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Checklist of freshwater red algae (Rhodophyta) in Bosnia and Herzegovina

by

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Abstract

The paper provides an overview of all freshwater red algae species recorded to date in the territory of Bosnia and Herzegovina. Based on fieldwork and analysis of all available previously published data, it was determined that a total of 15 taxa from eight genera have been recorded to date: *Bangia* (1), *Audoinella* (3), *Batrachospermum* (2), *Peludicola* (1), *Shaethia* (1), *Lemanea* (4), *Paralemanea* (2) and *Hildenbrandia* (1). All taxa were found in clear, cold, well-oxygenated water. Bosnia and Herzegovina is very rich in different types of aquatic habitats. More than 100 sites were visited during the field research, but there are still many potential habitats where freshwater red algae can be found, which will be explored in the coming years. This work is the first step toward establishing long-term monitoring and listing of protected and threatened red algae in Bosnia and Herzegovina.

Key words: algae, checklist, conservation, diversity, Rhodophyta, taxonomy

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1. Introduction

Most members of Rhodophyta are marine seaweeds, but there is a substantial number of taxa that inhabit freshwater and terrestrial environments (Kumano 2002). Freshwater algae account for approximately 3–5% of the estimated > 7000 species within the Rhodophyta lineage (Vis & Necchi 2021). They occur primarily in the headwaters of rivers and streams where the riverbed is shallow and has a hard substrate such as rocks or boulders, and in slow- to fast-flowing streams or rivers with low to high conductivity (Necchi et al. 1993; Necchi 2016). There are also taxa of red algae that occur in inland habitats such as lakes, waterfalls, ponds and less typical habitats such as hot springs, as well as their forms that grow in endolithic and aerophytic habitats (Vis & Necchi 2021). Despite the importance of this group in water ecosystems, studies of the taxonomy and ecology of freshwater red algae are rather sparse compared to those of other algal groups (Kwadrans & Eloranta 2010).

About 60 species of freshwater algae have been recorded in Europe, and many countries have their own lists, e.g. Austria (23 taxa), Belgium (22), Croatia (18), Hungary (9), Poland (22), Slovakia (15), Switzerland (12), Spain (20). More than a third (24 taxa) of the European taxa were found at only one or very few sites. Most taxa occur in running waters, but some also occur in lakes, on wet substrates, in hot springs, or in garden ponds (Kwadrans & Eloranta 2010). Some Southeastern European countries have their own lists of freshwater red algae, e.g. Bulgaria (Temniskova et al. 2008), Croatia (Koletić et al. 2020), Romania (Cărăuş 2002; 2012; 2017), Serbia (Cvijan et al. 2003).

Considering the diversity of water bodies and moist habitats in Bosnia and Herzegovina, the number of documented cyanobacteria and algae species is quite low, indicating insufficient exploration of these territories. The first data on algae in Bosnia and Herzegovina come from the work of Kummer and Sendtner (1849), who found two species of macroalgae: *Cladophora glomerata* (Linnaeus) Kützing in the Trstionica River near Kakanj and *Chara gymnophylla* (A.Braun) A.Braun in the Stavnja River near Podlugovi (Gligić 1955; Mašić 2020).

The first data on the diversity of freshwater red algae in Bosnia and Herzegovina were provided by Protić (1901).

The present study combines information from the literature and on newly collected specimens to provide an up-to-date assessment of freshwater red algae diversity in the territory of Bosnia and Herzegovina. Information is also provided on the basic physical and chemical parameters of the water in which freshwater red algae were found, as well as on the characteristics of taxa that are new to the algal flora of Bosnia and Herzegovina.

