	3	**20**
Stauroneis tackei **(Hustedt) Krammer et Lange-Bertalot**	**EN**	4	3	4	4	1	2	3	**21**
Stenopterobia delicatissima **(Lewis) Brébisson**	**VU**	3	3	4	3	1	2	3	**19**
Stenopterobia intermedia **(Lewis) Van Heurck**	**DD**	–	–	–	–	–	–	–	–
Surirella bifrons **Ehrenberg**	**EN**	4	3	4	4	1	2	3	**21**
Surirella biseriata **var. *constricta* (Ehrenberg) Grunow**	**DD**	–	–	–	–	–	–	–	–
Surirella spiralis **Kützing**	**VU**	3	3	4	4	1	2	3	**20**
Surirella tenera **Gregory**	**VU**	3	4	4	3	1	2	2	**19**
Tetracyclus rupestris **(Kützing) Grunow**	**DD**	-	-	-	-	-	-	-	-
Note: The list of diatoms contains only freshwater taxa, due to scarce data on other ecological groups in the country.									
CHRYSOPHYCEAE									
Bicosoeca depoucquesiana **Bourrelly**	**NT**	4	1	4	1	1	4	1	**16**
Bicosoeca urceolata **Fott**	**NT**	4	1	4	1	1	2	1	**14**
Chromulina globosa **Pascher**	**NT**	4	1	4	1	1	4	1	**16**
Chromulina hokeana **Pascher**	**NT**	4	1	4	1	1	4	1	**16**
Chromulina pascheri **Hofeneder**	**EN**	4	4	4	3	1	4	1	**21**
Chrysocapsa planktonica **Pascher**	**NT**	4	1	4	1	1	4	1	**16**
Chrysostephanosphaera globulifera **Scherffel**	**VU**	4	4	4	3	1	3	1	**20**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Dinobryon annulatum **Hilliard et Asmund**	**EN**	4	4	4	3	1	4	1	**21**
Dinobryon bavaricum **Imhof**	**NT**	4	1	4	1	1	2	1	**14**
Dinobryon behningii **Swirenko**	**EN**	4	4	4	3	1	4	1	**21**
Dinobryon borgei **Lemmermann**	**VU**	3	4	4	2	1	2	1	**17**
Dinobryon elegans **f. *glabra* Korshikov**	**EN**	4	4	4	3	1	4	4	**24**
Dinobryon eurystoma **(Stokes) Lemmermann**	**VU**	4	4	4	3	1	2	1	**19**
Dinobryon korshikovii **Matvienko**	**EN**	3	4	4	2	1	4	4	**22**
Dinobryon sertularia **var. *protuberans* (Lemmermann) Krieger**	**EN**	4	4	4	3	1	4	1	**21**
Dinobryon stokesii **var. *neustonicum* Petersen et Hanzen**	**EN**	4	4	4	3	1	4	1	**21**
Epipyxis marchica **(Lemmermann) Hilliard et Asmund**	**EN**	3	4	4	2	1	4	3	**21**
Epipyxis proteus **(Wisłouch) Hilliard et Asmund**	**VU**	3	4	4	2	1	4	1	**19**
Epipyxis stokesii **(Lemmermann) Smith**	**EN**	4	4	4	4	1	4	1	**22**
Kephyrion cupuliforme **Conrad**	**EN**	4	4	4	3	1	4	4	**24**
Kybotion globosum **(Matvienko) Bourrelly**	**EN**	3	4	4	2	1	4	4	**22**
Monosiga vitošensis **Valkanov**	**CR**	4	4	4	3	4	4	4	**27**
Paraphysomonas takahashi **Cronberg et Kristiansen**	**CR**	4	4	4	4	4	4	1	**25**
Phaeodermatium rivulare **Hansgirg**	**EN**	4	4	4	3	1	3	2	**21**
Polykyrtos vitreus **Pascher**	**VU**	4	1	4	1	1	4	4	**19**
Syncrypta pallida **(Korschikov) Bourrelly**	**EN**	4	4	4	3	1	4	4	**24**
SYNUROPHYCEAE									
Mallomonas actinoloma **var. *maramuresensis* Péterfi et Momeu**	**VU**	3	4	4	4	1	3	1	**20**
Mallomonas valkanoviana **(Valkanov) Conrad** (Syn. *Mallomonas pyriformis* Valkanov)	**CR**	4	4	4	1	4	4	4	**25**
Spiniferomonas abei **Takahashi**	**EN**	4	4	4	4	4	3	1	**24**
XANTHOPHYCEAE									
Arachnochloris maior **Pascher**	**EN**	4	4	4	3	1	4	3	**23**
Botryochloris cumulata **Pascher**	**EN**	4	4	4	4	1	4	1	**22**
Botrydiopsis arhiza **Borzì**	**NT**	3	4	2	1	1	2	1	**14**
Botrydium corniforme **Wodenitscharov**	**CR**	4	4	4	4	4	4	4	**28**
Botrydium milleri **Wodenitscharov**	**EN**	3	4	4	4	1	4	4	**24**
Botrydium pachydermum **Miller**	**VU**	3	1	4	2	1	4	4	**19**
Botrydium tuberosum **Iyengar**	**VU**	4	1	4	1	1	4	4	**19**
Bumilleriopsis closterioides **Pascher**	**EN**	4	4	4	3	1	4	2	**22**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Bumilleriopsis peterseniana **Vischer et Pascher**	**NT**	3	4	3	3	1	1	1	**16**
Centritractus africanus **Fritsch et Rich**	**NT**	3	2	4	2	1	3	1	**16**
Centritractus belenophorus **var.** ***skujae*** **Kiriakov**	**EN**	4	1	4	1	4	4	4	**22**
Centritractus brunneus **Fott**	**NT**	3	1	4	1	1	4	1	**15**
Centritractus heteracanthus **Vodeničarov**	**EN**	4	1	4	1	4	4	4	**22**
Chlorobotrys regularis **(W. West) Bohlin**	**VU**	3	4	4	2	1	2	1	**17**
Goniochloris triradiata **Pascher**	**VU**	4	4	4	2	1	4	1	**20**
Mischococcus sphaerocephalus **Vischer**	**VU**	3	2	4	2	1	4	1	**17**
Ophiocytium arbuscula **(A. Braun) Rabenhorst**	**VU**	4	4	4	2	1	1	3	**19**
Ophiocytium lagerheimii **Lemmermann**	**VU**	3	4	4	2	1	4	1	**19**
Raphidiella fascicularis **Pascher**	**VU**	4	1	4	1	1	4	4	**19**
Trachychloron regulare **Pascher**	**CR**	4	4	4	4	1	4	4	**25**
Trachydiscus minutus **(Bourrelly) Fott**	**NT**	3	1	4	1	1	4	1	**15**
Trachydiscus sexangulatus **Ettl**	**NT**	3	1	4	1	1	4	1	**15**
Tribonema tenerrimum **Heering**	**DD**	–	–	–	–	–	–	–	–
PHAEOTHAMNIOPHYCEAE									
Phaeoschizochlamys mucosa **Lemmermann**	**CR**	4	4	4	4	4	4	4	**28**
Phaeothamnion confervicola **Lagerheim**	**CR**	4	4	4	3	4	3	4	**26**
EUSTIGMATOPHYCEAE									
Ellipsoidion solitare **(Geitler) Pascher**	**EN**	4	4	4	4	1	4	2	**23**
Visheria gibbosa **Pascher**	**EN**	4	4	3	3	1	4	2	**21**
Vischeria undulata **Pascher**	**EN**	4	4	3	4	1	4	2	**22**
Vischeria stellata **(Chodat ex Poulton) Pascher**	**EN**	4	3	3	3	4	3	3	**23**
HAPTOPHYTA									
Hymenomonas coccolithophora **Massart et Conrad**	**EN**	3	2	4	2	1	4	4	**23**
CHLOROPHYTA									
Ankistrodesmus setigerus **var.** ***undosus*** **Hortobágyi**	**DD**	–	–	–	–	–	–	–	–
Borodinella polytetras **Miller**	**NT**	4	3	4	1	1	2	1	**16**
Bulbochaete basispora **Wittrock et Lundell ex Hirn**	**VU**	3	4	4	4	1	2	1	**19**
Bulbochaete tenuis **Hirn**	**VU**	4	4	4	1	1	2	1	**17**
Binuclearia tectorum **(Kützing) Beger**	**NT**	3	4	2	2	1	2	1	**15**
Botryococcus neglectus **(W. et G.S. West) Komárek et Marvan**	**EN**	4	4	4	3	1	3	2	**21**
Carteria rotunda **Ettl H. et O.**	**VU**	4	4	4	2	1	4	1	**20**
Catena viridis **Chodat**	**EN**	4	4	3	3	1	4	4	**23**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Chlainomonas rubra **(Stein et R.C.Brooke) Hoham**	**EN**	4	1	4	4	1	3	4	**21**
Chlorococcum pinquideum **Arce et Bold**	**VU**	4	4	1	4	1	4	1	**19**
Choricystis hindakii **Tell**	**VU**	4	1	4	3	1	4	1	**18**
Closteridium petkovii **Vodenicharov**	**CR**	4	4	4	3	4	4	4	**27**
Coelastrella aeroterrestrica **Tschaikner, Gärtner et Kofler**	**CR**	4	2	4	4	4	4	4	**26**
Coelastrella terrestris **(Reisigl) Hegewald et Hanagata**	**CR**	4	4	4	4	4	2	4	**26**
Coelastropsis costata **(Korshikov) Fott et Kalina**	**EN**	4	4	4	3	1	4	1	**21**
Coelastrum proboscideum **f.** ***minor*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Coelastrum scabrum **Reinsch**	**VU**	4	4	4	3	1	2	1	**19**
Crucigeniopsis divergens **(Smith) Hindák**	**VU**	3	4	4	2	1	4	1	**19**
Dangeardinella saltathrix **Pascher**	**EN**	4	4	4	4	1	4	3	**24**
Desmodesmus grahneisii **(Heynig) Hegewald**	**EN**	4	4	4	4	1	4	2	**23**
Desmodesmus pannonicus **(Hortobágyi) Hegewald**	**VU**	3	2	4	2	1	4	1	**17**
Desmodesmus pseudodenticulatus **(Hegewald) Hegewald**	**CR**	4	4	4	4	1	4	4	**25**
Desmodesmus serratus **(Corda) S. S. An, Friedl et Hegewald**	**NT**	2	2	4	2	1	1	4	**16**
Dichotomococcus bacillaris **Komárek**	**VU**	3	2	4	2	1	4	1	**17**
Dichotomococcus capitatus **Korshikov**	**VU**	4	1	4	1	1	4	3	**18**
Dichotomococcus curvatus **Korshikov**	**NT**	3	2	4	2	1	2	1	**15**
Dicloster acuatus **Jao, Wei et Hu**	**CR**	4	4	4	4	1	4	4	**25**
Dictyosphaerium granulatum **Hindák**	**EN**	4	4	4	3	1	4	4	**24**
Didymocystis inermis **(Fott) Fott**	**VU**	3	4	4	2	1	4	2	**20**
Didymogenes anomala **(Smith) Hindák**	**VU**	3	2	4	2	1	4	1	**17**
Dimorphococcus lunatus **A. Braun**	**VU**	2	2	4	2	1	2	4	**17**
Dispora crucigenioides **Printz**	**VU**	3	4	4	2	1	2	3	**19**
Dispora speciosa **Korshikov**	**EN**	3	4	4	2	1	4	3	**21**
Dunaliella lateralis **Pascher et Jahoda**	**EN**	4	4	4	4	1	4	1	**22**
Elakatothrix gelatinosa **Wille**	**NT**	3	2	4	2	1	2	1	**15**
Elakatothrix parvula **(Archer) Hindák**	**EN**	4	4	4	4	1	4	1	**22**
Ellipsoidion solitare **(Geitler) Pascher**	**EN**	4	4	4	4	1	4	2	**23**
Enallax costatus **(Schmidle) Pascher**	**NT**	2	4	3	2	1	2	1	**15**
Enallax coelastroides **(Bohlin) Skuja**	**VU**	2	4	4	2	1	4	1	**18**
Geminella interrupta **Turpin**	**NT**	4	1	4	1	1	2	1	**14**
Geminella minor **(Nägeli) Heering**	**VU**	4	4	4	3	1	2	1	**19**
Glaucocystis nostochinearum **var.** ***incrassata*** **Lemmermann**	**CR**	4	4	4	4	1	4	4	**25**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Gloeocystis major f. *sphaerica* Petkoff	**CR**	4	4	4	4	4	4	4	**28**
Gloeocystis vesiculosa var. *alpina* Schmidle	**EN**	3	4	4	4	1	4	1	**21**
Glochiococcus aciculiferus (Lagerheim) Silva	**NT**	2	2	4	2	1	2	1	**14**
Gloeotaenium loitlesbergerianum Hansgirg	**CR**	4	4	4	4	1	4	4	**25**
Gongrosira calcifera Krieger	**EN**	4	4	4	4	1	3	1	**21**
Gongrosira debaryana Rabenhorst	**VU**	3	4	4	3	1	2	1	**18**
Gongrosira incrustans (Reinsch) Schmidle	**NT**	3	2	4	2	1	2	1	**15**
Gongrosira schmidlei Richter	**VU**	4	4	4	1	1	4	1	**19**
Gongrosira scourfieldii G. S. West	**VU**	3	4	4	1	1	4	1	**18**
Granulocystopsis calyptrata Hindák	**EN**	4	4	4	3	1	4	1	**21**
Heleochloris pallida Korshikov	**EN**	4	4	4	4	1	4	3	**24**
Hindakia tetrachotoma (Printz) C. Bock, Pröschold et Krienitz	**VU**	3	4	4	2	4	2	1	**20**
Hydrianum gracile Korshikov	**EN**	3	4	4	4	1	4	4	**24**
Hydrianum viride (Scherffrel) Ettl	**VU**	3	4	4	4	1	2	2	**20**
Interfilum paradoxum Chodat et Topali	**EN**	4	4	3	4	1	2	3	**21**
Juraniella javorkae (Hortobagyi) Hortobagyi	**NT**	3	1	4	1	1	4	1	**15**
Kentrosphaera bristoliae Smith	**VU**	4	1	4	1	1	4	2	**17**
Keratococcus saxatilis (Komarková-Legnerová) Hindák	**VU**	3	4	4	2	1	2	2	**18**
Koliella spiculiformis (Vischer) Hindák	**CR**	4	4	4	4	1	4	4	**25**
Lagerheimia circumfilata (Seligo) Hegewald et Schmidt	**EN**	4	4	4	3	1	4	1	**21**
Lanceola spatulifera (Korshikov) Hindák	**VU**	3	2	4	2	1	4	1	**17**
Lauterborniella elegantissima Schmidle	**VU**	2	2	4	2	1	4	2	**17**
Lobocystis michevii Stoyneva	**CR**	4	4	4	4	1	4	4	**25**
Lobomonas francei Dangeard	**VU**	4	1	4	1	1	4	4	**19**
Lobomonas gracilis Christen	**EN**	4	4	4	1	1	4	4	**22**
Lobomonas irregularis Wawrik	**EN**	4	4	4	3	1	4	4	**24**
Lobomonas monstruosa Korshikov	**NT**	4	1	4	1	1	4	1	**16**
Lobomonas stellata Chodat	**NT**	4	1	4	1	1	4	1	**16**
Macrochloris multinucleata (Reisigl) Ettl et Gärtner	**CR**	3	2	4	4	4	4	4	**25**
Micracantha minutissima Korshikov	**NT**	4	1	4	1	1	4	1	**16**
Micractinium crassisetum Hortobágyi	**VU**	3	2	4	2	1	4	4	**20**
Micractinium valkanovii Vodenicharov	**DD**	–	–	–	–	–	–	–	–
Microspora formosana Okada	**CR**	4	4	4	4	1	4	4	**25**
Microspora irregularis (West et G. S. West) Wichmann	**EN**	3	4	4	4	1	4	1	**21**
Microspora loefgrenii (Nordstedt) Lagerheim	**EN**	4	4	4	4	4	3	1	**24**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
***Microspora loefgrenii* (Nordstedt) Lagerheim**	**EN**	4	4	4	4	4	3	1	**24**
***Microthamnion kutzingianum* f. *madarense* Petkoff**	**EN**	4	1	4	3	4	4	4	**24**
***Neglectella eremosphaerophila* Vodeničarov et Benderliev**	**CR**	4	4	4	4	4	4	1	**25**
***Neodesmus danubialis* Hindák**	**NT**	4	1	4	1	1	4	1	**16**
***Nephrochloris incerta* Geitler et Gimesi**	**EN**	4	4	4	3	1	4	4	**24**
***Nephroselmis discoidea* Skuja**	**VU**	3	2	4	2	1	4	1	**17**
***Oedogonium acrosporum* De Bary ex Hirn**	**VU**	1	4	4	3	1	2	3	**18**
***Oedogonium acrosporum* var. *bathmidosporum* Hirn**	**VU**	4	4	4	3	1	2	1	**19**
***Oedogonium balcanicum* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium braunii* Kützing ex Hirn**	**NT**	4	1	4	1	1	2	1	**14**
***Oedogonium borisianum* Wittrock ex Hirn**	**VU**	4	4	4	3	1	2	1	**19**
***Oedogonium cardiacum* var. *polymorphum* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium crispum* Wittrock ex Hirn**	**VU**	4	1	4	1	1	2	4	**17**
***Oedogonium cyathigerum* Wittrock ex Hirn**	**VU**	4	4	4	1	1	2	3	**19**
***Oedogonium cyathigerum* var. *rumelica* Istvanffi**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium globosum* Nordstedt ex Hirn**	**EN**	4	4	4	3	1	2	3	**21**
***Oedogonium intermedium* Wittrock**	**VU**	3	4	4	2	1	2	1	**17**
***Oedogonium inversum* f. *major* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium itzigsohnii* De Bary ex Hirn**	**EN**	4	4	4	3	1	2	4	**22**
***Oedogonium jordanovii* Vodenicharov**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium longatum* Kützing**	**VU**	3	2	4	2	1	2	4	**18**
***Oedogonium magnusii* forma Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium minus* Wittrock ex Hirn**	**EN**	4	4	4	3	1	2	4	**22**
***Oedogonium oblongum* Wittrock ex Hirn** (Syn. *Oedogonium parvulum* Vodenicharov)	**NT**	3	2	4	2	1	2	1	**15**
***Oedogonium orientale* Jao**	**EN**	4	4	4	3	1	4	1	**21**
***Oedogonium plagiostomum* Wittrock ex Hirn**	**NT**	4	1	4	1	1	2	3	**15**
***Oedogonium pringsheimii* Cramer ex Hirn**	**VU**	4	1	4	1	4	2	4	**20**
***Oedogonium punctatostriatum* De Bary ex Hirn**	**VU**	4	4	4	4	1	2	1	**20**
***Oedogonium pusillum* Kirchner ex Hirn**	**VU**	4	4	4	3	1	2	1	**19**
***Oedogonium rufescens* Wittrock ex Hirn**	**EN**	4	4	4	4	1	2	4	**23**
***Oedogonium rufescens* f. *intermedia* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Oedogonium sociale* Wittrock ex Hirn**	**NT**	3	2	4	2	1	2	1	**15**
***Oedogonium suecicum* Wittrock ex Hirn**	**VU**	4	4	4	3	1	2	1	**19**
***Oedogonium vaucheri* A. Braun ex Hirn**	**NT**	3	2	4	2	1	2	1	**15**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Oedogonium vernale (Hassall) Wittrock	DD	–	–	–	–	–	–	–	–
Oocystis gigas f. *intermedia* Petkoff	CR	4	4	4	4	4	4	4	**28**
Oocystis irregularis (Petkoff) Printz	CR	4	4	4	4	1	4	4	**28**
Oonephris palustris Komárek	VU	3	4	4	2	1	4	2	**20**
Palmellopsis texensis (Groover et Bold) Ettl et Gärtner	CR	4	4	4	4	1	4	4	**25**
Palmodictyon varium (Nägeli) Lemmermann	VU	3	4	4	2	1	2	4	**20**
Palmodictyon viride Kützing	VU	3	4	4	2	1	2	2	**18**
Paradoxia paradoxioides (Cirik) Hegewald et Reymond	VU	4	1	4	3	1	4	1	**18**
Parallela transversalis (Brébisson) Novis, M. Lorenz, Broady et E. A. Flint	VU	4	4	4	3	1	3	1	**20**
Pediastrum vagum Kützing	DD	–	–	–	–	–	–	–	–
Peterfiella alata (Peterfi) Gerloff	EN	4	4	4	1	1	4	4	**22**
Phacotus minusculus Bourrelly	EN	4	4	4	3	1	4	1	**21**
Pithophora roettleri (Roth) Wittrock	EN	4	3	4	3	1	2	4	**21**
Pleodorina illinoisensis Kofoid	NT	3	1	4	1	1	2	1	**13**
Pocillomonas flos-aquae Steinecke	VU	3	4	4	2	1	4	1	**19**
Porochloris filamentorum Pascher	EN	4	4	4	3	1	4	4	**24**
Porochloris leptochlamys Pascher	CR	4	4	4	4	1	4	4	**25**
Porochloris tetragona Pascher	EN	4	4	4	3	1	4	4	**24**
Pseudodictyochloris multinucleata (Broady) Ettl et Gartner	EN	4	1	4	4	1	4	4	**22**
Pseudokirchneriella extensa (Korshikov) Hindák	EN	3	4	4	2	1	4	3	**21**
Pseudokirchneriella gracillima (Bohlin) Hindák	EN	4	4	4	4	1	2	3	**22**
Pseudokirchneriella roselata (Hindák) Hindák	EN	3	4	4	2	1	4	4	**22**
Pseudotetrastrum punctatum (Schmidle) Hindák	VU	3	4	4	2	1	4	1	**19**
Pteromonas aequiciliata (Gicklhorn) Bourrelly	VU	4	1	4	1	1	2	4	**17**
Pteromonas cordiformis Lemmermann	EN	3	4	4	3	2	1	4	**21**
Pteromonas torta Korshikov	VU	3	2	4	2	1	4	1	**17**
Pseudodictyochloris multinucleata (Broady) Ettl et Gärtner	CR	4	3	4	4	4	4	4	**27**
Quadricoccus laevis Fott	NT	4	1	4	1	1	3	1	**15**
Quadricoccus verrucosus Fott	NT	4	1	4	1	1	3	1	**15**
Raciborskiella uroglenoides Svirenko	VU	4	1	4	1	1	4	4	**19**
Radiococcus planctonicus Lund	VU	4	4	4	2	1	2	2	**19**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Radiofilum conjunctivum **Schmidle**	**EN**	4	4	4	4	1	2	4	**23**
Radiophillum mesomorphum **Skuja**	**EN**	4	4	4	3	1	2	4	**22**
Raphidonema tatrae **var.** ***yellowstonense*** **Kol**	**EN**	4	1	4	4	1	4	4	**22**
Scenedesmus danubialis **Hortobágyi**	**EN**	3	4	4	2	1	4	4	**22**
Scenedesmus parvus **(Smith) Bourrelly**	**VU**	3	4	4	2	1	2	1	**17**
Scherffelia dubia **(Scherffel) Pascher**	**EN**	4	4	4	3	1	4	2	**22**
Schizochlamydella delicatula **(West) Korshikov**	**VU**	3	4	4	2	1	3	1	**18**
Scotinosphaera gibberosa **(Vodenicarov et Benderliev) Wujek et Thompson** (Syn. *Kentrosphaera gibberosa* Vodenicarov et Benderliev)	**VU**	3	1	3	1	4	4	4	**20**
Scourfeldia complanata **G. S. West**	**EN**	4	4	4	3	1	4	3	**23**
Selenochloris angusta **Pascher**	**VU**	3	2	4	2	1	4	4	**20**
Siderocelis sphaerica **Hindák**	**EN**	3	4	4	2	1	4	4	**22**
Skujaster asteriferus **(Fott) Vodenicarov**	**CR**	4	4	4	4	1	4	4	**25**
Spermatozopsis exsultans **Korshikov**	**VU**	3	2	4	2	1	4	1	**17**
Sphaerellopsis fluviatilis **(Stein) Pascher**	**VU**	4	4	4	4	1	1	2	**20**
Sphaeroplea annulina **var.** ***lata*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Sphaeroplea soleirolii **var.** ***crassisepta*** **(Rieth) Ramanathan**	**NT**	4	1	4	1	1	4	1	**16**
Stigeoclonium thermale **A. Braun**	**VU**	3	3	4	3	1	2	4	**20**
Tetrachlorella ornata **Korshikov**	**NT**	4	1	4	1	1	2	1	**14**
Tetradesmus cumbricus **var.** ***apiculatus*** **Korshikov**	**VU**	4	1	4	1	1	4	4	**19**
Tetradesmus lunatus **Korshikov**	**CR**	4	4	4	4	1	4	4	**25**
Tetrastrum peterfii **Hortobágyi**	**EN**	3	4	4	3	1	4	4	**23**
Tetrastrum hortobagyi **var.** ***regulare*** **Kirjakov et Vodeničarov**	**DD**	–	–	–	–	–	–	–	–
Tetrastrum triacanthum **Korshikov**	**VU**	3	2	4	2	1	4	3	**19**
Tetrastrum triangulare **(Chodat) Komárek**	**EN**	4	4	4	3	1	2	3	**21**
Thorakomonas feldmannii **Bourrelly**	**VU**	4	1	4	1	1	4	4	**19**
Thorakomonas irregularis **Korshikov**	**VU**	4	1	4	1	1	4	4	**19**
Thorakomonas korschikoffii **Conrad**	**VU**	3	2	4	2	1	4	4	**20**
Trochiscia nivalis **Lagerheim**	**VU**	4	1	4	4	1	3	2	**19**
Trochiscia stellata **Vodenicharov et Benderliev**	**EN**	4	4	4	3	4	4	1	**24**
Trochisciopsis tetraspora **f.** ***minor*** **Gärtner, Uzunov, Stoyneva, Kofler et Ingolić**	**CR**	4	4	4	4	4	4	4	**28**
Uronema africanum **Borge**	**VU**	3	2	4	1	1	4	2	**17**
Uronema confervicolum **Lagerheim**	**NT**	3	2	4	2	1	2	1	**15**
Uronema elongatum **Hodgetts**	**VU**	3	4	4	2	1	2	4	**20**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Ulothrix gigas (Vischer) Mattox et Bold	**EN**	4	4	4	4	1	4	1	**22**
Uronema intermedium Bourrelly	**VU**	3	2	4	2	1	4	4	**20**
Uronema terrestre Mitra	**CR**	4	4	4	4	1	4	4	**25**
Valkanoviella vaucheriae Bourrelly	**EN**	4	1	4	1	4	4	4	**22**
Wislouchiella planctonica Skvortzov	**NT**	4	1	4	1	1	4	1	**16**
STREPTOPHYTA									
Actinotaenium borgeanum (Skuja) Kouwets et Coesel	**VU**	3	4	4	2	1	3	1	**18**
Actinotaenium clevei (Lundell) Teiling	**EN**	4	4	4	4	1	4	1	**22**
Actinotaenium crassiusculum (De Bary) Teiling	**EN**	4	4	4	4	1	4	2	**23**
Actinotaenium cruciferum (De Bary) Teiling	**VU**	4	4	4	3	1	2	1	**19**
Actinotaenium cucurbitinum (Bisset) Teiling	**VU**	3	4	4	2	1	2	1	**17**
*Actinotaenium lagenarioides (*Roy) Teiling	**EN**	3	4	4	1	1	4	4	**21**
Actinotaenium minutissimum (Nordstedt) Teiling	**VU**	3	4	4	2	1	3	1	**18**
Actinotaenium palangula (Brébisson ex Ralfs) Teiling	**VU**	3	4	4	2	1	2	1	**17**
Actinotaenium rufescens (Cleve) Teiling	**NT**	3	2	4	2	1	2	1	**15**
Actinotaenium turgidum (Brébisson ex Ralfs) Teiling	**NT**	3	2	4	2	1	2	1	**15**
“Arthrodesmus incus var. *ralfsii* forma Petkoff”	**DD**	–	–	–	–	–	–	–	–
Closterium acutum var. *subrectum* Petkoff	**CR**	3	3	4	4	4	4	4	**26**
Closterium bandericense Petkoff	**CR**	4	3	4	4	4	4	4	**27**
Closterium baillyanum var. *belassicense* Petkoff	**EN**	4	1	4	1	4	4	4	**22**
Closterium bicurvatum var. *major* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium delpontei (Klebs) Wolle	**NT**	4	3	4	1	1	1	1	15
Closterium dianae var. *arcuatum* (Brébisson ex Ralfs) Rabenhorst	**VU**	3	4	4	2	1	2	1	**17**
Closterium dianae var. *arcuatum* f. *crassior* Roubal	**CR**	4	4	4	4	4	4	4	**28**
Closterium dianae var. *pseudodianae* (Roy) Krieger	**VU**	4	4	4	4	1	2	1	**20**
Closterium eboracense Turner	**VU**	3	4	4	2	1	2	1	**17**
Closterium ehrenbergii f. *curtum* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium ehrenbergii f. *rhodopea* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium incurvum f. *intermedia* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium jenneri f. *longior* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium jenneri f. *minus curvata* Petkoff	**DD**	–	–	–	–	–	–	–	–
Closterium macilentum Brébisson	**NT**	4	1	4	1	1	2	1	**14**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
***Closterium moniliferum* f. *devnense* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Closterium parvulum* f. *longior et latior* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Closterium pritchardianum* Archer**	**NT**	3	4	3	2	1	2	1	**16**
***Closterium rostratum* var. *brevirostratum* f. *longior* Petkoff**	**DD**	–	–	–	–	–	–	–	–
***Closterium rostratum* var. *bulgaricum* Vodenicharov et Kabasanova**	**DD**	–	–	–	–	–	–	–	–
***Closterium setaceum* Ehrenberg ex Ralfs**	**DD**	–	–	–	–	–	–	–	–
***Closterium venus* var. *robustum* Petkoff**	**DD**	–	–	–	–	–	–	–	–
"*Closterium venus* f. *major* Petkoff"	**DD**	–	–	–	–	–	–	–	–
***Closterium ulna* var. *striolatum-punctatum* Elenkin**	**EN**	4	4	4	3	1	4	1	**21**
***Cosmarium amoenum* Brébisson ex Ralfs**	**VU**	3	4	4	2	1	2	1	**17**
***Cosmarium annulatum* (Nägeli) De Bary**	**NT**	3	2	4	2	1	2	1	**15**
***Cosmarium bioculatum* var. *depressum* (Schaarschmidt) Schmidle**	**VU**	3	4	4	2	1	2	1	**17**
***Cosmarium bulgaricum* Roubal**	**CR**	3	4	4	4	4	4	4	**27**
***Closterium calosporum* Wittrock**	**VU**	3	4	4	2	1	2	1	**17**
***Cosmarium conspersum* var. *minor* Roubal**	**CR**	4	1	4	4	4	4	4	**25**
***Cosmarium cucumis* f. *tetragona* Petkoff**	**CR**	4	3	4	4	4	4	4	**27**
***Cosmarium cymatopleurum* f. *minor* Roubal**	**CR**	4	4	4	4	4	4	4	**28**
***Cosmarium bipunctatum* Börgesen**	**VU**	4	4	4	3	1	2	1	**19**
***Cosmarium bireme* var. *galiciense* Gutwinski**	**CR**	4	4	4	4	1	4	4	**25**
***Cosmarium biretum* Brébisson ex Ralfs**	**VU**	4	4	4	3	1	2	1	**19**
***Cosmarium broomei* Thwaites ex Ralfs**	**VU**	4	1	4	3	1	2	4	**19**
***Cosmarium calcareum* Wittrock**	**VU**	4	4	4	3	1	2	1	**19**
***Cosmarium circulare* var. *messikommeri* Krieger et Gerloff**	**EN**	4	4	4	3	1	4	1	**21**
***Cosmarium conspersum* var. *latum* (Brébisson) West et G. S. West**	**VU**	3	1	4	2	1	2	4	**17**
***Cosmarium controversum* West**	**EN**	4	4	4	4	1	4	1	**22**
***Cosmarium cylindricum* Ralfs**	**NT**	3	2	4	2	1	3	1	**16**
***Cosmarium debaryi* Archer**	**NT**	2	4	4	2	1	2	1	**16**
***Cosmarium galeritum* var. *sultanlarum* Petkoff**	**CR**	4	4	4	3	4	4	4	**27**
***Cosmarium hammeri* Reinsch**	**NT**	3	2	4	2	1	2	1	**15**
***Cosmarium hammeri* var. *homalodermum* (Nordstedt) West et G. S. West**	**NT**	2	2	4	2	1	2	1	**14**
***Cosmarium hexalobum* Nordstedt**	**VU**	4	4	4	3	1	2	1	**19**
***Cosmarium hornavanense* Gutwinski**	**VU**	4	4	4	4	1	2	1	**20**
„*Cosmarium hornavanense* forma Petkoff“	**DD**	–	–	–	–	–	–	–	–

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Cosmarium hornavanense var. *minor* Roubal	CR	3	2	4	4	4	4	4	**25**
Cosmarium kjellmanii Wille	NT	3	1	4	1	1	2	1	**13**
Cosmarium logiense var. *retusum* Petkoff	CR	4	4	4	4	4	4	4	**28**
Cosmarium laeve f. *fix retusa* Petkoff	CR	4	4	4	4	4	4	4	**28**
Cosmarium minimum West et G. S. West	VU	4	4	4	4	1	2	1	**20**
Cosmarium moniliforme Ralfs	NT	4	1	4	1	1	2	1	**14**
Cosmarium nasutum f. *aperta* Roubal	CR	4	3	4	4	4	4	4	**27**
Cosmarium notabile f. *media* Petkoff	CR	4	4	4	4	4	4	4	**28**
Cosmarium novae-semliae Wille	VU	3	4	4	2	1	2	1	**17**
Cosmarium novae-semliae forma Petkoff	DD	–	–	–	–	–	–	–	–
Cosmarium obsoletum (Hantzsch) Reinsch	NT	3	2	4	2	1	2	1	**15**
Cosmarium obtusatum forma Petkoff	DD	–	–	–	–	–	–	–	–
Cosmarium ornatum Ralfs ex Ralfs	VU	4	4	4	3	1	2	1	**19**
Cosmarium pardalis Cohn	NT	3	1	4	1	1	2	4	**16**
Cosmarium punctulatum var. *subpunctulatum* f. *major* Petkoff	DD	–	–	–	–	–	–	–	–
Cosmarium quadratum var. *compressum* Roubal	CR	4	4	4	4	4	4	4	**28**
Cosmarium quadrifarium Lundell	VU	3	4	4	2	1	2	3	**19**
Cosmarium quadrum Lundell	NT	3	2	4	2	1	2	1	**15**
Cosmarium regnesi Reinsch	VU	4	1	4	3	1	2	4	**19**
Cosmarium speciosissimum Schmidle	EN	3	4	4	2	1	4	4	**22**
Cosmarium speciosum var. *biforme* f. *minor* Petkoff	CR	3	4	4	4	4	4	4	**27**
Cosmarium sportella Brébisson ex Kützing	VU	3	4	4	2	1	2	1	**17**
Cosmarium sportella f. *intermedium* Petkoff	CR	4	4	4	4	4	4	4	**28**
Cosmarium subcucumis f. *minor* Petkoff	CR	4	4	4	4	4	4	4	**28**
Cosmarium thwaitesii f. *minor* Petkoff	DD	–	–	–	–	–	–	–	–
Cosmarium vogesiacum Lemaire	EN	3	4	4	4	1	4	1	**21**
Cosmarium tumens Nordstedt	VU	4	1	4	1	1	3	4	**18**
Cylindrocystis jenneri (Ralfs) West et G. S. West	VU	4	4	4	3	1	2	1	**19**
Euastrum binale var. *retusum* f. *minor* Petkoff	CR	4	4	4	4	4	4	4	**28**
Euastrum bulgaricum Petkoff	CR	4	3	4	4	4	4	4	**27**
Euastrum crassangulatum var. *conicum* Roubal	CR	4	3	4	4	4	4	4	**27**
Euastrum crassangulatum var. *recte granulatum* Roubal	CR	4	1	4	4	4	4	4	**25**
Euastrum delpontei var. *tetragonum* Petkoff	EN	4	1	4	1	4	4	4	**22**
Euastrum denticulatum f. *minor* Petkoff	CR	4	4	4	4	4	4	4	**28**
Euastrum dubium var. *spinulosum* Petkoff	CR	3	3	4	4	4	4	4	**26**

Taxon/Conservation status and criteria	**CS**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**T**
Euastrum erosum **Lundell**	**VU**	3	3	4	4	1	2	1	**18**
Euastrum erosum **f.** ***minor*** **Roubal**	**EN**	3	1	4	4	4	4	4	**24**
Euastrum gayanum **De Toni**	**VU**	4	4	4	4	1	2	1	**20**
Euastrum insulare **(Wittrock) Roy**	**VU**	3	4	4	2	1	2	1	**17**
Euastrum montanum **West et G. S. West**	**VU**	4	4	3	4	1	2	1	**19**
Euastrum transiens **Gay**	**EN**	4	4	3	4	1	4	1	**21**
Euastrum montanum **var.** ***cosmariiforme*** **Roubal**	**CR**	4	1	4	4	4	4	4	**25**
Euastrum montanum **f.** ***major*** **Roubal**	**CR**	3	3	4	4	4	4	4	**26**
Euastrum retusum **f.** ***intermedia*** **Petkoff**	**CR**	4	4	4	4	4	4	4	**28**
Euastrum sublobatum **var.** ***simile*** **Roubal**	**CR**	4	1	4	4	4	4	4	**25**
Euastrum verrucosum **var.** ***polymorphum*** **Petkoff**	**CR**	3	3	4	4	4	4	4	**26**
Genicularia spirotaenia **(De Bary) De Bary**	**VU**	3	4	4	2	1	2	2	**18**
Mesotaenium degreyi **Turner**	**VU**	3	4	4	4	1	2	1	**19**
Mesotaenium chlamydosporum **var.** ***violascens*** **(De Bary) Krieger**	**NT**	4	1	4	1	1	3	1	**15**
Mesotaenium endlicherianum **var.** ***grande*** **f.** ***brevior*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Mesotaenium macrococcum **(Kützing ex Kützing) Roy et Bisset**	**VU**	3	4	4	2	1	2	1	**17**
Mesotaenium mirificum **Archer**	**EN**	4	4	4	3	1	4	4	24
Micrasterias apiculata **Meneghini ex Ralfs**	**VU**	3	2	4	2	1	2	4	**18**
Micrasterias crux-melitensis **(Ehrenberg) Trevisan**	**VU**	3	2	4	2	1	4	4	**20**
Micrasterias thomasiana **Archer**	**NT**	3	2	4	1	1	2	1	**14**
Micrasterias papilifera **var.** ***glabra*** **f.** ***riloensis*** **Petkoff**	**CR**	4	4	4	4	4	4	4	**28**
Mougeotia faveolatospora **Kirjakov**	**NT**	4	1	4	1	1	4	1	**16**
Mougeotia angusta **(Hassall) Czurda**	**NT**	4	3	4	1	1	2	1	**16**
Netrium digitus **var.** ***bulgaricum*** **Roubal**	**CR**	3	2	4	4	4	4	4	**25**
Netrium digitus **var.** ***constrictum*** **f.** ***minor*** **Petkoff**	**CR**	3	4	4	3	4	4	4	**25**
Netrium digitus **var.** ***lamellosum*** **(Brébisson ex Kützing) Grönblad**	**VU**	3	2	4	2	1	2	4	**18**
Netrium digitus **f.** ***rhomboideum*** **(Grönblad) Kossinskaja**	**VU**	3	4	4	2	1	3	1	**18**
Netrium naegelii **(Brébisson ex Archer) West**	**NT**	2	4	4	2	1	2	1	**16**
Onychonema filiforme **(Ralfs) Roy et Bisset**	**VU**	3	4	4	2	1	2	4	**20**
Penium asperum **Petkoff**	**CR**	3	2	4	4	4	4	4	**25**
Penium curtum **f.** ***majus*** **Wille**	**CR**	4	4	4	4	1	4	4	**25**
"*Penium navicula* **var.** ***inflatum*** **f.** ***longior*** **et** ***tenuor*** **Petkoff"**	**DD**	–	–	–	–	–	–	–	–

Taxon/Conservation status and criteria	**CS**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**T**
Penium polymorphum **(Perty) Perty**	**NT**	4	1	4	1	1	2	1	**14**
Penium spirospermum **f.** ***longior*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Roya anglica **G. S. West**	**VU**	4	4	4	1	1	2	1	**17**
Roya pseudoclosterium **(Roy) West et G. S. West**	**EN**	4	4	4	3	1	4	4	**24**
Sphaerozosma aubertianum **f.** ***archeri*** **(Gutwinski) Petlovany**	**EN**	4	4	4	4	1	4	1	**22**
Sphaerozosma vertebratum **Brébisson ex Ralfs**	**VU**	3	4	4	2	1	2	1	**17**
Spirogyra acumbentis **Vodenicarov**	**EN**	4	4	4	4	4	2	1	**23**
Spirogyra adnata var. obscura **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Spirogyra areolata **f.** ***subinflata*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Spirogyra cavata **Vodenicarov**	**EN**	4	1	4	1	4	4	4	**22**
Spirogyra columbiana **Czurda**	**VU**	3	2	4	2	1	4	3	**19**
Spirogyra jugalis **(Dillwyn) Kützing**	**DD**	–	–	–	–	–	–	–	–
Spirogyra neglecta **f.** ***minor*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Spirogyra nitida **f.** ***varians*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Spirogyra spinescens **Kirjakov**	**CR**	4	4	4	1	4	4	4	**25**
Spirotaenia erythrocephala **Itzigsohn**	**EN**	4	4	4	3	1	4	1	**21**
Spirotaenia fusiformis **West et G. S. West**	**EN**	4	4	4	4	1	4	1	**22**
Spirotaenia turfosa **West et G. S. West**	**EN**	4	4	4	4	1	4	1	**22**
Spondylosium papillosum **West et G. S. West**	**EN**	3	4	4	2	1	3	4	**21**
Spondylosium pygmaeum **Cooke**	**VU**	3	4	4	2	1	2	4	**20**
Staurastrum arachne **Ralfs ex Ralfs**	**VU**	4	4	4	4	1	2	1	**20**
Staurastrum avicula **var.** ***lunatum*** **(Ralfs) Coesel et Meesters**	**VU**	3	2	4	2	1	2	4	**18**
Staurastrum bieneanum **Rabenhorst**	**VU**	3	4	4	2	1	2	1	**17**
Staurastrum brevispina **Brébisson**	**NT**	3	1	4	2	1	2	3	**16**
Staurastrum capitulum **Brébisson**	**VU**	3	4	4	2	1	2	2	**18**
Staurastrum echinatum **f.** ***minor*** **Petkoff**	**CR**	4	4	4	4	4	4	4	**28**
Staurastrum forficulatum **var.** ***subsenarium*** **(West et G. S. West) Coesel et Meesters**	**CR**	4	4	4	4	1	4	4	**25**
Staurastrum furcigerum **f.** ***armigerum*** **Nordstedt**	**DD**	–	–	–	–	–	–	–	–
Staurastrum hexacerum **Wittrock**	**VU**	3	1	4	2	1	2	4	**17**
Staurastrum hystrix **Ralfs**	**EN**	4	4	4	4	1	2	4	**23**
Staurastrum inconspicuum **Nordstedt**	**DD**	–	–	–	–	–	–	–	–
Staurastrum inflexum **Brébisson**	**NT**	4	1	4	1	1	2	3	**16**
Staurastrum insigne **Lundell**	**VU**	4	2	4	2	1	3	4	**20**
Staurastrum lanceolatum **Archer**	**VU**	3	4	4	2	1	3	1	**18**
Staurastrum longipes **(Nordstedt) Teiling**	**VU**	3	4	4	2	1	2	4	**20**

Taxon/Conservation status and criteria	CS	A	B	C	D	E	F	G	T
Staurastrum margaritaceum **Meneghini ex Ralfs**	**EN**	3	4	4	3	1	2	4	**21**
Staurastrum muricatiforme **var.** ***minus*** **Roubal**	**CR**	4	3	4	4	4	4	4	**27**
Staurastrum punctulatum **f.** ***minor*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Staurastrum pyramidatum **West**	**NT**	3	2	4	2	1	2	1	**15**
Staurastrum rugulosum **Brébisson ex Ralfs**	**EN**	4	4	4	4	1	3	4	**24**
Staurastrum saxonicum **Bulnheim**	**EN**	4	4	4	4	1	4	1	**22**
Staurastrum senarium **var.** ***spinosum*** **Roubal**	**CR**	4	1	4	4	4	4	4	**25**
Staurastrum sexcostatum **var.** ***productum*** **forma Petkoff**	**DD**	–	–	–	–	–	–	–	–
Staurastrum striolatum **(Nägeli) Archer**	**VU**	4	4	4	3	1	2	1	**19**
Staurastrum subpunctulatum **Gay**	**EN**	4	4	4	4	1	3	4	**24**
Staurastrum tohopecaligense **var.** ***trifurcatum*** **West et G. S. West**	**EN**	4	4	4	4	1	3	3	**23**
Staurastrum turgescens **De Notaris**	**VU**	4	4	4	3	1	2	1	**19**
Staurastrum vestitum **var.** ***orbelicum*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Staurastrum vestitum **var.** ***semivestitum*** **f.** ***intermedium*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Staurodesmus clepsydra **(Nordstedt) Teiling**	**NT**	4	1	4	1	1	2	1	**14**
Staurodesmus extensus **(O. F. Andersson) Teiling**	**VU**	4	4	4	3	1	2	1	**19**
Staurodesmus mucronatus **var.** ***delicatulus*** **(G. S. West) Teiling**	**EN**	4	4	4	3	1	4	2	**22**
Staurodesmus pterosporus **(Lundell) Bourrelly**	**VU**	4	4	4	4	1	2	1	**20**
Tetmemorus granulatus **Brébisson ex Ralfs**	**VU**	3	3	3	4	1	2	1	**17**
Tetmemorus intermedius **Woronichin**	**DD**	–	–	–	–	–	–	–	–
Tetmemorus laevis **var.** ***minutus*** **(De Bary) Willi Krieger**	**VU**	3	4	4	2	1	4	1	**19**
Tortitaenia alpina **(Schmidle) Brook**	**EN**	4	4	4	4	1	4	1	**22**
Xanthidium basidentatum **(Børgesen) Coesel**	**EN**	4	4	4	4	1	3	4	**24**
Xanthidium fasciculatum var. oronense **West et G. S. West**	**VU**	3	4	4	3	1	4	1	**20**
Zygnema chalybeospermum **Hansgirg**	**NT**	3	2	4	2	1	3	1	**16**
Zygnema ericetorum **var.** ***scrobiculatum*** **Petkoff**	**DD**	–	–	–	–	–	–	–	–
Zygnema vaginatum **Klebs**	**VU**	3	4	4	3	1	3	1	**19**

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article. The paper was prepared after the idea of the first author and the contribution to the list is as follows: the list of diatoms was prepared by Ts. Isheva and P. Ivanov; list for all other groups was prepared by B. Uzunov and M. Stoyneva-Gärtner, where B. Uzunov made aeroterrestrial and Pirin algae and the background of the distribution in Bulgaria was prepared by P. Hristova.

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NEW RECORDS OF RARE AND THREATENED LARGER FUNGI FROM MIDDLE DANUBE PLAIN, BULGARIA

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Abstract. New data about the distribution of eleven rare larger fungi for Bulgaria from the Middle Danube Plain (Pleven District) are presented in the paper. Nine species are of a high conservation value, included in the Red List of fungi in Bulgaria. Three of them are enlisted also in the Red Data Book of the Republic of Bulgaria. Seven taxa are new records from Middle Danube Plain.

Key words: ascomycetes, basidiomycetes, Bulgarian mycota, new chorological data

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INTRODUCTION

The present work provides new chorological data for eleven rare larger fungi (ascomycetes and basidiomycetes) in Bulgaria, found during the field works in 2014–2015, in the Middle Danube Plain (Pleven District). Nine species are with a high conservation value, included in the Red List of fungi in Bulgaria (Gyosheva et al. 2006). Three of them *Amanita caesarea* (Scop.: Fr.) Pers.*, Auriscalpium vulgare* Gray and *Cortinarius bulliardii* (Pers.) Fr.) are enlisted also in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Gyosheva 2015a-c).

Only 115 larger fungi have been reported from the Pleven's Hills so far (Gyosheva & Tzonev 2005). Six of them are included in the Red List of fungi in Bulgaria: *Amanita vitttadinii* (Moretti) Vittad., *A. caesarea*, *Arrhenia spathulata* (Fr.: Fr.) Redhead, *Hohenbuehelia petaloides* (Bull.: Fr.) Schulzer, *Hygrophorus russula* (Schaeff.) Kauffman and *Phallus hadriani* Vent.

The Danube Plain is one of the most poorly studied floristic regions in Bulgaria regarding mycodiversity. About 130 species larger fungi (ascomycetes and basidiomycetes) have been reported so far from this region (Denchev & Assyov 2010; Dimitrova & Gyosheva 2009; Gyosheva et al. 2012; Gyosheva & Tzonev 2005; Peev et al. 2015). Seven species are from the Red List of fungi in Bulgaria. Only two species: *Amanita caesarea* and *Pithya cupressima* (Pers.: Fr.) Fuckel are from the Red Data Book of the Republic of Bulgaria. *Tuber macrosporum* Vittad. is a rare and less known for Bulgaria species, also reported from another part of the Danube Plain (Gyosheva et al. 2012). Therefore the present paper presents important new data about the distribution in the Middle Danube Plain of these eleven rare taxa, seven of which are newly recorded for the Danube Plain and nine of which are taxa of a high conservation value.

MATERIAL AND METHODS

The larger fungi were found during the periods September – November 2014 and 2015 by the second author, in the predominant natural and secondary plant communities in the Middle Danube Plain, mostly Kailaka Protected Area: communities of *Quercus cerris* L., *Quercus fraintetto* Ten.*, Carpinus orientalis* Mill., *Tilia tomentosa* Moench and plantations of *Pinus nigra* Arn. but also from the natural forests in Chernelka Natural Monument and in the vicinity of Gorni Dabnik Dam. The investigated areas are almost the same with the previous research from the area (Gyosheva & Tzonev 2005).

The fungi were registered following the tracking method. The identification was confirmed by the use of the works of Courtecuisse & Duhem (1995), Dennis (1968), Krieglsteiner (2000, 2001) and Phillips (2006). The studied specimens are kept at the Mycological Collection of the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia (SOMF). The threat status follows the Red List of fungi in Bulgaria (Gyosheva et al. 2006). The author's name of fungal taxa are abbreviated according to Kirk & Ansell (2004) and Index Fungorum.

RESULTS

New localities of rare larger fungi for Bulgaria in the Middle Danube Plain

Ascomycota

Otidea alutacea **(Pers.) Massee**

Specimen examined: In the Itzovo Branishte locality, between the Pleven town and Jassen village, on soil, near plantation of *Pinus nigra*, 11.10.2015, leg. R. Tzonev, det. R. Tzonev & M. Gyosheva (SOMF 26610), 43.408097N 24.564297E

Vulnerable (VU) species, previously known from the Danube Plain near Rakovitsa village (Dimitrova & Gyosheva 2009).

Basidiomycota

Amanita caesarea **(Scop.) Pers.** (Fig. 1)

Specimen examined: near Gorni Dubnik Dam locality, in community of *Quercus cerris* and *Q. frainetto* , 02.10. 2014, leg. & det. R. Tzonev (SOMF 26611), 43.362316N 24.306672E

Vulnerable (VU) species. Enlisted in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Gyosheva 2015a). So far reported for the Middle Danube Plain from oak forests in Itzovo Branishte locality (Gyosheva & Tzonev 2005).

Fig. 1.

A. franchetii **(Boud.) Fayod.**

Specimen examined: Kailaka Protected Aarea, Bohotska forest, in community of *Q. cerris*, 25.10. 2015, leg. R. Tzonev, det. R. Tzonev & M. Gyosheva (SOMF 26612), 43.341909N 24.306754E.

During the field observation the species was recorded as widespread in the oak forest also in Chernelka Natural Monument (Todorovo village) and Burkach village (43.270660N 24.422897E) and in the vicinities of Gorni Dabnik Dam (43.362082N 24.306754E).

Vulnerable (VU) species. The record is new for the Pleven's Hills and the Danube Plain.

***Auriscalpium vulgare* Gray**

Specimen examined: Kailaka protected area, *P. nigra* plantation, 02.11.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26613), 43.352035N 24.644206E.

Endangered (EN) species. Enlisted in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Gyosheva 2015b). The record is new for the Danube Plain.

***Clitocybe alexandri* (Gillet) Gillet**

Specimen examined: near the Chernelka River (Chernelka Natural Monument), in forest of *Carpinus orientalis*, 25.10.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26614), 43.340026N 24.558050E.

The finding is new for the Danube Plain. The species is rare for Bulgaria. It was reported only once from Bulgaria – Rila Mts, Borovets locality, in beech community (Stoychev & Gyosheva 2005).

***Cortinarius bulliardii* (Pers.) Fr.**

Specimen examined: near the Chernelka River (Chernelka Natural Monument), in forest of *C. orientalis*, 25.10.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26615), 43.340249N 24.552678E. .

Endangered (EN) species. Enlisted in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Gyosheva 2015c). This is the first record for the Danube Plain.

***Hygrophorus russula* (Schaeff.) Kauffman**

Specimen examined: near the Chernelka River (Chernelka Natural Monument), in forest of *C. orientalis*, 25.10.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26616), 43.340284N 24.558032E. .

Vulnerable (VU) species. It was already reported from the region: from Kailaka Protected Area, in community of *Q. cerris* and *Q. frainetto* (Gyosheva & Tzonev 2005).

***Phallus hadriani* Vent.**

Specimen examined: Itzovo Branishte locality, on dry pasture, 09.11.2015, leg. R. Tzonev, det. M. Gyosheva, 43.415301N 24.556129E.

Near Threatened (NT) species. It was reported for the Middle Danube Plain from Totleben village (Gyosheva & Tzonev 2005).

Pisolithus arrhizus **(Scop. : Pers.) Rauschert**

Specimen examined: Itzovo Branishte locality, on dry pasture, 09.11.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26619), 43.415278N 24.554675E.

Near Threatened (NT) species. This is the first record for the Danube Plain.

Tulostoma brumale **Pers.**

Specimen examined: Kailaka Protected Area, on calcareous soils, in community of *C. orientalis*, 02.11.2015, leg. R. Tzonev, det. R. Tzonev & M. Gyosheva (SOMF 26617), 43.380672N 24.632225E.

Rare species for Bulgaria. Recorded for the first time from the Danube Plain.

Typhula filiformis **(Bull.) Fr.** (Fig. 2)

Specimen examined: Itzovo Branishte locality, between Pleven town and Jassen village, on decaying twigs and leafs in forest litter, in community of Silver Lime (*Tilia tomentosa*), 18.10.2015, leg. R. Tzonev, det. M. Gyosheva (SOMF 26618), 43.408968N 24.569255E.

It is not a common species in Bulgaria. It had been reported from Sofia region, Sofia city – Borisova Gradina Park (Hinkova1955) and from Western Stara Planina Mts, between Tsaritchina and Tseretsel village (Assyov et al. 2010). This is the first record for the Danube Plain.

Fig. 2

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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FIRST RECORD OF *MARASMIUS LIMOSUS* AND *PHOLIOTA CONISSANS* (BASIDIOMYCOTA) IN BULGARIA

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Abstract. The paper provides information on the first finding of *Marasmius limosus* Quél. and *Pholiota conissans* (Fr.) M. M. Moser in Bulgaria. Both fungi were found as saprotrophs on decaying leaves and stems of *Typha angustifolia* L. in the karstic swamp Dragomansko Blato. Morphological data obtained by light microscopy are provided for both species. The easy recording of both species in the swamp in the middle of October allows the suggestion for further autumn searching for macromycetes in wetlands.

Key words: Dragomansko Blato, karstic swamp, monocot saprotrophs, *Typha angusitifolia*.

Marasmius limosus Quél. and *Pholiota conissans* (Fr.) M. M. Moser (Syn. *Pholiota graminis* (Quél.) Singer) are among macromycetes which can grow on wetland monocots such as *Carex, Cyperus, Deschampsia, Eleocharis, Juncus, Molinia, Phragmites, Scirpus* and *Typha* (Redhead 1981). Therefore these fungi are spread in different wetlands throughout the North Temperate Zone (Redhead 1981; Hansen & Knudsen 1992; Bas et al. 1995, 1999). Although the surface of Bulgarian non-lotic wetlands is more than 10^5 ha and many data on their biodiversity

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are available (Stoyneva & Michev 2007b), their macromycetes are very poorly studied and need further attention (Gyosheva 2007a). Quite scarce are the data on macromycetes on non-lotic wetland monocots in Bulgaria. Barsakoff (1929) reported the ascomycete *Disciotis venosa* (Pers.) Arnould (Syn. *Peziza venosa* Pers.) on stems of *Schoenoplectus lacustris* (L.) Palla (Syn. *Scirpus lacustris* L.) from the swamp Dragomansko Blato and later on Gyosheva (2007b) included *Mycena typhae* (Schweers) Kotl in the species list for the swamp Gorno Boyansko Blato. Recently *Mycena tubarioides* (Maire) Kühner was published from a dry stem of *Typha latifolia* L. and from dead stems of *Carex* spp. and *Juncus* spp. (Gyosheva et al. 2012; Ganeva & Roussakova 2015). The present paper provides new data on the macromycetes which develop on wetland monocots in the karstic swamp Dragomansko Blato (IBW0012 in Stoyneva & Michev 2007a).

Barsakoff (1929) visited the swamp Dragomansko Blato on 15th September 1928. The author of the present article inspected the same wetland for macromycetes 87 years later, on 18th October 2015. Then two new for Bulgaria species were found on decaying parts of *Typha angustifolia* L.: *Marasmius limosus* Quél. and *Pholiota conissans* (Fr.) M. M. Moser. Their basidiomata were collected for further investigations by Olympus BX53 microscope on non-permanent slides. The photos were taken by Olympus DP72 camera. Fungal names follow the Index Fungorum. The collected specimens are kept in the Mycological Collection of the Department of Botany of Sofia University "St. Kliment Ohridski".

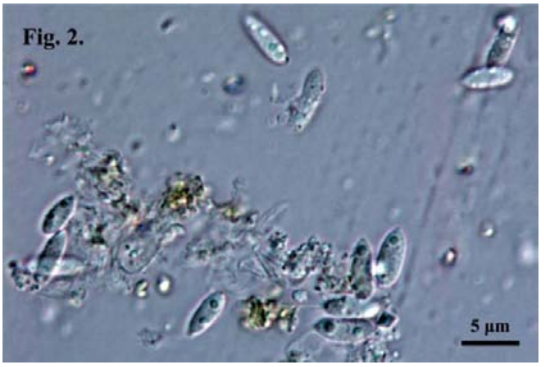
Below morphological data obtained by light microscopy (LM) on both new species are provided:

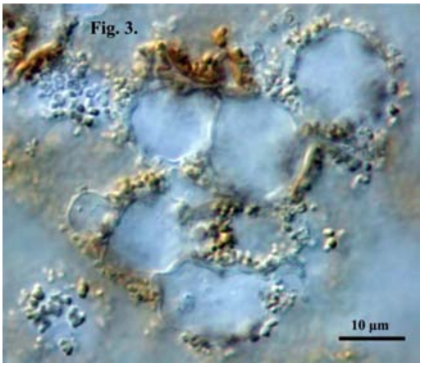
***Marasmius limosus* Quél.**

Pileus was 0.8–3.5 mm in diameter, convex, beige in colour with central umbonate cinnamon brown disc (**Fig. 1**). Lamellae were 6 to 9, broadly adnate, white in colour. Stipe was 0.1–0.2 mm wide and 15–25 mm long, dark brown to whitish at the apex, smooth and shining (**Fig. 1**). Spore print was white. Basidiospores were 6–8 x 3–4.5 μm, ellipsoid (**Fig. 2**). The pileipellis elements were broadly clavate, 12–19 μm in diameter and covered by numerous warts, yellow ochre in colour (**Fig. 3**). Cheilocystidia were 8.5–10 x 14–16 μm covered by warts similar to elements of pileipellis.

Fig. 1. Basidiomata of *Marasmius limosus* scattered on a dead leave of *Typha angusitifolia*, collected from the karstic swamp Dragomansko blato.

The basidiomata of M*arasmius limosus* were found only on a single dead leave of a cattail (*Typha angusitifolia* L.; **Fig. 1**).



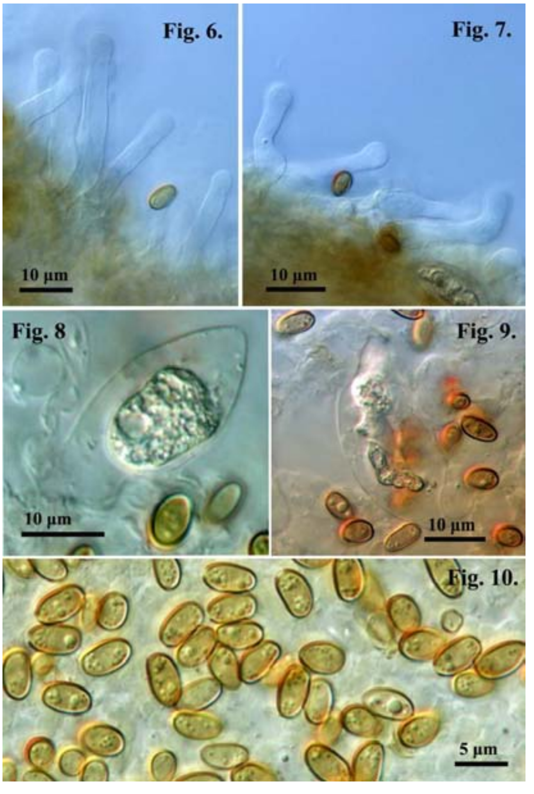


Figs. 2–3. *M. limosus*: 2 – Basidiospores, 3 – Elements of pileipellis covered by yellow ochre warts

***Pholiota conissans* (Fr.) M. M. Moser** (Syn. *Pholiota graminis* (Quél.) Singer)

Pileus was 15–50 mm in diameter, convex to plano-convex with age, at the beginning pale yellow ochre in colour then with reddish brown center, slightly viscid, with appressed-fibrillose scales, and slightly appendiculated margin (**Fig. 4**). Lamellae were adnate to emarginate, young pale yellow-brown then red-brown in colour (**Fig. 5**). Stipe was 20–60 x 2–4 mm, cylindrical, pale yellow at the beginning, later becoming red-brown from base upwards (**Figs. 4–5**). Cheilocystidia were 25–30 x 4–5 µm, cylindrical to lageniform, subcapitate to capitate, smooth, and colourless (**Figs. 6–7**). Chrysocystidia were 25–30 x 10–14 µm, broadly fusoid with pale yellowish content (**Figs. 8–9**). Spore print was red-brown in colour. Basidiospores were 5–6.5 x 3–4 µm, ovoid, with smooth brownish wall and distinct germ pore (**Fig. 10**).

Figs. 4–5. Basidiomata of *Pholiota conissans* on decaying stems of *Typha angusitifolia* L., collected from the karstic swamp Dragomansko Blato.



Figs. 6–10. *Pholiota conissans*: 6–7 – Cheilocystidia, 8–9 – Chrysocystidia, 10 – Basidiospores.

Basidiomata of *Pholiota conissans* were scattered on decaying stems of *Typha angusitifolia* in many places in the swamp (**Figs. 4–5**).

The both newly recorded fungal species were saprotrophic on dead leaves and stems of *Typha angusitifolia*. The decaying mass of these plants is a good developing source for many saprotrophic macromycetes species (Redhead 1981, 1984). Taking these considerations into account together with the fact that both species discussed here were easily detected in the middle of October, it is possible to suggest conducting of future investigations of macromycetes in Bulgarian wetlands during the autumn season when the overground part of wetland monocots is decomposed.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interests regarding the publication of this article.

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REVIEW OF THE CURRENT STATUS AND FUTURE PERSPECTIVES ON *PSEUDOGYMNOASCUS DESTRUCTANS* STUDIES WITH REFERENCE TO SPECIES FINDINGS IN BULGARIA

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Abstract. Emerging infectious diseases are a well-known threat to the wildlife and require complex research. There is a rapidly accumulating knowledge on the infectious disease of bats (White Nose Syndrome - WNS/White Nose Disease - WND) and its causative agent – the pathogenic fungus *Pseudogymnoascus destructans.* Although mass mortality of bats, known since a decade, is currently restricted to North America, the pathogen is of global concern as a potential threat to other hibernating bat populations. Therefore five years after the first comprehensive synthesis on the fungal ecology and relevant knowledge gaps (Foley et al. 2011), we decided to summarize the published information on the pathogen morphology, reproduction, ecological requirements, geographic distribution and systematic position. In addition, the present review compiles the available data on the affected bat species, mechanisms of WND, on the host response and on the effective treatment strategies with possible methods for *fighting* the pathogen to reduce the mortality in affected regions as well. Special attention is paid to the finding of the fungus in Bulgarian caves.

Key words: bats, caves, *Geomyces destructans*, geomycosis, nature conservation, White Nose Disease, White Nose Syndrom

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INTRODUCTION

Emerging infectious diseases are a well-known menace to the wildlife, often causing mass mortalities of different organisms, threatening them with extinction (*e.g.* Daszak et al. 2000; De Castro & Bolker 2004; Hoyt et al. 2015 and citations there-in). The parasitological threats to biodiversity conservation have been defined also as a pathogen pollution (Cunningham et al. 2003). Among them are the White Nose syndrome (WNS)/White Nose Disease (WND) affecting bats. It was first reported in 2006 and since then was continuously emerging (*e.g.* Blehert et al. 2009; Turner & Reeder 2009; Frick et al. 2010; Caven et al. 2012; Cryan et al. 2013a among the many others). It affected solely hibernating bat species and lead to regional population bats collapses with extensive local extinctions in North America (Pikulla et al. 2012; Frick et al. 2015). There it had been documented in 26 states of U.S.A. and 5 Canadian provinces and caused the death of estimated 6 millions individuals (U.S. Fish and Wildlife Service 2015; Frick et al. 2016). This zoonosis is comparable with the chytridiomycosis in amphibians, Colony Collapse Disorder in bees, and Snake Fungal Disease in snakes, and is probably the most large-scale extinction of mammals in modern history (Cryan et al. 2010). Its causative agent is the psychrophilic ascomycetous fungus *Pseudogymnoascus destructans* (Blehert et Gargas) Minnis et D. L. Lindner (Syn. *Geomyces destructans* Blehert et Gargas). Later on *P. destructans* was found in Europe and Asia, but with apparently little or no mortality among the bats from these regions and this lead to suggestions on the fungus origin from these areas and its long co-evolution with the bats there (*e.g.* Puechmaille et al. 2010, 2011c; Zukal et al. 2016). In addition to the unprecedented numbers of sick and killed animals (90–100% of the populations in some areas of North America), it was registered that the bats affected by WNS act strangely during cold winter months, including flying outside during the day and clustering near the entrances of caves and other hibernation areas (Coleman 2014). Recent evaluation of the ecosystem services provided by bats have revealed that many species offer unique and large-scale monetary benefits to agricultural industry (*e.g.* through pollination, controlling of pest insect populations in subtropical coffee and cacao plantations) and we have just started to understand their ecological role in natural ecosystems (*e.g.* top-down regulators of insect populations in forest habitats – for details see Voigt & Kingston 2016). In the same time bats are extremely vulnerable to anthropogenic impact, especially nowadays, in the changing world of the Anthropocene (op. cit.). Therefore their conservation is of key importance for the environment and indirectly for the human society. Logically, the significance of the "novel fatal infectious disease of hibernating bats" provoked strong interest to the fungal pathogen and its effects, first generalized by Foley et al. (2011) and Puechmaille et al. (2011b) with outlining of the relevant knowledge gaps. Many of these gaps have been fulfilled through the research carried during the last years, but meanwhile still other questions remained and also new questions raised.

Thus, according to Cohn (2012) bats and WNS continued to remain a conundrum. Therefore we decided to summarise the available information on *P. destructans*, on the mechanisms of disease and the host-pathogen interactions, including the host response, on effective treatment strategies and on the possible methods for *fighting* the pathogen with emphasis on the newest investigations. Special part of the review is targeted on the species findings in Bulgaria.

1. The White Nose Syndrome (WNS), the White Nose Disease (WND) and the *geomycosis:* Historical notes, spread of the infection, terminology, affected bat species, descriptions of symptoms and causative fungal agent

The **White Nose Syndrome (WNS)** was first documented on a photograph, taken on 16th of February 2006 in Howe's cave, New York (Turner & Reeder 2009; Gargas et al. 2009) and named after the white fussy growth on bat wings, ears and muzzle (Veilleux 2008; Reeder & Turner 2008; Turner & Reeder 2009; Blehert et al. 2009). It was also associated with unusual winter activity of bats and mass mortality in New York state (Veilleux 2008) and later on in North-eastern United States and South-eastern Canada, where it has led to severe population declines (Bat Conservation International, 2015). The according disease was defined later by the presence of cupping erosions on the skin caused by infection by *P. destructans*, which is determined by histopathological examination (Meteyer et al. 2009), although the name WNS was still used in the paper. Therefore, following Frick et al. (2016) it has to be stressed that the term WNS was originally used to describe the symptoms associated with bats in the field (visible fungal growth on skin surfaces, depletion of fat reserves, altered torpor patterns and aberrant winter behaviour) and had an original definiton of syndrome (*e.g.* Veilleux 2008; Reeder & Turner 2008; Turner & Reeder 2009) before the disease was fully characterized as a pathogenic cutaneous infection of skin tissues. A lot of confusion arose around application of the term WNS for infections occurring in Europe since they were pathologically similar to those in North America but did not include mass mortality or unusual winter behaviour (Puechmaille et al. 2011c). Then Chaturvedi & Chaturvedi (2011) stated that WNS was neither an exclusive presentation nor an all-encompassing description of *P. destructans* infections in bats. They insisted that continued use of this terminology to describe bat disease carried the risk of undue focus on one symptom of what was likely to be a complex host– pathogen interaction. Therefore both authors, following the conventional way of formation of mycological and veterinary terms, proposed to use the term ***geomycosis*** (from the fungal first name *Geomyces* and suffix *–cosis* [Gr.] used for a disease, morbid state) instead of WNS. However, in their proposal, the term *geomycosis* was adopted to describe infections caused by two different psychrophillic pathogens from the genus *Geomyces* Traeen – *G. destructans* and *G. pannorum* (Link) Sigler et J. W. Carmich. (recently *Pseudogymnoascus pannorum* (Link) Minnis & D. L. Lindner).The last is a rare pathogen which causes skin and nail infections in humans, and bone infections in dogs (for details and citations see Chaturvedi & Chaturvedi 2011) but also is rather common on hibernating bats (Vanderwolf et al. 2013, 2015). Therefore the use of the term *geomycosis* would not allow the differentiation between infection by the two *Geomyces* species, infections that result in very different outcomes. The name *geomycosis* was used by some authors (*e.g.* Pikula et al. 2012), but obviously in order to avoid new misinterpretations caused by this broader term and to reflect the taxonomic renaming of *G. destructans* in *Pseudogymnoascus destructans*, a new term – **White Nose Disease (WND)** – was coined by Paiva-Cardoso et al. (2014).However, despite its original definition as a syndrome, the term WNS is still routinely used to refer the cutaneous infection caused by *P. destructans*. This led to a certain new confusion among some researchers, which, most probably, could be overcome be wider acceptance of the term WND (Paiva-Cardoso et al. 2014; Frick et al. 2016) and further consequent differentiation between the disease (WND - diagnosed by cupping erosions; Meteyer et al. 2009) from the syndrom (WNS) - mostly diagnosed by field observations; Veilleux 2008; Reeder & Turner 2008; Turner & Reeder 2009). However, in the text below both terms WNS and WND will be used in the way in which they were originally applied by the cited authors.

The Little brown bat (*Myotis lucifugus*) is the most **affected species** by WND and WNS. Although a few examples of its summer colonies persisting in pockets around the affected areas have been documented (*e.g.* Dobony et al. 2011; Coleman & Reihard 2014), its numbers decreased by 90–91% in 5 states (Turner et al. 2011; Coleman & Reichard 2015) and, in case that no action is taken, a local extinction of the species by 2020 is predicted (Frick et al. 2010). Great risk of extinction at a global scale is faced also by Northern long-eared bat *Myotis septentrionalis* (Langwig et al. 2012), which since 2015 is enlisted as a federally threatened species by the U.S. Fish and Wildlife Service. However, no connection between colony size and disease impact has been observed (Frick et al. 2015), probably because the initial mortality of the species due to WND was higher in larger colonies (Langwig et al. 2012). Except these two species, according to Thogmartin et al. (2013), Coleman (2014) and Coleman & Reichard (2014) five more cave hibernating bats, including two endangered (EN) species have been affected: *Eptesicus fuscus, Myotis leibii, M. grisescens* (EN), *M. sodalis* (EN) and *Perimyotis subflavus.*

However, the presence of *P. destructans* or skin infection by the pathogen not obligatory coincides with lethality. It was proved that mortality rates differ by species even in America (Turner et al. 2011; Frick et al. 2015) and that European and some Palearctic Asian populations have not been affected to mass mortality (*e.g.* Puechmaille et al. 2011c; Zukal et al. 2016 and citations there-in). According to Coleman (2014), Coleman & Reichard (2014) and Vanderwolf et al. (2015) bat species on which *P. destructans* has been detected with no confirmation of disease, were as follows: *Corynorhinus rafinesquii, C.*

townsendii virginianus (EN), *Lasionycteris noctivagans, Lasiurus borealis, Myotis austroriparius* and one federally listed species was found in the affected area that have not yet been confirmed with WNS or fungal infection: *Corynorhinus townsendii ingens* (EN). Even earlier, during spring of 2010, DNA of *P. destructans* was detected in three additional species of hibernating bats (*Myotis austroriparius, M. grisescens, M. velifer*) west of the Appalachian Region (*e.g.* Missouri and Oklahoma), yet mortality was not observed (USGS 2010 – cit. acc. to Flory et al. 2012). However, it has to be underlined that in some cases observations of fungal presence without mortality or symptoms (*e.g.* bats flying during daytime in winter – for details see the text below) may simply reflect detection of the disease in its earliest stages (Flory et al. 2012). Non-lethal WND is reported for the European species *Myotis blythii* (Syn. *M. oxygnathus*), *M. myotis*, *M. daubentonii, M. bechsteinii, M. nattereri, M. brandtti, M. emarginatus, M. dasygneme, Eptesicus nilssonii, Barbastella barbastellus, Plecotus auritus* and *Rhinolophus hipposideros* (Puechmaille et al. 2011c; Pikula et al. 2012; Bürger et al. 2013; Paiva-Cardoso et al. 2014, Zukal et al. 2014). In addition to WNS documentation, the presence of *P. destructans* in North America was detected by swab sampling and quantitative PCR methods (Muller et al. 2013) in *Myotis austroriparius, Corynorhinus townsendii virginianus, C. rafinesquii* and *Lasionycteris noctivagans* (Bernard et al. 2015), and in Europe – in *Myotis mystacinus* (Martinková et al. 2010) and *M. blythii* (Wibbelt et al. 2010). One additional species, *M. escalerei*/ sp. A was suspected to be affected by the fungus via photographic documentation (Puechmaille et al. 2011c). Recently, the WND causative agent was found in North-eastern China (Hoyt et al. 2016) in 6 more species of bats: *Myotis chinensis, M. leucogaster, M. macrodactylus, M. petax, Murina ussuriensis and Rhinolophus ferrumequinum* without causing apparent mortality. With the increase of the scope of the investigated regions and studies on *P. destructans* by different methods, the species is detected in new areas and the list of bat species affected or associated with the fungus is increasing. The geographic distribution of *P. destructans* and the reasons for lack of mass mortalities in the Palearctic are discussed below in the text and in §3. As outlined by Frick et al. (2016), the list of species with *P. destructans* infection is likely to increase parallel to the sampling intensity but the general trend of species most infected is unlikely to change.

Recently there is strong evidence that the WNS/WND **causative agent is the fungus *Pseudogymnoascus destructans*** (*e.g.* Blehert et al. 2009; Meteyer et al. 2009; Chaturvedi et al. 2010; Cryan et al. 2010; Lorch et al. 2011; Warnecke et al. 2012; Zhang et al. 2014). The *Pseudogymnoascus destructans* infection (**Pd infection** hereafter) of bat wings, which represent the biggest surface of exposed skin in the body, is presumed to be a primary cause of WNS and subsequent mortality (Cryan et al. 2010; Flory et al. 2012; Knudsen et al. 2013). Unlike other fungal skin pathogens in endothermic animals, it invades deeply the host skin in addition to the skin superficial infections (Meteyer et al. 2009). The hyphae of *P. destructans* are visible as a white cotton-like growth on the bat muzzle, wings and ears (*e.g.* Blehert et al. 2009), where they penetrate hair follicles and the associated sebacious and apocrine glands. The Pd infection ranges from cup-like intraepidermal colonies with erosions to severe ulceration of the affected skin and deep invasion by fungal hyphae into the underlying dermal connective tissue (*e.g.* Meteyer et al. 2009; Pikula et al. 2012; Wibbelt et al. 2013). According to Frick et al. (2016) the damage of the muzzles is less important than deep damage of the bat wings. The last leads to severe physiological disorders most notably related to the homoestasis (electrolytic and water balance) and thermoregulation with subsequent behavioral changes during hibernation (*e.g.* Blehert et al. 2009; Boyles & Willis 2010; Castle & Cryan 2010; Cryan et al. 2010, 2013b; Lorch et al. 2011; Willis et al. 2011; Flory et al. 2012; Ben-Hamo et al. 2013; Knudsen et al. 2013; Warnecke et al. 2013; Verant et al. 2014). Neither behavioural (choosing roosts with high air humidity, licking condensed water from the fur, seeking warm conditions and/or insect prey to offset metabolic costs of remaining euthermic, *etc.*) nor physiological adaptations (*e.g.* metabolic warming of the bodies to euthermic conditions of ca. 35 °C by arousing from hibernation) are able to compensate fully the resulting bat dehydaration to which animals are especially sensitive during hibernation, when all the vital functions are minimized (*e.g.* Boyles & Willis 2010; Dobony et al. 2011; Meteyer et al. 2011; Storm & Boyles 2011; Flory et al. 2012; Brownlee-Bouboulis & Reeder 2013). In addition, according to the summary in the WNS News in The Underground Movement (Anonymous 2014) arousing could also be provoked by: 1) skin irritation and, once awakened, bats should groom in attempt to clear the fungus from the affected skin; or 2) motivation of bats to leave the hibernaculum in an adaptive response to limit the spread of infection (reflecting either the movement of infected bats away from healthy ones or the movement of healthy bats away from infected ones). It has to be stressed that due to more frequent disrupting of the torpor Pd-infected bats may roost closer to the cave entrance than uninfected bats and roosting in clusters may reduce evaporating loss during torpor (op. cit.). Recently there is no doubt that behavioral changes are an important part of the bat response to the pathogen infection. However, yet they are not fully understood. One of the reasons for this lies in the difficulties of observation of free-ranging bats in nature. Therefore it is not clear whether the behavioral changes detected so far represent adaptive or maldaptive responses (op. cit.). Continuous infrared videography in laboratory conditions allowed Wilcox et al. (2014) to make observations on the behavior of infected *Myotis lucifigus* that would have been impossible in the field and to obtain some rather unexpected results: 1) infected bats did not demonstrate an increase in grooming behavior compared to uninfected controls; 2) infected bats did not visit a water source in the enclosure more often than uninfected controls; 3) activity levels in infected bats were similar to those of uninfected controls in terms of latency to onset and frequency of activity; however, infected bats were active for less time than uninfected controls; 4) reduced rates of clustering were observed in infected bats compared to uninfected controls, with fewer bats in clusters and more bats roosting alone. These results, inspite of the need to be interpreted with caution due to some unpredictable differences in laboratory and wild conditions, provide additional insight into the mechanisms of disease responses. Up to know there is accumulated clear evidence that the Pd infection is connected with considerable fitness reduction and hypotonic dehydration and it has been suggested that infected bats were more often forced to interrupt their torpor to drink and to activate their immune system, which finally depletes their fat stores and causes death because of starvation and weakness (*e.g.* Foley et al. 2011; Reeder et al. 2012; Warnecke et al. 2012; Cryan et al. 2013a; Langwig et al. 2015a). The multiple early arousals in mid winter and outdoor day flights are generally considered as a typical, but abnormal hibernation behaviour related with Pd infection and mass bat mortalities. Some bats with Pd infection might be capable to survive by arousing from hibernation and seeking warm conditions or pray (Boyles & Willis 2010; Dobony et al. 2011; Meteyer et al. 2011; Storm & Boyles 2011) and Flory et al. (2012) showed that environmental conditions both inside and outside hibernacula are likely to influence winter survival.

The lethal outcome can be enhanced or caused also by the chronic respiratory acidosis (Moore et al. 2013), oxidative stress (Moore et al. 2013) and some immune system malfunctions (LeibundGut-Landmann et al. 2012). Paradoxically, all the adaptations that allow bats to conserve energy and survive the adverse winter conditions (such as decreased body temperature and roosting in big groups) also provide perfect conditions for the growth of the pathogen due to its specific ecological requirements (for details see §3).

In this context, it is very important to understand the mechanisms underlying the ability of European bats to survive the infection. After the first genetic confirmation of the presence of *P. destructans* in Europe by Puechmaille et al. (2010), based on the 2009 samples from hibernating *M. myotis* in France, during the last few years it became clear that *P. destructans* is widely distributed all over the Old continent without causing mass morbidity or mortality. Up to now the fungus has been confirmed in Austria, Belgium, Croatia, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Latvia, Luxemburg, the Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Switzerland, Turkey (European part), Ukraine and the United Kingdom (*e.g.* Gebhardt 2010; Martínková et al. 2010; Puechmaille et al. 2010, 2011a-c; Wibbelt et al. 2010; Kubátová et al. 2011; Šimonovičová et al. 2011; Mestdagh et al. 2012; Pikula et al. 2012; Sachanowicz et al. 2014; Bürger et al. 2013; Paiva-Cardoso et al. 2014; Pavlinić et al. 2014; Frick et al. 2016; Zukal et al. 2016) and recently was documented in Bulgaria (see details below in §6). So far, although searched for, the species had not been recorded from Italy and Sweden (Voyron et al. 2010; Nilsson 2012; Mulec et al. 2013).

Two different hypothesis explained the disparity of mortality between North

America and Europe: 1) the European fungus may be less virulent or European bats may have evolved immunity to it (Wibbelt et al. 2010; Puechmaille et al. 2011c); 2) differences in winter environmental conditions outside hibernacula in both continents (*e.g.* sustained subfreezing temperatures) were accepted as important co-factor for WNS virulescense and disease mortality (Flory et al. 2012). Although at first it was thought that infection with *P. destructans* in Europe was restricted to superficial skin layers only (Wibbelt et al. 2013), the later electron microscopic studies of bat wings revealed the same cup-like erosions characteristic of the disease on both sides of the Atlantic (Bandouchova et al. 2015). The last data, based on studies of bats from the Czech Republic (individuals from 6 species, PCR-positive for *P. destructans*), were the first which confirm the presence of severe lesions aside of North America. The authors suggested that the European bats may be only tolerant but not resistant to the fungus and that the inter-continental differences in the outcome of WNS in bats in terms of morbidity/mortality may not be due to differences in the pathogen itself. Earlier it had been already proved that the experimental infections with European isolates of *P. destructans* cause mortality in American bat species (Warnecke et al. 2012). The new data obtained by Zukal et al. (2016) provided evidence for both endemicity and tolerance to this persistent virulent fungus in the Palearctic, suggesting that host-pathogen interaction equilibrium had been established**.** After it became clear that the differences in bat response to the fungus were not due to differences in the pathogens, it is possible to suppose with a high probablility that the differences in the bat response to the fungus are mostly due to the factors such as environmental conditions in the roost, the bat or the cave microbiome, or species specific physiological reactions (*e.g.* Puechmaille et al. 2011b).

In attempt to clarify the exact **mechanisms of WND pathogenesis**, O'Donoghue et al. (2015) conducted a thorough research on the fungus secretome and recorded 3 serine endopeptidases, 2 serine carboxipeptidases, an aspartyl endopeptidase and lipolytic enzymes such as lipases and phospholipases. The serine endopeptidases isolated were named Destructin 1, 2, and 3 respectively. Out of these Destructin 1 has the highest activity and is able to degrade β-sheets of collagen in contrast to collagenases which aim at the α-spirals. It shows homology with enzymes produced by the nematophitic fungi *Dactylellina varietas* Yan Li, K. D. Hyde & K. Q. Zhang and *Arthrobotrys conoides* Drechsler for degradation of nematode cuticle (Yang et al. 2007a, b), as well as with the endopeptidase isolated from *Engyodontium album* (Limber) De Hoog, better known as Proteinase K, and some peptidases from entomophilous fungi. *P. destructans* carboxipeptidases are similar to carboxipeptidases in *Saccharomyces cerevisiae* Meyen ex E. C. Hansen and *Aspergillus niger* Van Tieghem, and the aspartyl endopeptidase has a homologue in *Candida albicans* (C. P. Robin) Berkhout, where it serves for adhesion to the cells of the epithelium, degradation of host proteins, penetrating the mucose layer, and evading host immune response (Naglick et al. 2004). In many dermatophytic fungi serine, as well as aspartyl endopeptidases, are also able to degrade keratin (Santos & Braga-Silva 2013). Subtilisin serine protease is recently identified in *Batrachochytrium dendrobatidis* Longcore, Pessier et D. K. Nichols, where it degrades antimicrobal peptides on frog skin. Potentially applicable inhibitors of Destructin action are PMSF, antipain, and chemostatin, the last reducing collagen degradation by 77%.

2. *Pseudogymnoascus destructans* morphology, reproduction and systematic position

Morphological features of the pathogen **mycelium** are quite clear. On Saboraud Dextrose Agar (SDA) colonies are white at the margin and with central sterile white overgrowth (Gargas et al. 2009). Conidial masses at colony centers are grey to grey-green and the colony reverse is uncoulored on Corn Meal Agar (CMA), and drab to hair brown on Sabouraud agar (Gargas et al. 2009). Colonies on Malt Extract Agar (MEA) are initially white, but after spore production and aging they quickly darkened from the center to a dull gray, often showing a faint green hue (Puechmaille et al. 2010). Similar characteristics are given also by Martínková et al. (2010) and Šimonovičová et al. (2011).

The most characteristic feature of the fungus is the morphology of the anamorph and in particular of the asexual reproduction spores – conidiospores. On CMA they are 5–12 × 2.0–3.5 µm, tapering basally to 1.5–2.0 µm and apically to 0.5–1.5 µm, truncate with prominent scars at one or both ends, smooth and lightly pigmented; predominantly curved, sometimes oval, obovoid, or cymbiform, moderately thick-walled at maturity and readily seceding, borne singly at the tips, on the sides, or in short chains on verticillately branched conidiophores (Gargas et al. 2009). Conidiospores on MEA are hyaline, irregularly curved, broadly crescent-shaped (typically 6–8 µm long and 3–4 µm wide), and narrowed at each end, one of which was broadly truncate, often showing an annular frill (Puechmaille et al. 2010). The size of conidiospores according to Šimonovičová et al. (2011) is 4.6–6.0 x 1.5–3.1 µm and they are formed in short chains on branched erect conidiophores. Details on the fungal conidiophores are provided by Gargas et al. (2009). There is only one species, known that to be macroscopically similar to *P. destructans,* which can be confused with it when growing on bats: *Trichophyton redellii* Minnis, Lorch, D. L. Lindner et Blehert (Lorch et al. 2015). This species, described from Wisconsin, Indiana and Texas, seems to be native to the U.S.A. and as far as we know, does not cause any harm to the bats. The two species can be distinguished when the bats are illuminated from above with UV light (infections caused by *T. redellii* were not observed to produce an orange-yellow fluorescence when exposed to ultraviolet light as has been reported for *P. destructans* infections by Turner et al. 2014, Lorch et al. 2015), by histological examination (only *P. destructans* penetrates deep in the derma and forms cup-like erosions, whereas with infections of *T. redellii,* the fungal colonization pattern often has an active edge with a central zone of clearing, similar to what is observed in classic human ringworm infection – Lorch et al. 2015) or by observations of spores under the microscope (conidiospores of *T. redellii* are radially symmetric, obovate to pyriform, attached laterally to the sides or ends of hyphae and are sessile or on very short pedicels, while in *P. destructans* conidia are distinctive asymmetrically curved, or crescent-shaped, borne at the ends of verticillately branched conidiophores – Gargas et al. 2009; Lorch et al. 2015).

According to our best knowledge, so far the **teliomorph and sexual process of *P. destructans* remains cryptic** (for details see the text below) but Palmer et al. (2014) suggested that the sexual recombination may allow the pathogen to adapt to its environment and hosts, despite its slow growth.

An intriguing and at the same time controversial question is that of *P. destructans* **systematics position** and evolutionary origin. The fungus was first described in 2009 after being isolated from infected bats of the species *Myotis lucifugus* and *M. septentrionalis* (Gargas et al. 2009). According to the phylogenetic tree built on the bases of small subunit (SSU) and internal transcribed spacer (ITS), the newly described fungus was placed in the ascomycetous genus *Geomyces*. There its closest relatives were *Pseudogymnoascus pannorum, P. roseus* Raillo and *P. verrucosus* Rice et Currah (Puechmaille et al. 2010).

The species epitheton *destructans* was given because of the devastating effect the fungus had on bat populations in North America. As a consequence, the main attention was turned towards studies of the fungus in the bat hibernacula and this led to the documentation of many *Geomyces* "species". For example, Johnson et al. (2013) obtained eleven *Geomyces* isolates spread in seven clades and Lorch et al. (2013a) also recorded a significant diversity of *Geomyces* isolates in 24 soil samples from bat hibernacula based on sequencing of ribosomal RNA regions (ITS and PIS – partial intergenic spacer), in both studies the alignment of *Geomyces* was based on maximum-likelihood phylogenetic analysis. A special note has to be made that the samples in the last study were the same as those used for molecular analysis by Lindner et al. (2011), in which many *Geomyces* isolates, including non-pathogenic to bats, were found.

The lack of a modern taxonomic evaluation and of a phylogenetic framework of the group motivated Minnis & Lindner (2013) to apply a larger number of molecular markers and to revise the place of *Geomyces destructans* and its relatives in the Tree of Life. By sequencing and analysing the ITS region, large subunit (LSU), rDNA, MCM7, RPB2, and TEF1 from a diverse array of *Geomyces* and allies, Minnis & Lindner (2013) came to the conclusion that the fungus should be placed in the genus *Pseudogymnoascus* Raillo with the members of the *Pseudogymnoascus roseus* species complex as its closest relatives. True *Geomyces* species were defined as the members of the basal lineage based on phylogenetic placement of the type species, *Geomyces auratus* Traaen. However, the obtained results should be interpreted with caution because all the species used in the analyses originated from the U.S.A., where the pathogen was just recently introduced (LEOPARDI ET AL. 2015). Therefore the demonstrated position of the WND causative agent may be biased by the lack of data from both Asia and Europe, where it originally evolved (*e.g.* LEOPARDI ET AL. 2015; ZUKAL ET AL. 2016) and further changes in its classification may be expected.

Sexual reproduction in *P. destructans* is not yet observed and therefore it has to be stressed that the position of the species among Ascomycota is due only to the molecular data and therefore it is positioned ***Incertae sedis* in Dothideomycetes of Ascomycota**. The traditional mycological classification approach would require to keep it among the mitosporic fungi untill the observation of the sexual process and its relevant structures. In spite of the lack of direct observation of the sexual reproduction, it has to be outlined that PALMER ET AL. (2014) discovered and molecular characterized heterothallic mating system in fungal isolates from the Czech Republic. In the opinion of the authors, the coexistence of two mating types of *P. destructans* suggested the presence of mating populations in Europe. So far, fungal populations in North America are thought to be clonal as only one mating type has been observed, but the potential for sexual recombination indicates that continued vigilance is needed (OP. CIT.). Further work is necessary to find and characterize the sexual cycle of *P. destructans* regarding both theoretical and practical needs.

3. *Pseudogymnoascus destructans* ecology, transporting vectors and distribution

Ecologically, *Pseudogymnoascus destructans* is considered to be a **psychrophilic species** with a growth temperature ranging from 3 to 20 °C and no growth occurring at 24 °C or higher (*e.g.* GARGAS ET AL. 2009; JOHNSON ET AL. 2013). The optimal growth has been pointed to be between 5 and 10 °C (BLEHERT ET al. 2009), between 8 and 14 °C (LANGWIG ET AL. 2012), between 10 and 14 °C (VERANT ET AL. 2012), or between 12.5–15.8 °C (GARGAS ET AL. 2009; TURNER ET AL. 2011). This "cold-loving" peculiarity is quite important for the fungus because it is similar to the temperature which can be found in cavernous humid hibernacula (*e.g.* caves, adits, cellars, old mines) of many bat species (*e.g.* WEBB ET AL. 1996; FLORY ET AL. 2012; BÜRGER ET AL. 2013) and therefore to the temperature of the bats in torpor (*e.g.* BOYLES & WILLIS 2010; HOYT ET AL. 2015) .

In addition to the cold preferences, or perhaps in relation with it, is the typical for the species **slow growth.** According to GARGAS ET AL. (2009) colonies on CMA and SDA after 16 days reach diameter 1.0 mm at 3 °C, 5 mm at 7 °C, 8 mm at 14 °C.

An alarming fact regarding *P. destructans* ecology is its **ability to survive and to grow not only on bats, but also in cave environment even in the absence of the host** (LORCH ET AL. 2013A, B), which points on the ability of the infected caves to serve as pathogen reservoirs (PUECHMAILLE ET AL. 2011C; RAUDABAGH & MILLER 2013). The ability to survive long in the absence of the host in the lab was shown by Hoyt et al. (2014). This **potential facultativity of *P. destructans* as a pathogen**, greatly increases the risk of further WNS distribution and prevents bats to recolonize a site once after the pathogen has arrived (op. cit.). The ability of fungal pathogens like *P. destructans* to persist outside their host, likely increases their impact on populations and increases the risk of extinction (Fisher et al. 2012; Hoyt et al. 2014).

World-wide known is the great spectrum of enzymes in saprotrophic fungi and therefore it has to be expected that diverse enzymes should be found in *P. destructans* in case it is capable of **saprotrophic activity**. Even before the findings of Lorch et al. (2013a, b) it was shown *in vitro* that the fungus was able to produce b-glucosidase, N-acetyl-b-glucosaminidase, acid and alkaline phosphatases, esterase/esterase lipase/ lipase, leucine and vailine arylamidase, naphthol-AS-B1-phophohydrolase, various proteinases (albumin/casein/gelatin), and urease, while no enzymatic activity had been indicated for cystine arylamidase, a-chymotrypsin, alpha/beta galactosidase, trypsin, bglucoronidase, a-fucosidase, and a-mannosidase (Chatuverdi et al. 2010). Some of these enzymes (urease, proteinase /aspartyl/ and superoxide dismutase) exist in other pathogenic fungi (Brock 2008; Casadevall et al. 2003) and are considered dual virulence factors (Smyth et al. 2013).

Raudabagh & Miller (2013) examined six isolates from four Eastern and Midwestern states and demonstrated that the fungus is alkalitolerant, able of nitrogen utilization, and is capable of saprobically utilizing many complex carbon-containing cave substrates. They demonstrated that all six isolates were capable of growth and sporulation on dead fish, insect, and mushroom tissues. Regarding details of this study it has to be stressed that in neutral to alkaline environments, nitrate, nitrite, ammonium, and amino acids sources are all sufficient for good growth of the fungus, while uric acid is a potential nitrogen resource under alkaline conditions. Importantly, *P. destructans* demonstrated urease activity which had been proposed as a dual use virulence factor in the pathogenesis of *Cryptococcus neoformans* (San Felice) Vuill. and other pathogenic fungi by Casadevall et al. (2003) and Hung et al. (2007). The results of Raudabagh & Miller (2013) suggest that regardless of whether *P. destructans* is keratinophilic or keratinolytic, it is capable of generating a microenvironment in which keratinaceous substrates found in caves and cave soils (such as bird feathers and mammal hair and skin, incl. bat skin) are more susceptible to degradation and can serve as an important resource for *P. destructans*. The same authors showed that similar to keratinaceous substrates, chitinaceous substrates are important resources for the fungus. It cannot degrade chitin but rather utilizes other nutritional components found in chitinaceous substrates (*e.g.* proteins and lipids). Smyth et al. (2013) demonstrated that *P. destructans* could penetrate dead moss cell walls. Taking this into account, Raudabagh & Miller (2013) proved that the fungus could produce b-glucosidase and therefore, most probably, it could degrade cellulosic substrates. However, they stated that although cellulosic substrates could be potential substrates for *P. destructans*, they are not suitable for long-term colonization in caves or portions of caves that have frequent moisture fluctuations.

Reynolds & Barton (2014) also compared the saprotrophic activity of the pathogen and other closely related species from soil and showed that all the enzymes required for saprotrophic growth (especially in peculiar cave conditions where light and substrate resources are limited) are present in *P. destructans*. Among them are the cellulases and lipases which decompose plant debris, chitinases which degrade dead insect bodies and ureases which are very useful for utilizing nitrogen from bat urine or guano. The obtained data characterize *P. destructans* as a generalist decomposer and suggest that it may evolved not from dermatophytic, but from saprotrophic cave fungi. The reduced activity of the enzymes described in comparison to the enzymes of obligate saprophs, was taken by the authors as a sign for reduced selective pressure on the ability to use decaying matter as a primary source of food, associated with its long evolution as a pathogen. Reynolds & Barton (2014) proved low chemolitic activity and explained it as an aid in survival on the nutrient-limited surface of the bat wing membrane. These statements could be further supported by genetic studies which could also potentially provide a molecular clock for the timing of the movement of *P. destructans* out of the soil/ cave sediment environment into its host (op. cit.).

Through controlled experiments, it was determined that WNS/WND is spread by direct contact with its causative fungus (Lorch et al. 2011). Most evidence show that **the main vector of the disease are the animals themselves** (for example, new affected sites are situated along bat migration routes – Reynolds & Barton 2014), but the facultative pathogen character of the fungus suggests that the **infection via contact with contaminated substrate is surely possible**. According to Langwig et al. (2015b), when *P. destructans* is introduced to a new site, it is found only in close proximity to bats during the first year, but the next season it is already found in half of the environmental samples even far from the animals. The second year is also characterized by an elevated risk of mortality as bats get infected right after they enter the winter roost. In attempt to estimate the risk of extinction for whole colonies, Reynolds et al. (2015) used a mathematical model of *P. destructans* distribution considering the quantity of organic carbon in the soil, the length of the hibernation season and the availability of substances that inhibit the growth of the fungus. The results showed that *P. destructans* was most abundant in substrates rich in organics, especially cellulose, although growth was possible even in a silicate sand with a very low organic content. Especially alarming is the fact that according to the model, if no inhibitors are present, the pathogen can be found in the environment a 100 years after its introduction even in the absence of bats, and if inhibition is taken into account it can survive in substrates with high organic content. However, the main factor on which bat survival depends, is the length of the hibernating season – according to the model, period of 120 days seems to the critical, although other authors point out 102 days (Lorch et al. 2011).

Another possible vector for the fungal mycelia and spores are the wing

mites from the family Spinturnicidae, which are ectoparasites of hibernating bats (Lučan et al. 2016). Doubtless further research will confirm or reject this hypothesis, which points that in addition to the transport of fungal propagules, mites may facilitate entry of the fungal hyphae through the epidermis of bats via injuries caused by their bites. These injuries could explain previous findings of virulent skin infections by Bandouchova et al. (2015) when no signs of fungus keratinolytic activity were observed in the stratum corneum of bats under ultramicroscopy. The transmission of the fungus by parasites logically explains also the earlier observations of higher infections in bats, which overwinter in closer clusters (*e.g.* Zukal et al. 2014).

The **macroecological interactions between bats and the fungus** were investigated by Frick et al. (2015). Using data from 1118 winter roosts of 16 bats species on both continents collected for the past 30 years, the authors show that bat population density in Europe is similar to that in America after the introduction of *P. destructans,* suggesting that the fungus could potentially be an important factor that shaped the biogeography of bats in Europe.

The **origin of *P. destructans*** was long debatable and different hypothesis have been put forward to explain the emergence of the disease and its causative agent (Puechmaille et al. 2011b). However, the hypothesis most supported since the species was described was that introduction and not evolution *in situ* led to the appearance of *P. desctructans* in America. Nowadays it gained further support from genetic analisys (*e.g.* Warnecke et al. 2012; Leopardi et al. 2015; Zukal et al. 2016). Leopardi et al. (2015) sequenced and compared eight genomic loci of fungal isolates from both continents and showed that while European isolates are highly polymorphic (eight different haplotypes), there is almost no variation among North American isolates. Moreover, the haplotype that is most common in Germany, France, Belgium and Luxembourg is 100% identical to the one from the U.S.A. and Canada which points at Western European populations of *P. destructans* as the source of the American isolate. Khanket (2014) found that the population in Canada had the same genotype as those from the U.S.A. and there was also evidence of minor genetic variation in three Canadian isolates. All these results agree with the photographic data on the presence of white fungal growth on bats in Europe much before WND has been known, as well as with the fact that the fungus is not associated with mass bat mortality in the Old Continent (Puechmaille et al. 2011b, c; Wibbelt et al. 2013). Newest investigations by Zukal et al. (2016) support this opinion and even spread the area of the Palearctic origin of *P. destructans* to the Asian territory and authors claimed the endemicity of the species.

Taking into account that bat movements across the Atlantic are rare events on geological times, it is possible to suggest with a high probability that the pathogen was firstly introduced in the New York state by a human, most probably a tourist, caver or researcher that visited caves in Europe prior to visiting Howe's cave in New York (Puechmaille et al. 2011c; Leopardi et al. 2015). All this once more emphasises the need of strict control on the transport of biological materials between continents and of high hygiene culture for cavers and tourists visiting relatively isolated ecosystems.

4. Bat immune and neuroendocrinological response to WNS/WND

The topic of immunity to fungal infections is of interest and understanding the nature and function of the immune response to fungi and is an exciting challenge that might set the stage for new approaches to the treatment of fungal diseases, from immunotherapy to vaccines (Romani 2011). The past decade has witnessed the development of a wide range of new approaches to elucidate events that occur at the host-fungus interface (op. cit.). Hibernation is generally associated with a significant reduction in all metabolic processes and profoundly affected immune system regulation, but little is known on how bat immune system function and vary seasonally (*e.g.* Reeder & Moorre 2013 and citations there-in). Therefore it is of particular interest to study the immune response to *P. destructans* in bats. Successful resistance against pathogen invasion involves the coordinated elevation of multiple innate and adaptive immune mechanisms but there is a paucity of information regarding bat immune responses against fungal pathogens in paricular (*e.g.* Moore et al. 2013; Reeder & Moore 2013; Rapin et al. 2014 and citations there-in). From one side, dermatophytic fungi are known to activate the innate immune response, which slows down the growth of the pathogen and leads to some tolerance towards it (Netea et al. 2008). On the other hand, most often the infection can be cleared completely after the activation of the adaptive immunity, but it is exactly the adaptive immunity that is most suppressed during hibernation in different from bats mammals (*e.g.* Cahil et al. 1967; Maniero 2000; Bouma et al. 2012; Sieckmann et al. 2014). Taking this into account, it might be not surprising that *P. destructans* can overcome host defensive mechanisms. In any case, before providing the recent achievements on the topic, we would like to stress that yet many results are contradictory, some processes respond to Pd infection/ WNS to different degrees and even in different directions and therefore underlying mechanisms and their biological meaning are yet to be described (*e.g.* Moore et al. 2013).

Quite recently Field et al. (2015) proved that WNS caused significant changes in gene expression in hibernating bats including pathways involved in inflammation, wound healing and metabolism. The comparison of the transcriptome of healthy and Pd infected *Myotis lucifugus* by these authors shows elevated levels of lectin receptors of C-type such as CLEC4D (MCL), CLEC4E (MINCLE), CLEC7A (dectin–1), CLEC6A (dectin–2) and of Toll-like receptor 9. They are a part of the innate immune response and are typical for the initial stages of other fungal infections (*e.g.* like those caused by *Candida albicans*). Up-regulated are also the levels of multiple cytokines, including interleukins IL–1β, IL–6, IL–17C, IL–20, IL–23A, IL–24, and G-CSF and chemokines, such as Ccl2 and Ccl20 and G/H synthase 2 (cyclooxygenase–2), that generate eicosanoids and other nociception mediators. However, monocytes, neutrophils, and active T-helper cells, which promote the adaptive immunity, have been not detected, which is on conformity with the results of other histological investigations. This may be due to the shortness of euthermic periods or to the specific inhibition of hemotactic signals provoked by *P. destructans*, which is the case with the amphibian infecting fungus *Batrachochytrium dendrobatidis*. Up-regulation of interleukins 1 and 6, kallikrein–6, katepsin S, and the enzymes cyclooxygenase–2 and phospoholipase A2, which participate in the acute inflammation processes, has mostly negative effects on bats as it increases wing membrane damage and interrupts torpor. Activation of genes from the lipid metabolism is also detrimental as it is associated with faster depletion of fat reserves crucial for surviving the winter. However, no significant levels of antibodies against *P. destructans* have been detected in European bats infected with the pathogen, suggesting that it is not the adaptive immune response that accounts for the differences in WNS survival rate on the two continents and on some remnant American populations, which may be developing resistence to WNS (Johnson et al. 2015).

Moore et al. (2013) found elevated levels of circulatng leukocytes in WNS-affected *M. lucifugus* – an attempted defence against *P. destructans*, probably related to documented changes in thermoregulatory behaviors of diseased bats. Although this response is not enough to clear the pathogen, it raises the possibility that some bats may be better equipped to resist infection than others (Puechmaille et al. 2011c) with the potential for directional selection and evolution of the immune defence towards the fungus. Earlier studies of Moore et al. (2011) showed that bats affected by WNS experience both relatively elevated and reduced innate immune responses depending on the microbe tested, although the cause of observed immunological changes remains unknown. Additionally, considerable trade-offs may exist between energy conservation and immunological responses. Relationships between immune activity and torpor, including associated energy expenditure, are likely critical components in the development of WNS.

Since the physiological adjustments which influence energy balance and thermoregulation before, during and after hibernation result from precise regulation of neuroendocrine activity, the euroendocrinological research of bats is of great importance in the attempts to improve understanding of mechanisms underlying mortality and test the potential of bat populations to evolve resistance or tolerance in response toWNS (Willis & Wilcox 2014). The last authors reviewed the effect of three key hormonal mechanisms – leptin, melatonin and glucocorticoids – in hibernating animals and proposed hypotheses regarding bats WNS-effects on these systems and their evolution. They suggested that bats with the least sensitivity to leptin (a lipostat hormone associated with metabolism, feeding behaviour and therefore with winter energy balance in bats) could accumulate more mass (larger fat stores) in the fall prior to hibernation and therefore would have a better chance of surviving WNS and reproduce in the following spring compared to other individuals (Willis & Wilcox 2014). Thus, the bats characterized by the lowest leptin levels in autumn will exhibit greater survival from WNS and relatively high reproductive rates in spring and it was predicted that fall leptin sensitivity should be lower in post-WNS populations compared to populations that have not yet been affected. In relation to melatonin, as a signal influencing seasonal and diurnal biological rhythms, they predicted that bats affected by WNS may have elevated levels of melatonin during the later stages of infection as they reduce clustering and begin to synchronize arousals with the dark phase, *i.e.* there should be detectable differences in melatonin secretion and sensitivity between pre- and post-WNS bat populations. In relation to glucocorticoids (GCs – steroid hormones underlying the physiological stress response), Willis & Wilcox (2014) predicted that bats with WNS should exhibit increased GCs levels beyond those normally seen in healthy, undisturbed hibernating bats and perhaps similar to bats frequently disturbed by predators (or researchers mimicking predators). Thus at least part of the explanation for increased arousal frequency in bats with WNS reflects a heightened physiological stress response.

GCs might also influence the healing and recovery process for the small proportion of bats that survive WNS, particularly if the disease represents a chronic stressor. Contrary to the logical opinion that if infected animals survive the winter period, the rapidly activated immune system under euthermic conditions will easily fight WNS and eradicate *P. destructans* from the organism, it was shown that the sudden reversal of immune suppression in bats upon the return to euthermia is a great risk for them (Meteyer et al. 2012). The same authors proved that some of the infected individuals, which survived winter with WNS, in spring could manifest immune reconstitution inflammatory syndrome (IRIS) and this possesed a great risk for bats emerging from hibernation. As their immune function is restored in spring and suddenly encounters the pathogen, beginning to combat the fungal infection, the rapid neutrophilic inflammatory response can, paradoxically, cause severe negative pathology (extensive necrosis and oedema) and likely mortality for some individuals. As with IRIS in humans, the intensity and extent of tissue infection determines if this exuberant inflammatory response (known as immunopathology) will cause severe tissue damage and death, or will eliminate the pathogen and lead to host recovery (Meteyer et al. 2012).

5. "Fighting" *Pseudogymnoascus destructans* and WNS/WND

Due to the key role that bats play in the ecosystems, strategies for limiting *P. destructans* distribution or decontaminating of the already infected sites in America, are of crucial importance. After accepting of the U.S.A. National WNS Management Plan (Coleman et al. 2011) designed to organize *fighting* against the disease, various solutions to prevent the WNS epidemic have been offered. They had to include identification of chemical and biological treatments and effective environmental manipulations. Some of them included spreading of vaccines or antibiotics in the roosts, removing infected individuals from the populations, or closing caves and changing their microclimate so that it is no longer optimal for the development of *P. destructans*. However, these classic disease management practices seem not to be realistic options for management of disease in the wild bat populations with their peculiar ecology and obviously can affect other cave inhabitants, and provoke other undesirrable changes of the cave ecosystems. Therefore the most promising seems to be the implementing of biological control on the pathogen growth, where a special requirement to the control means is they to have inhibitory activity at low levels. Soils and cave sediments in particular, which host numerous microbes that compete with each other, are likely to offer a ready set of fungicides that wait to be tested.

The volatile organic compounds (VOCs) produced mainly by soil bacteria all over the globe and, most importantly, acting as fungicids even without a direct contact, became a foreground in the research for finding novel treatment options and tools to combat the devastating WND (*e.g.* Kerr et al. 1999; Zou et al. 2007; Cornelison et al. 2014a, b). The last authors tested the efficacy of several VOCs produced by the genera *Pseudomonas* and *Bacillus* with broad spectrum of antifungal activity proved earlier by Xu et al. (2004) and Fernando et al. (2005). Laboratory analyses of Cornelison et al. (2014a) showed successful inhibition of *P. destructans* growth by decanal, 2-ethyl–1-hexanol, nonanal, benzothiazole, benzaldehyde and N,N-dimethyloctylamine in concentrations below 1 ppm. In addition to the checking the effects of individual VOCs, the last authors investigated formulations for synergistic effects. Most effective were the synergistic actions of 2-ethyl–1-hexanol combined with benzaldehyde, decanal, N,N-dimethyloctylamine and nonanal respectively, the last pair being able to inhibit the growth of the fungus by 95% for 14 days after inoculation. The long-term eficacy of studied VOCs in low quantities, and their possibilities to be applied directly (without modifications as they have been purchased in pure liquids) in combination with the increased inhibitory effect at low temperatures (ca. 4 ^{o}C) similar to these in hibernacula, proved by the authors, classifies these bacterially derived VOCs as important potential agents of biological control. On the other hand, this study stimulates further research on similar compounds in order to enlarge the potential pool of VOCs, which are able to inhibit the growth of *P. destructans* and thus to disrupt its transmission. Moreover, the stronger effect of the synergistic blends of VOCs mixtures in comparison with pure derivates provides better opportunities for creation of powerful treatment tools and supports the idea of using soil-based fungistasis in fight against Pd infection (op. cit.). A problem that still remains to be solved is the spread of these compounds *in vivo*, and the same authors suggest the use of aerosol sprays similar to the commercially available air fresheners after proper scientific assessments and approvals. Neverthelees of the means of application, we should always consider to stuck as close as possible to natural biological processes in attempt to diminish to lowest rates the negative impact on the cave ecosystems that are as unique, as fragile.

The identification of inducible biological agents with contact-independent anti-*P. destruct*ans activity is a milestone in the development of viable biological control options for *in situ* application (Cornelison et al. 2014b). The authors tested the widely distributed bacterium *Rhodococcus rhodococcus*, which is often used for bio-remediation or for slowing down fruit ripening (Pierce et al. 2011). Cornelison et al. (2014b) provided the first example of contact-independent antagonism of this devastating wildlife pathogen obtained after evaluation of various application methods of induced cells of *R. rhodochrous* strain DAP96253 for potential in situ application, including whole-cell application, non-growth fermentation cell-paste, and fixed-cell catalyst at psychrophillic conditions (at temperatures 15 °C, 7 °C and 4 °C). The non-growth fermentation cell-paste demonstrated persistent inhibitory activity and represented the most promising application method evaluated. It was 100% effective against *P. destructans* for more than 80 days, did not require additional growth media and did not pose a significant threat to the natural cave ecosystems (op. cit.).

As well as bacteria, fungi can also compete with *P. destructans*. *Candida albicans* secretes trans,transfarnesol (TT-farnesol) – a sesquiterpene and a *quorum-sensing* molecule with antifungal properties (*e.g.* Weber et al. 2008; Semighini et al. 2006; Brilhante et al. 2013). TT-farnesol is effective against other important pathogens such as bacterium *Streptococcus mutans* (Jeon et al. 2011) and therefore it was tested in different concentrations against *P. destructans* by Raudabaugh & Miller (2015). Although it does not actually kill *P. destructans*, even in concentrations that are naturally occurring in the environment, TT-farnesol effectively inhibits fungal growth to permit bat survival till the end of the hibernating season (op. cit.).

Another **potential solution for WNS/WND control is given by the microorganism communities inhabiting bat skin.** Hoyt et al. (2015) tested 133 bacterial morphotypes, all belonging to the genus *Pseudomonas*, isolated from two bat species – *Eptesicus fuscus* and *Myotis lucifugus*. Six of them successfully inhibited *P. destructans* growth in the lab. The advantages of these "treatment tools" in addition to their anti-fungal properties, which make them promising candidates to be possible probiotic protectors of bats against WNS are the ubiquitous character of *Pseudomonas* and its ability to use the mycelial networks of fungal colonies as a mean of transport can be useful for *in situ* implementation (Warmink et al. 2011). Previous experiments with members of the same genus isolated from the environment have also been successful and proved possibilities to use natural antagonists of *P. destructans* which inhibit its growth and/or limit its effects on bats. Fritze et al. (2012) tested *in vitro* the anti-fungal properties of *Pseudomonas veronii*-like PAZ1, isolated from the mycelium of the causative agent of the European black alder die-off *Phytophthora alni* Brasier et S. A. Kirk. It showed significant inhibition of *P.*

destructans on 3 different media, up to complete growth arrest on potato-dextrose agar with yeast extract (mPDA). The authors supposed that the antagonistic effect are due to bacterial peculiar secondary metabolites – cyclolipodepsipeptides, which opens the future possibilities for their isolation and individual testing. Although these bacteria provide encouraging results undur laboratoty conditions, it remains unclear how they would be applied to wild bats and if they would also be efficient under natural conditions.

In the present review, we do not discuss the substances from and relations between bacteria and other fungi found in hibernating sites together or near to *P. destructans*, since there is still no knolwedge on the role of these organisms in fungus life and their relationships (*e.g.* Barlow et al. 2009; Amelon & Knudsen 2010; Chatuverdi et al. 2010; Cryan et al. 2010). Studies on the microbiota of bats have focused on gut and fecal microbiota, with little attention given to the external microbiota (*e.g.* Zanowiak et al. 1993; Muhldorfer 2012; Phillips et al. 2012). Kooser et al. (2015) showed for first time biogeographic differences in the abundance and diversity of external bat microbiota. Their study included 202 (62 cave-netted, 140 surfacenetted) bat samples belonging to 13 species of bats from western U.S.A. uninfected with WNS and the authors managed to identify differences in microbiota diversity among sites, and between cave bats versus surface-netted bats, regardless of sex and species. These results present novel information about the factors that shape external microbiota of bats providing new insights into potential vulnerability of different bat species to WNS. However, still most of the research is turned towards antagonistic bacteria species which can produce active substances inhibiting the fungus (Amelon & Knudsen 2010; Fritze et al. 2012).

Other decisions for active management of WNS include using artificial roosts that can be cleaned every year in order to exclude the possibility of bats getting infected with *P. destructans* from the environment. Such an experimental hibernacula was built in Tennessee and existing military bunkers have been used as artificial hibernaculum in the northeastern U.S.A., though it is still early to evaluate their effectiveness (Frick et al. 2016). Some authors also suggest supplying hibernating bat with electrolytes, given that their depletion plays an important role in progression of the disease (Frick et al. 2016). Breeding bats in captivity has also been discussed, but in general considered to be too difficult. However, captive colonies could be used at least to provide animals for laboratory experiment, thus reducing researchers' impact on wild populations (Frick et al. 2016).

Important impications were provided by Johnson et al. (2014). They proved that host and environmental characteristics are significant predictors of WNS mortality and outlined environmental and quantitative pathogen characteristics which could be useful in further for pathogen prevention. The results obtained showed that female bats were significantly more likely to survive hibernation, as were bats hibernated at 4 °C, and bats with greater body condition at the start of hibernation. Johnson et al. (2014) conducted captive studies and pointed the need to quantify dynamics of pathogen exposure in free-ranging bats, as dynamics of WNS produced in captive studies inoculating bats with several hundred thousand conidia may differ from those in the wild. Generally similar are the results of Grieneisen et al. (2015) from another 2-year captive study of the same species, designed to determine the impact of hibernacula temperature and sex on WNS survivorship in *Myotis lucifigus*. They demonstrated that colder hibernacula were more favourable for survival, that WNS mortality varied among individuals and that female bats might be more negatively affected by WNS than male bats.

According to the findings summarized above and following Zhang et al. (2014) it is possible to state that all results underscore the need for integrated disease control measures that target both bats and *P. destructans* and that urgent steps are still needed for the mitigation or control of the pathogen to save bats. Currently, many projects are concentrated on different aspects of fighting the disease and positive results are expected. However, before applying whatever strategies for decontamination of already infected sites or healing already diseased animals, it is of primary importance to eliminate the human factor in transmitting the pathogen. Shelley et al. (2013) tested various methods of disinfecting cave clothes and equipment. They discovered that washing in temperatures above 50 ºC or placing in Lysol solution in concentration 1:64 are 100% effective against *P. destructans* and do not significantly decrease equipment quality. Regarding cave visits for scientific purpose, Puechmaille et al. (2011b) pointed out that transport of samples could also be a cross-contamination source as *P. destructans* spores are able to germinate after being stored for 8 days in RNAlater or dry. On the other hand, 70% ethanol can kill the fungus after a minimum of 24 hours, while only 30 minutes are enough for absolute ethanol. That is why, when transporting pathogen samples for DNA research, the use of absolute ethanol is recommended, especially for places where *P. destructans* has not yet been observed.

6. Studies on *Pseudogymnoascus destructans* in Bulgaria and future perspectives

In Bulgaria *P. destructans* was observed on bats by B. Petrov and S. Stoycheva in 2011 and 2012 (B. Petrov, pers. comm.), but was first first discovered microscopically in 2014 by the Bulgarian authors of these review (and D. Zlatanova) in environmental samples from the caves Lednitzata in Rodopi mountains and Raichova Dupka in Central Balkan National Park (Toshkova 2014; Zhelyazkova 2014; Toshkova & Zhelyazkova 2014) and later its identity was confirmed by DNA analysis at the University of Greifswald, Germany by S. Puechmaille (Toshkova & Zhelyazkova 2014). A few months later the fungus was documented by DNA analysis in the samples from the cave Ivanova Voda, also in Rodopi Mts (Puechmaille, in litt.). The characteristic white fungal growth on the muzzle and the wings of the bats was observed on numerous occasions during the last winter monitoring of bat populations in the country (season 2014–2015) – Zhelyazkova & Toshkova (unpubl.) An interesting observation from this year is the late hibernation of *Myotis myotis/blythii* in a cave situated in the Western Balkan Mts – in the beginning of June some male bats were still in torpor and all of them had the characteristic for *P. destructans* white growth on the muzzle, ears, and wings. This was observed for the first time in Bulgaria, although other authors have previously reported torpid bats in May and June throughout Europe (Puechmaille et al. 2011a).

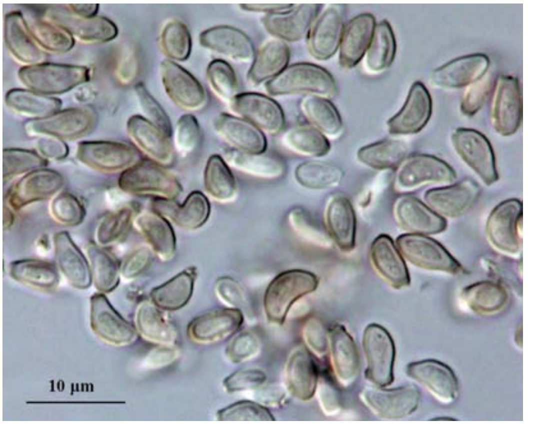

Fig. **1.** Colony of *Psedogymnoascus destrutans* on malt extract agar from the cave Raichova Dupka.

Fig. 2. Conidiospores of of *Psedogymnoascus destructans* from the cave Raichova Dupka.

As Bulgaria is one of the most important countries in Europe regarding bat numbers and species diversity, it is a suitable place for investigations on the biology of *P. destructans* in its native environment and its evolved interactions with its hosts that have led to the *peaceful* co-occurrence of bats and fungi. So far, multiple researches have concentrated on finding the exact processes accounting for the differences between the survival rates in European and American WND-positive bats, but still without any significant results. Pushing this matter further is of great importance for understanding the distribution mechanisms and evolution of wildlife diseases, especially when having in mind the ever increasing traffic of people and products between continents, which inevitably leads to transport of various microorganisms and increases the probability of introduction of new diseases in naïve ecosystems (Cunningham et al. 2003). Up to now, the disease is devastating for North American bat populations but for the first time it made societies and governments fully aware of the indispensable role these animals play in the ecosystems. WND already greatly influenced conservation planning and population monitoring of temperate bats in North America (Foley et al. 2011) and mutual efforts of researchers all over the globe already led to some advances in various methods of limiting the mycosis distribution and even curing infected bats and it is possible that some of them soon will be applicable in a large scale. Although in Europe and Asia flying mammals are not directly threatened by WND, it is important to use the disease popularity to promote a responsible attitude towards caves and their inhabitants. At present, many cavers and speleologists do not even wash their equipment between visiting different underground sites, which is not a good strategy for their protection. As it has been already proposed by PUECHMAILLE ET AL. (2011B), in order to be effective in fighting the epidemic and to prevent similar cases in the future, a combination of high-tech lab science, regular field monitoring, and education should be used.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article. All authors contributed equally to this paper.

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FLORA, MYCOTA AND VEGETATION OF KUPENA RESERVE (RODOPI MOUNTAINS, BULGARIA)

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Abstract. The paper represents results from recent complex studies of flora, mycota and vegetation within the Kupena Reserve (Rodopi Mts, Bulgaria). Twenty six species, referred to 2 divisions, 4 classes and 17 families are recorded for the bryoflora. The vascular flora is presented by 370 species from 57 families, 122 of which are considered as medicinal plants. Eighty seven species of larger ascomycetes and basidiomycetes are found and reported for first time in the reserve. Four of them are of a high conservation value. The vegetation cover is consisted of mixed and monodominant deciduous and coniferous forests, as well as of mire, riverbank and mesic grasslands. Thirteen types of habitats according to the Habitats Directive classification have been recorded within the reserve.

Key words: bryophytes, conservation, habitats, larger fungi, medicinal plants, plant communities, species diversity, vascular plants.

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INTRODUCTION

Kupena was designated as a strict reserve in 1961 with an area of 1761.1 ha and spread between 600 and 1400 m altitude. It is located in Western Rodopi Mts, northern parts of Batashka Mt and close to the town of Peshtera. The reserve is declared for protection of the natural landscape and wild flora and fauna and is listed (1977) in the UNESCO's Man and the Biosphere Programme (Executive Environment Agency 2015). Almost entire territory of the reserve falls into the Special Area of Conservation BG0001030 "Rhodopes-Western" under the Habitats Directive.

Results from a study on the recent vegetation in the reserve are published by Nikolov & Simenska (1985). The authors represent an overview of the variety of forest types determined by the altitude. The forest vegetation is characterized by the basic species composition of trees and shrubs and barely by the herbaceous species. A new species – *Carex lasiocarpa* Ehrh. (Hajek et al. 2005) and a new mire association – *Caricetum nigrae* Braun 1915 (Hajek et al. 2008) for the territory of Bulgaria were found within the reserve. A bigger achievement is the description of the new mire association *Geo coccinei-Sphagnetum contorti* Hajek et al. 2008 (Hajek et al. 2008). Only one fungal species *Hypholoma udum* (Pers.: Fr.) Kühner has been reported from the reserve so far (Gyosheva & Dimitrova 2011). This species, reported as *Psilocybe uda* (Pers.: Fr.) Gillet is included in the Red List of Bulgarian Fungi (Gyosheva et al. 2006) and in the Red Data Book of Republic of Bulgaria (Gyosheva 2015) under category *Endangered* (EN). The vegetation history of the reserve is revealed by the palynological studies of Bozilova et al. (1989), Huttunen et al. (1992) and Tonkov et al. (2013, 2014).

As it is to be seen from the brief review above, Kupena Reserve has been insufficiently investigated. The paper represents results from a recent more complex scientific research in the reserve and thus sets a base for further detailed studies.

MATERIAL AND METHODS

The study has been carried out during the vegetation season of 2014. The route method has been applied to describe the diversity of bryophytes, larger fungi, vascular plants and habitats. In the process of field studies the taxa found have been recorded in lists, and in case of difficulties to identify the species on the field samples were collected for laboratory work. Identification of taxa and nomenclature for vascular plants and bryophytes were according to the main taxonomic sources of Bulgaria (Kozhuharov 1992; Delipavlov & Cheshmedzhiev 2003; Jordanov 1963, 1964, 1966, 1970, 1973, 1976, 1979; Velchev 1982, 1989; Kozhuharov 1995; Kozhuharov & Anchev 2012; Petrov 1975). Author's name of fungal taxa are abbreviated according to Kirk & Ansell (2004) and Index Fungorum. The list of medicinal plants followed Appendix 1 of Medicinal Plants Act. Special attention has been paid to the taxa of a high conservation value. To evaluate the conservation status, the lists of established taxa were checked for endemics – Bulgarian and Balkan (Petrova & Vladimirov 2010), protected species (Appendix 3 of Bulgarian Biological Diversity Act), rare and endangered species according to Bulgarian Red Lists and Red Data Books (Petrova & Vladimirov 2009; Peev et al. 2015), Red List of the Bryophytes in Bulgaria (Natcheva et al. 2006), Red List of Fungi in Bulgaria (Gyosheva et al. 2006), as well as European and international documents (*e.g.* Bern Convention, CITES). The syntaxonomy follows the methodological school of Braun-Blanquet (1965). Habitats are defined according to the Habitats Directive (Council Directive 92/43/EEC).

RESULTS AND DISCUSSION

Bryophytes

Data on the distribution of bryophytes in Bulgaria show that 8% of the species found in Bulgaria so far (754 in total) have localities in Western Rodopi Mts. Bryophyte flora in the reserve comprises 26 species, referred to 2 divisions (liverworts and mosses), 4 classes and 17 families and occupies various substrata as decaying wood, rocks, bare soil, mire areas (***Appendix 1***). Bryophyte species composition is typical for well preserved forest habitats, which are not affected by human impact. One conservationally important bryophyte was found – *Calliergon giganteum* (Schimp.) Kindb. (**Table 1**), a species listed as Endangered (EN) in the Red List of Bryophytes in Bulgaria (Natcheva et al. 2006) and in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Peev et al. 2015). The species is hygrophyte growing in mires. It was found together with *Sphagnum subsecundum* Nees and *Aulacomnium palustre* in a habitat 91D0 Bog woodlands, which is of priority importance and listed in the Habitats Directive

Vascular flora

A total of 370 taxa of vascular plants has been found (***Appendix 1***). To Equisetophyta belong two species, ferns (Polypodiophyta) are represented by seven species, five species are conifers (Pinophyta) and others (354 taxa) are flowering plants (Magnoliophyta), including 98 monocots and 258 dicots. Plant diversity is spread within 59 plant families. The most species rich families are Poaceae (41 species), Asteraceae (30 species), Fabaceae (27 species), Rosaceae (24 species), and Lamiaceae and Cyperaceae (each with 20 species). Within the established families with the greatest number of genera is Poaceae (23) followed by Asteraceae (19), Lamiaceae (14) and Rosaceae (13). The most species-rich genera are *Carex* (16 taxa), *Ranunculus, Galium* and *Juncus* – each with 8 species, *Poa* (7 taxa), *Trifolium* and *Lathyrus* – each with 6 species and *Potentilla, Geranium* and *Myosotis* – each with 5 species.

Table 1. Species of conservation significance. Abbreviations used: Bal – Balkan, CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora, EN – *Endangered*, NT – *Near Threatened*, VU – *Vulnerable*; BBDA – Bulgarian Biological Biodiversity Act.

Species	**BBDA**	**Bern**	**CITES**	**Endemics**	**Red Books of Bulgaria**	**Red lists of Bulgaria**
Bryophytes						
Calliergon giganteum (Schimp.) Kindb.					EN	EN
Vascular flora						
Achillea clypeolata Sm.				Bal		
Carex elata All.					EN	EN
Carex limosa L.					EN	EN
Cirsium appendiculatum Griseb.				Bal		
Digitalis viridiflora Lindl.				Bal		
Fritillaria gussichiae (Degen et Doerfl.) Rix	+	+		Bal		NT
Geum rhodopaeum Stoj. et Stef.	+			Bal		NT
Lathraea rhodopea Dingler	+			Bal		NT
Orchidaceae spp. (see *App. 1*)			+			
Pastinaca hirsuta Pančić				Bal		
Potentilla palustris (L.) Scop.	+					VU
Pyrola media Sw.						VU
Larger fungi						
Auriscalpium vulgare Gray					EN	EN
Bondarzewia montana (Quél.) Singer					EN	EN
Lentaria byssiseda Corner						VU
Spathularia flavida Pers.: Fr.						NT

Medicinal plants

Among the recorded vascular plants 122 species are considered as medicinal plants. The richest families are Rosaceae (13 species), Lamiaceae (10 species) and Asteraceae (9 species). The region of Snezhanka cave has the greatest number of medicinal plants. Most of the medicinal plants found on the territory of Kupena reserve have limited distribution (only one locality) and low population density. According to the possibilities for collection from nature, medicinal plants of the reserve should be grouped as follows:

I – species forbidden for collection from nature for commercial purposes but with allowed collection for personal purposes according to Order RD–83/3.02.2014 of the Minister of Environment and Waters: 3 species – *Asplenium trichomanes* L., *Orchis* sp. div., *Valeriana officinalis* L.;

II – species with limited permission for collection from nature for commercial purposes with annually defined regions and quantities, according to Order RD–83/3.02.2014 of the Minister of Environment and Waters: 3 species – *Alchemilla vulgaris* complex, *Galium odoratum* (L.) Scop., *Primula veris* L.;

III – species object of preservation and regulated use from nature according to appendix 4 of Biodiversity Act: 4 species – *Dryopteris filix-mas* (L.) Schott., *Lilium martagon* L., *Orchis pallens* L., *Salix caprea* L.;

IV – wide distributed medicinal plants: 115 species. In this category as common species with abundant populations for the territory of Kupena reserve should be mentioned *Cardamine bulbifera* (L.) Crantz and *Euphorbia amygdaloides* L. as well as the dominants in coniferous forests like *Pinus sylvestris* L. and *Picea abies* (L.) Karst.

Larger fungi

The checklist of larger fungi found during the field studies in the reserve includes 87 species – 7 from Ascomycota and 80 from Basidiomycota. The species belong to 6 classes, 12 orders, 38 families and 57 genera and all of them are new records for Kupena Reserve. Four species are of a high conservation value, included in the Red List of Fungi in Bulgaria under different threat categories: *Auriscalpium vulgare* Gray – Endangered (EN), *Bondarzewia montana* (Quél.) Singer – Endangered (EN), *Lentaria byssiseda* Corner – Vulnerable (VU) and *Spathularia flavida* Pers.: Fr. – Near Threatened (NT) (**Fig. 1**). Two species of them (*Auriscalpium vulgare* and *Bondarzewia montana*) are included also in the Red Data Book of Plants and Fungi of the Republic of Bulgaria (Peev et al. 2015). Prevailing number of larger fungi was registered in forest habitats – coniferous and beech woods. The mixed woods (*Picea abies, Pinus sylvestris, Abies alba* Mill. and *Fagus sylvatica* L.) were exceptionally rich of fungal species.

Fig. 1. *Spathularia flavida* Pers.: Fr. – *Near Threatened* (NT) species in the Red List of fungi in Bulgaria.

Vegetation and habitats

The reserve territory is large, comprising diverse landscape and as a reflection of this the vegetation is also very diverse. This territory preserves most kinds of the Rodopi wild nature. The forests prevail and their distribution is determined by altitudinal climatic belts. At the foothills oak forests dominate. They are most species rich due to the open structure and thermophilic conditions. Mixed forests of *Carpinus betulus* L. and *Quercus daleschampii* Ten. are developed at the lower altitudes. In the tree layer *Acer campestre* L., *Fraxinus ornus* L. and *Tilia cordata* Mill. could be also found. *Festuca heterophylla* Lam., *Cardamine bulbifera* (L.) Crantz and *Melica uniflora* Retz. dominate within the aboveground layer. The beech forests occupy the higher elevation. They could be observed at different exposures, but are characterized by poorer biodiversity as compared to the oak forests. Regarding the soil reaction the beech forests are split to three categories on neutrophil, acidophil and carbonate terrains. The neutrophil forests belong to the widespread Asperulo-Fagetum association. Despite of some species specific to the Rodopi Mts, this association is typical example of Central European vegetation type. In the aboveground layer *Sanicula europaea* L., *Cardamine bulbifera, Lamiastrum galeobdolon* (L.) Ehrend. et Polatchek and *Melica uniflora* could be found very often. Another type of beech forests is represented by Luzulo-Fagetum association. It is the most species poor and *Luzula luzuloides* (Lam.) Dandy takes the dominant position in the aboveground level. On carbonate terrains communities of Cephalanthero-Fagion are developed. *Pinus nigra* subsp. *pallasiana* (Lamb.) Holmb. takes place rarely in these forests. A peculiarity of Cephalanthero-Fagion forests is the presence of different orchids like *Cephalanthera rubra* (L.) L. C. M. Richard, *Epipactis* spp. and *Neottia nidus-avis* (L.) Rich. Upwards the slopes the beech forests become mixed with *Abies alba*, *Pinus sylvestris* and *Picea abies*. The coniferous forests become the prevailing type on the highest mountain parts. Scots pine and spruce communities prevail, while *Abies alba* is present by single individuals. Syntaxonomically these communities are included in Vaccinio-Piceetea class. In the Rodopi Mts they are characterized by three strata – tree, herbaceous and moss. The herbaceous stratum most frequently includes *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Luzula sylvatica* (Hudson) Gandin and *Calamagrostis arundinacea* (L.) Roth. The moss layer is species rich and usually has high cover. Common species are *Dicranum scoparium* Hedw., *Hylocomium splendens* (Hedw.) Schimp., *Hypnum cupressiforme* Hedw. and *Eurhynchium angustirette* (Broth.) T. J. Kop. In the reserve territory coniferous forests occupy deep Cambisols with acidic reaction as a result of dissolved humic substances generated by slow decomposition process of pine needles. In Kupena reserve *Picea abies* forests belong to the climax vegetation. Mixed spruce and Scots pine forests are quite similar to the monodominant spruce stands despite that are developed mostly on slopes with southern exposure. We observed high density of young spruce individuals in these mixed forests which is an indication of ongoing successional process toward monodominant *Picea abies* woods.

In the forest openings we found grasslands dominated by *Festuca nigrescens* Lam. These communities are species rich and syntaxonomically are related to Molinio-Arrhenatheretea class. Forest fringes include grassland communities related to Trifolio-Geranietea class and Trifolion medii alliance.

Special attention deserve the wetland communities of Scheuchzerio-Caricetea nigrae class. These communities are very unique for the reserve territory. They are developed on plane areas or slight depressions covered all year by water table. The species diversity comprises *Carex elata* All., *Carex lasiocarpa* Ehrh., *Carex curta* Good, *Juncus effusus* L., *Potentilla palustris* (L.) Scop. A famous peatland with Caricetum nigrae association exists in the Kupena reserve. Close vicinity is occupied by Geo coccinei-Sphagnetum contorti assotiation (see Hajek et al. 2008). It is surrounded by coniferous forests which are a very good example of NATURA 2000 habitat 91D0 *Bog woodland. The peatland area has relict origin which is proved by fossil records of *Isoetes* L. by Lazarova et al. (2011).

Small rivers and brooks cross the reserve territory and their banks are covered by tall herb communities of Mulgedio-Aconitetea class. These communities are distinct and include Balkan endemics such as *Cirsium appendiculatum* Griseb.

Following the Directive 92/43 EEC for habitats, the reserve includes 3260 Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation, 6430 Hydrophyllous tall herb fringe communities of plants and of mountain to alpine level, 7140 Transition mires and quaking bogs, 8210 Calcareous rocky slopes with chasmophytic vegetation, 8220 Siliceous rocky slopes with chasmophytic vegetation, 9110 Luzulo-Fagetum beech forests, 9130 Asperulo-Fagetum beech forests, 9150 Medio-European limestone beech forests of the Cephalanthero-Fagion, 91BA Moesian silver fir forests, 91CA Rhodopide and Balkan Range Scots pine forests, 91D0 *Bog woodland, 9170 Galio-Carpinetum oak-hornbeam forests, 9410 Acidophilous *Picea* forests of the montane to alpine levels (Vaccinio-Piceetea).

***Syntaxonomical synopsis of identified communities*:**

Cl. Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939
- All. Piceion abietis Pawłowski et al. 1928
  - Ass. Vaccinio myrtilli-Piceetum abietis Šoltés 1976
- All. Dicrano-Pinion (Libbert 1933) Matuszkiewicz 1962
  - Ass. Vaccinio myrtilli-Pinetum sylvestris Juraszek 1928

Cl. Carpino-Fagetea Jakucs ex Passarge 1968
- All. Carpinion betuli Issler 1931
- All. Fagion sylvaticae Luquet 1926
  - Ass. Galio odorati-Fagetum sylvaticae Sougnez et Thill 1959
- All. Cephalanthero-Fagion Tüxen 1955
- All. Luzulo-Fagion sylvaticae Lohmeyer et Tüxen in Tüxen 1954
  - Ass. Luzulo luzuloidis-Fagetum sylvaticae Meusel 1937
- All. Tilio platyphylli-Acerion Klika 1955

Cl. Scheuchzerio-Caricetea nigrae Tuxen 1937
- All. Sphagno-Caricion canescentis Passarge (1964) 1978
  - Ass. Caricetum nigrae Braun 1915

All. Sphagno warnstorfii-Tomenthypnion nitentis Dahl 1956
Ass. Geo coccinei-Sphagnetum contorti Hajek et al. 2008
Cl. Trifolio-Geranietea sanguinei Müller 1961
All. Trifolion medii Müller 1962
Cl. Mulgedio-Aconitetea Hadač et Klika in Klika et Hadač 1944
All. Cirsion appendiculati Horvat et al. 1937

Appendix 1. List of taxa recorded in the Kupena Reserve.

Bryophytes
Marchantiophyta (Liverworts)
Jungermanniopsida
Geocalycaceae: *Chiloscyphus polyanthus* (L.) Corda
Bryophyta (Mosses)
Sphagnopsida (Peat mosses)
Sphagnaceae: *Sphagnum subsecundum* Nees
Polytrichopsida
Polytrichaceae: *Atrichum undulatum* (Hedw.) P. Beauv.; *Polytrichum commune* Hedw.
Bryopsida
Grimmiaceae: *Grimmia trichophylla* Grev.; *Racomitrium canescens* (Hedw.) Brid.; *R. sudeticum* (Funck) Bruch et Schimp.
Dicranaceae: *Dicranum scoparium* Hedw.; *Dicranum tauricum* Sapjegin
Ditrichaceae: *Ceratodon purpureus* (Hedw.) Brid.
Hedwigiaceae: *Hedwigia ciliata* (Hedw.) P. Beauv.
Aulacomniaceae: *Aulacomnium palustre* (Hedw.) Schwägr.
Bartramiaceae: *Bartramia pomiformis* Hedw.
Bryaceae: *Bryum alpinum* With.; *B. caespiticium* Hedw.
Mniaceae: *Mnium stellare* Hedw.
Campyliaceae: *Sanionia uncinata* (Hedw.) Loeske; *Calliergon giganteum* (Schimp.) Kindb.
Brachytheciaceae: *Brachytheciastrum velutinum* (Hedw.) Ignatov et Huttunen; *Homalothecium lutescens* (Hedw.) H. Rob.; *Cirriphyllum crassinervium* (Taylor) Loeske et M. Fleisch.; *Eurhynchium angustirete* (Broth.) T. J. Kop.
Climaciaceae: *Climacium dendroides* (Hedw.) F. Weber et D. Mohr
Hypnaceae: *Hypnum cupressiforme* Hedw.
Hylocomiaceae: *Hylocomium splendens* (Hedw.) Schimp.
Leucodontaceae: *Leucodon sciuroides* (Hedw.) Schwägr.

Vascular plants [medicinal plants are marked by asterix (*)]:
Equisetophyta
Equisetaceae: **Equisetum arvense* L.; **E. palustre* L.

Polypodiophyta

Athyriaceae: **Athyrium filix-femina* (L.) Roth;

Aspidiaceae: **Dryopteris filix-mas* (L.) Schott.

Aspleniaceae: *Asplenium adiantum-nigrum* L.; *A. onopteris* L; **A. trichomanes* L.

Hypolepidaceae: **Pteridium aquilinum* (L.) Kuhn;

Polypodiaceae: **Polypodium vulgare* L.

Pinophyta

Cupressaceae: *Juniperus communis* L.

Pinaceae: **Abies alba* Mill.; **Picea abies* (L.) Karst.; **Pinus sylvestris* L.*; P. nigra* subsp. *pallasiana* (Lamb.) Holmb.

Magnoliophyta

Magnoliopsida

Aceraceae: *Acer campestre* L.; **A. platanoides* L.; *A. pseudoplatanus* L.

Anacardiaceae: *Cottinus coggygria* L.

Apiaceae: *Aegopodium podagraria* L.;**Angelica sylvestris* L.; *Anthriscus sylvestris* (L.) Hoffm.; *Heracleum ternatum* Velen.; *Laser trilobium* (L.) Borkh.; *Oenanthe silaifolia* Bieb.; *O. stenoloba* Schur; *Pastinaca hirsuta* Pančić; *Physospermum cornubiense* (L.) DC.; **Sanicula europaea* L.

Araliaceae: **Hedera helix* L.

Asteraceae: *Achillea grandifolia* Friv.; **A. millefolium* L.; *A. clypeolata* Sibt. et Sm.; **Anthemis tinctoria* L.; *Arctium lappa* L.; **Artemisia vulgaris* L.; **Bellis perennis* L.; *Centaurea cuneifolia* Sirth. et Sm.; *C. phrygia* L.; *C. stoebe* L.; **Cichorium intybus* L.; *Cirsium appendiculatum* Griseb.; *C. arvense* (L.) Scop; *C. creticum* (Lam.) D'Urv.; *C. ligulare* Boiss.; *Hieracium murorum* Gr.*; H. umbellatum* L.; *Inula conyza* DC; *Leontodon autumnalis* L.; *L. hispidus* L.; **Leucanthemum vulgare* Lam.; *Mycelis muralis* (L.) Dumort.; **Solidago virgaurea* L.; *Petasites hybridus* (L.) P. Gaertner, B. Meyer et Schrerb.; *Prenanthes purpurea* L.; *Tanacetum corymbosum* (L.) Schultz-Bip.; *T. vulgare* L.; *Taraxacum* sect. *Ruderalia; *Tussilago farfara* L.

Betulaceae: *Alnus glutinosa* (L.) Gaertner; *Betula pendula* Roth; **Carpinus betulus* L.; *C. orientalis* Mill.; **Corylus avellana* L.; *Ostrya carpinifolia* Scop.

Boraginaceae: *Cynoglossum hungaricum* Simon.; *Myosotis arvensis* (L.) Hill; *M. ramosissima* Rochel; *M. scorpioides* L.; *M. sicula* Guss.; *M. sylvatica* Ehrh. ex Hoffm.; **Pulmonaria officinalis* L.; *P. rubra* Schott; **Symphytum officinale* L.; *S. tuberosum* L.

Brassicaceae: **Alliaria petiolata* (M. Bieb.) Cavara et Grande; *Alyssum murale* Waldst. et Kit.; *Arabis hirsuta* (L.) Scop.; *A. proccurens* Waldst. et Kit.; **Cardamine bulbifera* (L.) Crantz; *Erysimum cuspidatum* (Bieb.) DC; *Rorippa sylvestris* (L.) Besser.

Campanulaceae: *Campanula glomerata* L.; *C. patula* L.; **C. persicifolia* L.; *C. rapunculoides* L.

Caprifoliaceae: *Lonicera nigra* L.; **Sambucus nigra* L.; *Sambucus racemosa* L.; **Viburnum opulus* L.

Caryophyllaceae: *Dianthus deltoides* L.; *D. cruentus* Griseb.; **Lychnis coronaria* (L.) Desr.; **Lychnis flos-cuculi* L.; *Minuartia caespitosa* (Ehrh.) Deg.; *Scleranthus annuus* L.; *Silene armeria* L.; *S. roemeri* Friv.; *S. viridiflora* L.; *S. vulgaris* (Moench) Garcke; **Stellaria graminea* L.; *S. holostea* L.; **S. media* (L.) Vill.; *S. nemorum* L.; **Viscaria vulgaris* Röhl.

Celastraceae: *Euonymus europaeus* L.; *E. latifolius* (L.) Mill.

Cistaceae: *Helianthemum nummularium* (L.) Miller.

Cornaceae: ***Cornus mas* L.

Crassulaceae: *Sedum cepaea* L.; *S. pallidum* M. Bieb.

Dipsacaceae: *Dipsacus laciniatus* L.; **Knautia arvensis* (L.) Coult.; *K. drymeia* Heuff.

Ericaceae: **Vaccinium myrtyllus* L., **V. vitis-idaea* L.

Euphorbiaceae: **Euphorbia amygdaloides* L.; **E. cyparissias* L.; **Mercurialis perennis* L.

Fabaceae: *Astragalus glycyphyllos* L.; *Chamaecytisus hirsutus* (L.) Link; *C. supinus* (L.) Link; **Coronilla varia* L.; *Dorycnium herbaceum* Vill.; *Galega officinalis* L.; *Genista carinalis* Griseb.; *G. depressa* Bieb.; *G. lydia* Boiss.; *Lathyrus latifolius* L.; *L. laxiflorus* (Desf.) O. Kuntze; *L. niger* (L.) Bernh.; *L. pratensis* L.; *L. venetus* (Mill.) Wohlf; **L. vernus* (L.) Bernh.; *Lotus corniculatus* L.; *Medicago lupulina* L.; *Melilotus alba* Med.; **Trifolium alpestre* L.; *T. campestre* Schreber; *T. fragiferum* subsp. *bonannii* (C. Presl) Soják; *T. medium* L.; **T. pratense* L.; **T. repens* L.; *Vicia incana* Gouan.; *V. sepium* L.; *V. tetrasperma* (L.) Schreber.

Fagaceae: **Fagus sylvatica* L.; *Quercus dalechampii* Ten.; *Q. pubescens* Willd.

Geraniaceae: *Geranium columbinum* L.; **G. macrorrhizum* L.; *G. phaeum* L.; **G. robertianum* L.; *G. sanguineum* L.

Hypericaceae: **Hypericum cerastoides* (Spach) N. K. B. Robson; **H. maculatum* Crantz; *H. olympicum* L.; **H. perforatum* L.

Lamiaceae: *Ajuga genevensis* L.; **A. laxmanii* (L.) Benth.; *A. reptans* L.; *Calaminhta nepeta* (L.) Savi; **Clinopodium vulgare* L.; *Lamiastrum galeobdolon* (L.) Ehrend. & Polatschek; *Lamium garganicum* L.; **L. purpureum* L.; *Lycopus exaltatus* L.; **Mentha longifolia* (L.) Hudson; **M. spicata* L.; *Nepeta nuda* L.; **Origanum vulgare* L.; **Prunella vulgaris* L.; **Salvia glutinosa* L.; *Scutellaria columnae* All.; *S. velenovskyi* Reich. f.; *Stachys germanica* L.; **S. sylvatica* L.; **Teucrium chamaedrys* L.

Lythraceae: *Lythrum salicaria* L.

Oleaceae: **Fraxinus ornus* L.; *Jasminum fruticans* L.; *Ligustrum vulgare* L.; *Syringa vulgaris* L.

Onagraceae: *Circaea lutetiana* L.; *Epilobium angustifolium* L.; *E. collinum* C. C. Gmel.*; E. montanum* L.; *E. palustre* L.

Oxalidaceae: *Oxalis acetosella* L.

Plantaginaceae: *Plantago lanceolata* L.; *P. major* L.; *P. media* L.

Polygalaceae: *Polygala vulgaris* L.

Polygonaceae: *Rumex acetosa* L.; *R. acetosella* L.; *R. conglomeratus* Murray.

Primulaceae: *Lysimachia nummularia* L.; *L. vulgaris* L.; *Primula veris* L.

Pyrolaceae: *Orthilia secunda* (L.) House; *Pyrola media* Swartz; *P. minor* L.

Ranunculaceae: *Actaea spicata* L.; *Clematis vitalba* L.; *Ranunculus acris* L.; *R. auricomus* L.; *R. flammula* L.; *R. ficaria* L.; *R. millefoliatus* Vahl; *R. montanus* Willd.; *R. polyanthemos* L.; *R. repens* L.

Rosaceae: *Agrimonia eupatoria* L.; *Aremonia agrimonoides* (L.) DC.; *Alchemilla flabellata* Busser; *A. gracilis* Opiz.; *A. vulgaris* agg.*; Cotoneaster integerrimus* Medicus; *Crataegus monogyna* Jacq.; *Filipendula ulmaria* (L.) Maxim.; *F. vulgaris* Moenh; *Fragaria vesca* L.; *F. viridis* Duchesne; *Geum rhodopaeum* Stoj. et Stef.; *G. urbanum* L.; *Potentilla argentea* L.; *P. erecta* (L.) Raeusch.; *P. micrantha* Ramond. ex DC.; *P. palustris* (L.) Scop; *P. reptans* L.; *Prunus avium* L.; *Rosa canina* L.; *R. tomentosa* Sm.; *Rubus hirtus* Walds. & Kit.; *Sorbus aucuparia* L.; *S. torminalis* (L.) Crantz.

Rubiaceae: *Cruciata glabra* (L.) Ehrend.; *C. laevipes* Opiz; *Galium aparinae* L.; *G. lucidum* All.; *G. odoratum* (L.) Scop.; *G. palustre* L.; *G. pseudoristatum* Schur.; *G. rivale* (Sibth. & Sm.) Griseb.; *G. rotundifolium* L.; *G. verum* L.

Salicaceae: *Populus tremula* L.; *Salix caprea* L.

Saxifragaceae: *Saxifraga tridactylites* L.

Scrophulariaceae: *Digitalis viridiflora* Lindl.; *Lathraea rhodopea* Dingler; *Linaria vulgaris* Miller; *Rhinanthus rumelicus* Velen.; *Verbascum glabratum* Friv.; *V. longifolium* Ten.; *Veronica chamaedrys* L.; *V. montana* L.; *V. serpilifolia* L.; *V. urticifolia* Jacq.

Solanaceae: *Physalis alkekengii* L.

Tiliaceae: *Tilia cordata* Mill.; *T. platyphyllos* Scop.; *T. tomentosa* Moench.

Ulmaceae: *Ulmus minor* Miller.

Urticaceae: *Urtica dioica* L.

Valerianaceae: *Valeriana officinalis* L.

Verbenaceae: *Verbena officinalis* L.

Violaceae: *Viola canina* L.; *V. hirta* L.; *V. odorata* L.; *V. riviniana* Reichb.; *V. tricolor* L.

Liliopsida

Cyperaceae: *Carex canescens* L.; *C. caryophylea* Latourr.; *C. cuprina* (Heuff.) A. Kern.; *C. curta* Good.; *C. echinata* Murray; *C. elata* All.; *C. flava* L.; *C. hirta* L.;

C. humilis Leyss.; *C. lasiocarpa* Ehrh.; *C. laevigata* Sm.; *C. limosa* L.; *C. ovalis* Good.; *C. pallescens* L.; *C. rostrata* Stokes; *C. vesicaria* L.; *Eleocharis palustris* (L.) Roemer & Schultes; *E. uniglumis* (Link) Schultes; **Eriophorum angustifolium* Honckeny; **E. latifolium* Hoppe; *Scirpus sylvaticus* L.

Dioscoreaceae: *Tamus communis* L.

Juncaceae: *Juncus articulatus* L.; *J. atratus* Krocker; *J. compressus* Jacq.; *J. conglomeratus* L.; *J. effusus* L.; *J. filiformis* L.; **J. inflexus* L.; *J. thomasii* Ten.; *Luzula forsteri* (Sm.) DC.; *L. luzuloides* (Lam.) Dandy; *L. multiflora* (Retz.) Lej.; *L. sudetica* (Willd.) DC.; *L. sylvatica* (Hudson) Gaudin.

Liliaceae: **Colchicum autumnale* L.; *Erythronium dens-canis* L.; *Fritillaria gussichiae* (Degen & Dörfler) Rix; **Lilium martagon* L.; *Muscari commosum* (L.) Mill.; *Ornithogalum umbellatum* L.; *Paris quadrifolia* L.; *Polygonatum latifolium* (Jacq.) Desf.; **P. odoratum* (Miller) Druce; **Veratrum album* subsp. *lobelianum* (Bernh). Reichenb.

Orchidaceae: *Cephalantera damasonium* (Mill.) Druce; *C. longifolia* (L.) Fritsch; *C. rubra* (L.) L. C. M. Richard; *Dactylorhiza cordigera* (Fries) Soó; *D. maculata* (L.) Soó; *D. saccifera* (Brongn.) Soó; *Listera ovata (Neottia ovata)* (L.) R. Br.; *Neottia nidus-avis* (L.) Rich.; *Orchis coriophora* L.; **O. pallens* L.; **Platanthera bifolia* (Custer) Reichenb.f.; **P. chlorantha* (L.) L. C. M. Richard.

Poaceae: *Agrostis canina* L.; *A. capillaris* L.; *A. stolonifera* L.; *Alopecurus pratensis* L.; **Anthoxanthum odoratum* L.; *Arrhenatherum elatius* (L.) Beauv. ex J. Presl et C. Presl; *Brachypodium pinnatum* (L.) Beauv.; *B. sylvaticum* (Hudson) Beauv.; **Briza media* L.; *Bromus mollis* L.; *B. racemosus* L.; *Calamagrostis arundinacea* (L.) Roth; *C. epigeios* (L.) Roth; *Cynosurus cristatus* L.; *C. echinatus* L.; *Dactylis glomerata* L.; *Danthonia alpina* Vest; *Deschampsia caespitosa* (L.) Beauv.; *Festuca drymeja* Mert. et Koch.; *F. heterophylla* Lam.; *F. nigrescens* Lam.; *F. pratensis* Hudson; *F. rubra* L.; *F. rupicola* Heuffel; *F. valesiaca* Schleich. ex Gaud.; *Holcus lanatus* L.; *H. mollis* L.; *Hordelymus europaeus* (L.) Nevski; *Lerchenfeldia flexuosa* (L.) Schur; *Lolium perenne* L.; *Melica uniflora* Retz.; *Milium effusum* L.; *Nardus stricta* L.; *Phleum pratense* L.; *Poa angustifolia* L.; *P. annua* L.; *P. bulbosa* L.; *P. compressa* L.; *P. nemoralis* L.; *P. pratensis* L.; *P. trivialis* L.; *Sesleria coerulans* Friv.

LARGER FUNGI

Ascomycota

Leotiomycetes

Rhytismatales: ***Cudoniaceae:*** *Spathularia flavida* Pers.: Fr.

Pezizimycetes

Pezizales

Discinaceae: *Gyromitra esculenta* (Pers.) Fr.

Helvellacae: *Helvella lacunosa* Afzel.

Pezizaceae: *Peziza badia* Pers.

Pyronemataceae: *Humaria hemisphaerica* (F. H. Wigg.: Fr.) Fuckel
Sordariomycetes
Xylariales
Diatrypaceae: *Diatrype disciformis* (Hoffm.: Fr.) Fr.
Xylariaceae: *Kretzschmaria deusta* (Hoffm.: Fr.) P. M. D. Martin
Basidiomycota
Agaricomycetes
Agaricales

Agaricaceae: *Agaricus arvensis* Schaeff.; *Calvatia utriformis* (Bull.: Pers.) Jaap; *Lepiota clypeolaria* (Bull.: Fr.) P. Kumm.; *Lycoperdon echinatum* Pers.: Pers.; *L. mammiforme* Pers.: Pers.; *L. perlatum* Pers.: Pers.

Amanitaceae: *Amanita fulva* (Schaeff.) Fr.; *A. gemmata* (Fr.) Bertill.; *A. muscaria* (L.: Fr.) Pers.; *A. pantherina* (DC.: Fr.) Krombh.; *A. rubescens* Pers.: Fr.; *A. vaginata* (Bull.: Fr.) Lam.

Cortinariaceae: *Cortinarius cinnamomeus* (L: Fr.) Fr.

Hydnangiaceae: *Laccaria laccata* (Scop.: Fr.) Cooke

Hygrophoraceae: *Crysomphalina chrysophylla* (Fr.: Fr.) Clémençon, *Hygrocybe persistens* (Britzelm.) Singer var. *persistens*

Marasmiaceae: *Gymnopus dryophilus* (Bull.: Fr.) Murrill.; *G. peronatus* (Bolton: Fr.) Antonín, Halling et Noordel.; *Marasmiellus perforans* (Hoffm. et Fr.) Antonín, Halling et Noordel.; *M. rotula* (Scop.: Fr.) Fr.; *Marasmius oreades* (Bolton: Fr.) Fr.; *Megacollybia platyphylla* (Pers.: Fr.) Kotl. et Pouzar; *Mycetinus scorodonius* (Fr.: Fr.) A. W. Wilson

Mycenaceae: *Mycena pura* (Pers.: Fr.) P. Kumm.; *M. rosea* (Schumach.) Gramberg

Physalacriaceae: *Oudemansiella mucida* (Schrad.: Fr.) Höhn.

Pluteaceae: *Pluteus cervinus* (Schaeff.) P. Kumm.

Psathyrellaceae: *Coprinellus micaceus* (Bull.: Fr.) Vilgalys, Hopple et Jacq. Johnson

Schizophyllaceae: *Schizophyllum commune* Fr. : Fr.

Strophariaceae: *Galerina hypnorum* (Schrank: Fr.) Kühner; *Gymnopilus penetrans* (Fr.: Fr.) Murrill.; *Hypholoma fasciculare* (Huds.: Fr.) P. Kumm.

Tricholomataceae: *Clitocybe gibba* (Pers.: Fr.) P. Kumm.; *C. odora* (Bull.: Fr.) P. Kumm.; *Lepista sordida* (Fr.: Fr.) Singer; *Rickenella fibula* (Bull.: Fr.) Raithelh.

Boletales

Boletaceae: *Boletus edulis* Bull.: Fr.; *B. subtomentosus* L.; *Leccinum aurantiacum* (Bull.) Gray; *L. scabrum* (Bull.: Fr.) Gray; *Neoboletus luridiformis* (Rostk.) Gelardi, Simonini & Vizzini*;* *Xerocomellus chrysenteron* (Bull.) Sutara

Fig. 2. *Suillus grevilleii* (Klotzsch : Fr.) Singer

Gomphidiaceae: *Chroogomphus helveticus* (Singer) M. M. Moser

Suillaceae: *Suillus bovinus* (L.: Fr.) Roussel; *S. granulatus* (L.: Fr.) Roussel; *S. grevillei* (Klotzsch: Fr.) Singer (**Fig. 2**); *S. luteus* (L.: Fr.) Roussel; *S. variegatus* (Sw.: Fr.) Richon et Roze

Cantharellales

Cantharellaceae: *Cantharellus cibarius* Fr.: Fr. var. *cibarius*

Clavulinaceae: *Clavulina rugosa* (Bull.: Fr.) Schröt.

Hydnaceae: *Hydnum repandum* L.: Fr. f. *repandum*

Gomphales

Gomphaceae: *Ramaria botrytis* (Pers.: Fr.) Ricken

Lentariaceae: *Lentaria byssiseda* Corner

Phallales

Phallaceae: *Phallus impudicus* L.: Pers.

Polyporales

Fomitopsidaceae: *Fomitopsis pinicola* (Sw.: Fr.) P. Karst.; *Phaeolus schweinitzii* (Fr.: Fr.) Pat.

Polyporaceae: *Fomes fomentarius* (L.: Fr.) J. J. Kickx; *Polyporus badius* (Pers.) Schwein.; *P. leptocephalus* (Jacq.: Fr.) Fr.; *P. tuberaster* (Jacq.: Fr.) Fr.; *Pycnoporus cinnabarinus* (Jack.: Fr.) P. Karst.; *Trametes hirsuta* (Wulfen: Fr.) Pilát; *T. versicolor* (L.: Fr.) Lloyd; *Trichaptum abietinum* (Pers. ex J. F. Gmel. : Fr.) Ryvarden; *T. biforme* (Fr.) Ryvarden

Russulales

Auriscalpiaceae: *Auriscalpium vulgare* Gray

Bondarzewiaceae: *Bondarzewia montana* (Quél.) Singer

Russulaceae: *Lactarius aurantiacus* (Pers.: Fr.) Gray; *L. deliciosus* (L.: Fr.) Gray; *L. deterrimus* Gröger; *L. piperatus* (L.: Fr.) Pers.; *Russula cyanoxantha* (Schaeff.) Fr.; *R. delica* Fr.; *R. densifolia* Gillet; *R. grisea* (Pers.) Fr.; *R. vesca* Fr.

Stereaceae: *Stereum hirsutum* (Willd.: Fr.) Gray; *S. subtomentosus* Pouzar

Dacrymycetes

Dacrymycetales

Dacrymycetaceae: *Calocera cornea* (Batsch.: Fr.) Fr.

Tremellomycetes

Tremellales

Tremellaceae: *Tremella mesenterica* Retz.: Fr.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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REVIEW ON *QUERCUS DALECHAMPII TEN.* AND *QUERCUS PETRAEA* (MATTUSCHKA) LIEBL. IN THE VEGETATION OF BULGARIA

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Abstract. *Quercus dalechampii* Ten. and *Quercus petraea* (Mattuschka) Liebl. have close taxonomical features, ecological requirements and phytocenological characteristics. *Quercus dalechampii* is wide spread in Bulgarian mountains up to 1500 m a.s.l. *Q. petraea* does not make communities, but takes part in the communities of *Q. dalechampii* as single individuals. The aim of this review is to show taxonomical differences and some ecological and phytocenological characteristics of these two similar species.

Key words: *Quercus dalechampii, Quercus petraea,* oak forest, Bulgaria

The oak forests are widely presented in the vegetation of Bulgaria. In 1990, they covered 31,4% of the forest area (Radenski 1999). They are distributed on fore balkan and mountain belt from 300 to 1500 m a.s.l. in xerophytous, xeromesophytous and mesophytous habitats. The native oak species in Bulgarian

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vascular flora are: *Qurecus dalechampii* Ten., *Q. cerris* L., *Q. frainetto* Ten., *Q. petraea* (Mattuschka) Liebl., *Q. robur* L., *Q. hartwsisana* Stev., *Q. pedunculiflora* C. Koch, *Q. polycarpa* Schur, *Q. virgiliana* Ten., *Q. pubescens* Willd., *Q. mestensis* Bond. et Gančev, *Q. thracica* Stef. et Nedjalkov, *Q. trojana* Webb., *Q. cocifera* L. (Jordanov 1966; Assyov & Petrova 2012). *Q. dalechampii* and *Q. petraea* are often reported in a common group.

The detailed classification of oak forests in Bulgaria was made by Penev et al. (1969) and Popov (2002). *Quercus dalechampii* Mill (Balkan durmast) communities are an element of xeromesophytic microthermic forest vegetation (Bondev 1991). The wood floor is pure or mixed, often with different participation of *Carpinus betulus* L., *Carpinus orientalis* Mill., *Fagus sylvatica* L., *Acer platanoides* L., *Quercus polycarpa*, *Acer campestre* L., *Fraxinus ornus* L. The species that often predominate in the undergrowth and lower floors are: *Poa nemoralis* L., *Geum urbanum* L., *Helleborus odorus* Waldst. et Kit., *Dicranum scoparium* Hedw., *Pleurozium schreberi* (Brid.) Mitt., *Hypnum cupressiforme* Hedw. and others. In the biological spectrum the hemicryptophytes (over 50%) have the highest participation, followed by cryptophytes (over 10%). The phanerophytes are also represented by over 10% (*e.g.* Djankova et al. 2003; Pachedgjieva et al. 2004; Lyubenova et al. 2009; Gogushev et al. 2009).

A large number of associations with the participation of *Quercus petraea* (sessile oak, durmast) have been described in Bulgaria by applying the dominant method (Apostolova et al. 1997), where the species is dominant, subdominant or only participate. According to the floristic approach of Braun-Blanquet sessile oak forests are included in the alliance *Quercion petraeae* Zólyomi et Jakucs in Soó 1963 – thermophilic oak forests on acidic rock underground rock (Rodwell et al. 2002). Comparative analysis on the state of sessile oak forests in Europe is published by Lyubenova et al. (2015).

The forests of *Quercus dalechampii*, described in Bulgaria or its nearby areas by different authors are assigned to different classification schemes (*e.g.* Horvat et al. 1974; Bergmeier & Dimopoulos 2008; Gogushev 2009; Lyubenova et al. 2011; Assenov et al. 2013). They are classified in the class *Querco-Fagetea*, order *Fagetalia sylvaticae* and alliances *Fagion* and *Carpinion betuli*. The communities from ass. *Carpino-Fagetum* and *Galio-Carpinetum betuli* are grouped in ass. *Aegopodium podagraria-Carpinus betulus* (Dimitrov 2015). Gogushev (2009) classified *Quercus petraea* communities in the association *Genisto carinalis–Quercetum petraeae* Bergmeier in Bergmeier et Dimopoulos 2008. Pachedjieva (2011) assigned the sessile oak forests in the reserve “Kamenshtitsa” to the class *Quercetea pubescentis* (Oberd. 1948) Doing Kraft 1955, order *Quercetalia pubescenti-petreae* Klika, alliance *Quercion petraeae* Zólyomi et Jakucs in Soó 1963 (xeromesophytic forests of durmast) and the association *Genisto carinalis – Quercetum petraeae* Bergmeier in Bergmeier et Dimopoulos 2008.

Although *Q. petraea and Q. dalechampii* are widely known as similar species, it is to outlined that there are clear diagnostic features, which allow differentiation between the both oaks. They concern the leaves, fruits, flowers and species height.

Quercus dalechampii is smaller than *Q. petraea*. The height is up to 30 m. The leaves are smaller (to 15 cm in length and 5 cm in width), widest below the center or in the center. The leaves are situated uniformly on the branches, not only on the ends. The leaves are more chopped, on the upper side is nude and dark green, on the down side – downy with small cluster hairs. The nerves are 5–9, not parallel. The axes of male catkin have hairs. The male flowers have 6 parts perianth. The anthers are large with short stamen handles. The cupola is larger with knots on the flakes.

Quercus petraea is higher than *Q. dalechampii*. The height is more than 30 m. The leaves are bigger (to 16 cm in length and 10 cm in width), widest above the center or in the center. Weakly chopped, situated on the ends of branches, on the upper side are green, on the down side – light with short hairs. The nerves are 6–9 (11) couples. The axes of male catkin are naked or have rare hairs. The male flowers have 6–8 parts perianth. The anthers are smaller than stamen handles. The cupola is smaller without knots on the flakes (Jordanov 1966).

According to the literature available, the both oak species have similar ecological requirements. *Q. petraea* grows on colluvial, fresh, shallow soils, on limestone or silicate terrains, on dry and rich grey forest and cinnamon soils, or also on degraded soils (Kavrakova et al. 2009). *Q. dalechampii* grows on neutral to weakly acid, rarely carbonate soils, which are rich and moist to fresh. These soils acc. to Ninov (2002) are cinnamon forest (*Chromic Cambisols*), grey forest (*Luvisols*) and brown forest (*Cambisols*).

The geographical range of *Quercus petraea* is broad – it covers the areas of Europe, Anatolia, Transcaucasia (Tutin et al. 1964; Jordanov 1966; European forest genetic resources programme). The species is an European floristic element (Eur; Assyov & Petrova 2012) – **Fig. 1**. The communities of *Quercus dalechampii* have more limited distribution – they cover the areas of Southeastern Europe, Southeastern Austria, Italy, Siculy (Tutin et al. 1964; Jordanov 1966; European forest genetic resources programme). The species is a Submediterranean floristic element (subMed; Assyov & Petrova 2012) – **Fig. 2**.

In Bulgaria *Quercus dalechampii* is wide spread in the mountains up to 1500 m a.s.l. (Jordanov 1966) and covers large areas (450 000 ha) in the following mountains: Rodopi, Stara Planina, Sredna Gora, Osogovska Planina, Vlahina, Maleshevska Planina and Ograzhden. The participation of *Quercus petraea* in communities increases mainly on northern exposed weter terrains and with the increase of the altitude and on different inclinations. The forests of *Quercus dalechampii* are a part of mesophytous microtermal broadleaf native forest vegetation in Bulgaria. They form the hornbeam-durmast forest belt that sometimes enters in the beech belt. The monodominant forest with good developed spring sinusia prevail. On the lower mountain regions and in North-eastern Bulgaria *Quercus dalechampii* forms mixed forest with *Carpinus betulus*, and *Tilia* sp.; in Western Bulgaria – with

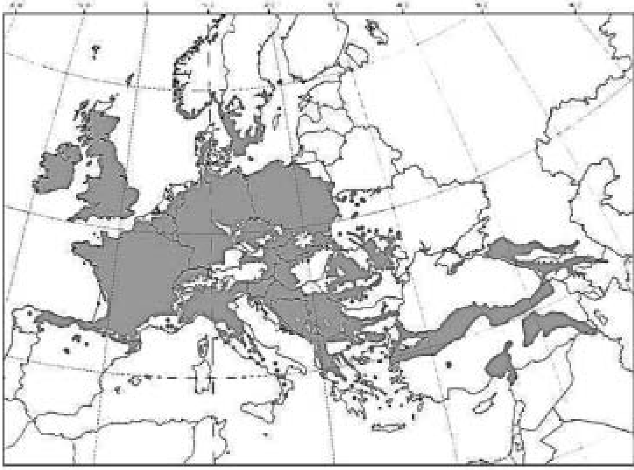

Fig. 1. Distribution of *Quercus petraea* (retrieved from http://www.euforgen.org/distribution-maps)

Fig. 2. Distribution of *Quercus dalechampii* (retrieved from http://www.euforgen.org/distribution-maps)

Q. frainetto Ten., and in Danube plain – with *Q. cerris* L. The accompaning species in durmast forest are *Carpinus orientalis*, *Crataegus monogina* Jacq., *Cornus mas* L., *Fraxinus excelsior* L., *Acer campestre*, *A. platanoides* and others (Lyubenova 2004).

In Western and Eastern Sredna Gora and Vitosha region on the upper border of the durmast belt *Quercus petraea* appears as single individuals, mixed with *Fagus sylvatica* (Jordanov 1966). In North Bulgaria it is spread in the Danube Plain (Assyov & Petrova 2012) and in Dobrudzha (Kavrakova et al. 2009).

According to Bondev (1991) *Quercus dalechampii* takes parts in the following native vegetation in Bulgaria:

Mesophytous and xeromesophytous microtermal vegetation in the coniferous forest belt:

20. Mixed silver pine (*Pinus silvestris* L.) and Balcanic durmast (*Quercus* *daleshampii* Ten.) forests

Mesophytous and xeromesophytous microtermal vegetation in the hornbeam-durmast forest belt:

51. Mixed Mizian beech (*Fagus sylvatica* L. ssp. *moesiaca* (K. Maly) Hyelmq); Balkanic durmast (*Ouercus daleshampii* Ten.*)*, mountain ashtree (*Fraxinos excelsior* L.), sycamore (*Acer pseudoplatanus* L.), Hyrcanum maple (*Acer hyrcanum* Fischh et Mey.), *etc.* forests

56. Hornbeam-Balkanic durmast forests (*Querceto-Carpineta betuli*) (over 600 m. a.s.l.)

57. Mixed ordinary hornbeam (*Carpinus betulus* L.) and cerris oak forests (*Quercus cerris*) partly with Balkanic durmast (*Quercus dalechampii*), maple (*Acer campestre* L.), *etc.*

58. Balkanic durmast forests (*Quercus dalechampii*)

59. Mixed Balkanic durmast (*Quercus dalechampii*) and aquatic hornbeam forest (*Ostrya carpinifolia* Scop.) partly with mountain ashtree (*Fraxinus excelsior* L.), flowering-ash (*Fr. ornus* L.), Oriental hornbeam (*Carpinus orientalis* L.), *etc.*

60. Mixed Balkanic durmast (*Quercus dalechampii* Ten.) cerris oak (*Quercus ceriis*) and *Quercus frainetto* Ten. forests

61. Mixed Balkanic durmast (*Quercus dalechampii* Ten.) and *Quercus frainettto* Ten. forests

62. Mixed Balkanic durmast (*Quercus dalechampii* Ten.) and Oriental hornbeam (*Carpinus orietalis* Mill.) forests, partly of secondary origin

63. Mountain ash-tree forests (*Fraxinos excelsior* L.) often mixed with Balkanic durmast (*Quercus dalechampii* Ten.)*, cerris oak* (*Quercus cerris* L.), flowering-ash (*Fraxinus ornus* L.), *etc*.

66. Mixed Black pine (*Pinus nigra* Arn.*)* and Balcanic durmast (*Quercus dalechampii* Ten.) forests

69. Mixed silverleaf lime (*Tilia tomentosa* Moench.), ordinary hornbeam (*Carpinus betulus* L.) or cerris oak (*Quercus cerris* L.) forests, partly also with Balkanic durmast (*Quercus dalechampii* Ten.), field maple (*Acer campestre* L.), *etc.*

According to the European University Information Systems organisation (EUNIS) *Q. petraea* and *Q. dalechampii* are classified in the following habitats:

G1.7641 Helleno-Moesian *Quercus petraea* forests,

G1.763 Helleno-Moesian *Quercus dalechampii* forests,

G1.76821 Central Moesian oriental hornbeam (*Quercus dalechampii*) forests

According to Gogushev (2009) the diagnostic species for the *Quercus dalechampii* communities are: *Quercus dalechampii* Ten., *Mycelis muralis* (L.) Dumort., *Lapsana communis* L., *Campanula trachelium* L., *Scutellaria columnae* Al., *Silene vulgaris* (Moench) Garcke, *Lathyrus vernus* Bernh., *Genista carinalis* Griseb. and *Galium pseudoaristatum* Schur. The diagnostic species for the communities, in which takes part *Quercus petraea,* are: *Quercus dalechampii* Ten., *Fagus sylvatica, Hypericum perforatum* L.*, Euphorbia amygdaloides* L,. *Genista* *carinalis* Griseb., *Fragaria vesca* L., *Poa nemoralis* and *Asplenium adianthum-nigrum* L. The constant species for the group of durmast coenoses are: *Quercus dalechampii, Poa nemoralis, Potentilla micrantha* Ramond ex DC*, Veronica chamaedrys* L.*, Fragaria vesca* L., *Galium pseudaristatum* Schur.*, Fagus sylvatica, Cystopteris fragilis* (L.) Bernh., *Hypericum perforatum* L. (Pachedjieva 2011).

According to the Directive 92/43/EEC *Quercus petraea* agg. (incl. *Q. daleschampii*) are classified into the following habitats:

91G0 Pannonic woods with *Quercus petraea* and *Carpinus betulus*

91I0–Euro-Siberian steppic woods with Quercus spp.

91M0–Pannonian-Balkanic turkey oak-sessile oak forests

9170 Galio-Carpinetum oak-hornbeam forests (Kavrakova et al. 2009).

The habitat of *Quercus dalechampii* have a conservation status, protected by the Bulgarian Biodiviresity Act and Counsil Directive 92/43 EC and is included in the Red Data Book of Bulgarian Natural Habitats as Mountain forests of *Carpinus betulus* and *Quercus dalechampii* with Code 27G1 and Near Threatened conservation status (Dimitrov 2015a). *Quercus petraea* also takes part in a habitat which has a conservation value: Lowland mesophilic oak and hornbeam forests. The habitat is protected by the Bulgarian Biodiviresity Act, Counsil Directive 92/43 EC and Bern Convention and is included in the Red Data Book of Bulgarian Natural Habitats with code 26G1 and Near Threatened conservation status (Dimitrov 2015b).

Two species are well known to have economic significance and are anthropogenically affected. Durmast was used for furniture manufacturing, and a flour for the birds can be made from its acorns. The leaves are used for forage and pasture (in mountains Ograzhden and Maleshevska Planina). Due to the clear felling much of the forests have offshoot origin (as it is well exemplified on the mountain Vlahina). Durmast forests are situated far away from the towns and therefore a part of them has comparatively preserved structure and natural restoration process takes part there (Lyubenova 2004).

In conclusion, it could be summarised that: 1) The both discussed oak species differ well by diagnostic features; 2) In Central Europe, the communities are dominated by *Quercus petraea* (Matt.) Liebl. (European floristic element) while in Bulgaria, Greece and Macedonia the communities are dominated by *Quercus dalechampii* Ten. (sub-Mediterranean floristic element); 3) The communities of *Quercus dalechampii* need more syntaxonomical investigations in Bulgaria and therefore a conduction of such targeted research will help to fill the lack of sufficient information on this topic.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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CORRIGENDA

to volume 99 of the Annual of Sofia University, Faculty of Biology, Book-2 Botany:

1. The sentence on p. 27 „Recently, diatoms from Bulgarian high altitude lakes have been investigated (Ognjanova-Rumenova 2012; Ognjanova-Rumenova et al. 2006, 2009, 2011; Ognjanova-Rumenova 2012)" has to be read as „Recently, diatoms from Bulgarian high altitude lakes have been investigated (Ognjanova-Rumenova 2012; Ognjanova-Rumenova et al. 2006, 2009, 2011; Ognjanova-Rumenova 2012; Wojtal et al. 2014)".

2. The following references are missing on p. 46:

Ognjanova-Rumenova N. 2012. Diversity, distribution and ecology of diatoms from nine high mountain lakes, Rila National Park (Bulgaria). – In: Proceedings of International Conference Ecology, Interdisciplinary Science and Practice, I: 80-88.

Ognjanova-Rumenova N. G, Vidinova Y. N. & Botev I. S. 2006. Abundance and species composition of diatoms and invertebrates in the Sedemte Ezera Cirque, Rila Mts (Southwest Bulgaria). – Phytol. Balcan. 12 (1): 25-36.

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Text, references, tables and figure captions should be submitted as .doc/docx (Times New Roman 12). In case of tables, when necessary, the font size could be smaller. Figures should be provided in .tif or .jpg format (min 300 dpi required). Details on their formatting and presentation are described in the end of the instructions.

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In preparing the manuscripts, the authors are kindly requested to adhere to the following instructions:

As a rule, the contributions should not exceed 16 printed pages. If a paper exceeds this limit, the authors are requested to obtain the editors' consent in advance. The text must be accurate and the language correct.

The title of the paper must be concise, but informative, describing the matter of the contribution as well as possible. The authors' given names must be spelled in full, while a middle name should be abbreviated. The authors' address(es) should be stated on the first page of the paper below the title and could be followed by e-mail addresses (the last is optional). In case of authors from different affiliations, a number (superscript) should be put in the end of the authors name and the same number with a normal font size should be placed before the address. The email and adress of the corresponding author should be indicated as a footnote on the first page (corresponding author: ....).

The proper paper text must be preceeded by an English summary **(„Abstract“)**, which should express the important new results precisely and should be limited to 300 words. Subsequently up to 6 **key words** (or key word combinations) are to be listed (in alphabetical order). The key words should not repeat those, which already are mentioned in the title.

The disposition of the paper sections should be in agreement with common use. The „**Introduction**“ should explain the purpose of the work and its relations to other studies in this field. Before the material and method description, optionally, due to author‘ decission, a chapter **„Studied site/s“** could be included. Descriptions of materials and methods should provide sufficient information to permit repetition of the experimental work. The origin of the material investigated, methods of preparation and the herbaria in which the vouchers are deposited, should be indicated completely. SI-units are requested. The geographic names should be transliterated from the common geographic names used in the certain country (e.g., Rodopi Mts instead of Rhodopes). Not commonly used abbreviations should be explained at the end of the chapter „**Material and methods**“. The „**Results**“ preferably have to be separated from the „**Discussion**“. The discussion should deal with the interpretation of the results, not only recapitulate them.

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The scientific names of the taxa (genera, species and lower ones) must be quoted completely, denominating the name of the genus, species epitheton (if necessary subspecies, cultivar etc.) and the author, when mentioned for the first time in the text. Full scientific names, as a rule, should be mentioned in the summary also. The author names in the scientific names should not be formatted. The classification system used is up to the authors, but in case of different from commonly approached, should be properly indicated.

The **Acknowledgments** may be inserted at the end of the text, before the literature references. Their correctness and ethics are total responsibility of the authors.

References to the works cited are given **in the text** by the name of the author and the year of publication, *e.g.*, Ivanov 1971, or (Ivanov 1971) and Ivanov & Petrov 1942 or (Ivanov & Petrov 1942), respectively. When more authors have to be cited semicolons between them should be used and works should be listed in chronological (not in alphabetical!) order, *e.g.* (Ivanov & Petrov 1942; Ivanov 1971; Babov 1987). In case of unchanged citation certain pages of a paper referenced should be indicated as follows: Ivanov 2013: 149–151, or Ivanov & Petrov 2013: 169. The abbreviated citation "et al." should be used in the text only in cases where three and more authors are involved, *e.g.* Ivanov et al. 1971, or Ivanov et al. (1971). In case of editor/ editors, they have to be indicated only in the reference list, but not in the text of the paper (*e.g.* Petrov 2013 in the text and Petrov I. (ed.) 2013....in the references). **References** to the cited works (and only those) are to be arranged alphabetically **at the end of the paper**, the papers of the same author(s) should be listed in chronological order and according to the number of co-authors. The well-known journals should be enlisted with their common abbreviations; the other journals should be written in full titles. The form of citations should conform to general use, as the following examples, organized for one, two and three or more authors (please note that after a punctuation mark an interval should be used):

Journals:

Ivanov I. P. 2013. Photosynthetic CO^2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

Ivanov I. P. & Petrov P. I. 2013. Photosynthetic CO^2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

Ivanov I. P., Petrov P. I. & Dimitrov V. N. 2013. Photosynthetic CO^2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

Books:

Petrov F. 2000. Grazing in water ecosystems. – In: Ivanov W., Stoyanov H. & Petrov F. (eds), Water ecosystems, Elsevier, New York, 59–105.

When the cited paper/chapter occupies only one page, it should be written as follows:

Petrov F. 2000. Lakes. – In: Ivanov W., Stoyanov H. & Petrov F. (eds), Water ecosystems, Elsevier, New York, p. 49.

For a book the citation is as follows:

Ivanov W., Stoyanov H. & Petrov F. 2000. Water ecosystems. Elsevier, New York, 265 pp.

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References to manuscripts in preparation and personal communications should not be included in the reference list, except for extremely significant data.

Electronic publications should be cited with their full web address, preferably with the last date of retrievement.

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Journal:

Petkoff S. 1925. La flore algologique du mont Pirin-planina.- Sbornik na Bulgarskata Akademiya na Naukite 20: 1–128 (In Bulgarian, French summ.).

Book:

Vodenicharov D., Draganov S. J. & Temniskova D. 1971. Flora of Bulgaria. Algae. Izd. Narodna Prosveta, Sofia, 642 pp. (In Bulgarian).

In case of other slavic languages, double titles could be provided (optional):

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tous green algae (Ulotrichineae, Ulotrichales, Chlorophyceae)].- Bull. Slov. Bot. Spol., Bratislava, Suppl. 1: 1–77 (in Slovakian).

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