2. Materials and methods

2.1. Study area

Bosnia and Herzegovina is located in Southeastern Europe, in the western part of the Balkan Peninsula, between 42˚26′ and 45˚15′N and 15˚45′ and 19˚41′E. It belongs to the western part of Southeastern Europe, where the impacts of the southern part of the northern subtropical belt and the northern part of the northern subtropical zone alternate. The total area of the country is 51209.2 km^2. The relief of Bosnia and Herzegovina is very diverse, both in terms of appearance and age, and in the way it was formed. Most of the country's relief consists of mountains of varying heights. The rest is flat and consists of parts of the Pannonian Plain, large basins and river valleys. The third part is a narrow strip on the Adriatic coast. The mountainous Dinaric morphostructure represents the source and catchment area from which waters, especially surface waters, flow into the Adriatic and Black Sea basins. The Black Sea basin covers approximately 70% of the total area of Bosnia and Herzegovina, while about 24% belongs to the Adriatic basin. Surface waters from the remaining 6% of the territory are lost in the water-impermeable karst area.

More than 100 sites were visited during this research. The locations where red algae were found within the territory of Bosnia and Herzegovina are marked on the map (Fig. 1). Sampling was conducted in various habitats: rivers, streams, springs, lakes, waterfalls, peatbogs, etc. (Fig. 2: A–D).

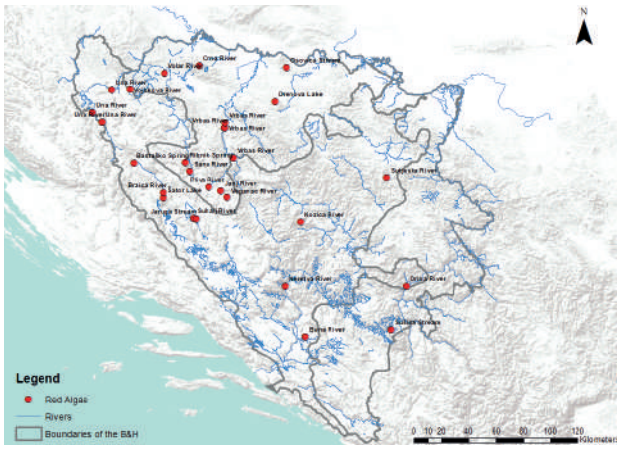

Figure 1

Map of the investigated sites in Bosnia and Herzegovina.

Journal owner: Faculty of Oceanography and Geography, University of Gdańsk, Poland

Figure 2

A) Crna River; B) Bastaško Spring; C) Vrbas River; D) Una River.

2.2. Literature data

To compile the checklist, the authors conducted a comprehensive review of all manuscripts pertaining to the distribution and ecology of freshwater red algae, starting with Protić's pioneering work. Protić's research, published in 1901, recorded the presence of the following species in the territory of Bosnia and Herzegovina: *Bangia atropurpurea*, *Audouinella chalybea*, *Audouinella pygmaea*, *Batrachospermum gelatinosum*, *Paludicola turfosa*, *Lemanea fluviatilis*, *Paralemanea torulosa*, *Hildenbrandia rivularis*. The taxonomic nomenclature has been revised, and the taxa are presented using currently accepted names.

2.3. Sample collection, algae identification and checklist preparation

Intensive fieldwork to study the red algal flora of Bosnia and Herzegovina was carried out between 2019 and 2023. A total of more than 100 sites were visited, including rivers, streams, springs and lakes, and taxa of red algae were found at a total of 26 localities. Chemical and physical parameters were measured directly in the field using WTW™ MultiLine™ 3420 Portable Digital Multiparamete. Algae were collected from various substrates (rock, stone, mud) from depths of up to 1 meter. Samples of red algae were collected by separating the talus from the rock or stone in the aquatic ecosystem using tweezers. The collected algal material was fixed with 4% formaldehyde. Some of the collected samples were herbaceous plants. All collected samples are deposited in the Herbarium of the University of Belgrade (BEO), Department of Algology, Mycology and Lichenology – algae wet collection. Morpho-anatomical identification of the collected algae was performed using a Nikon SMZ 745T stereomicroscope and a Carl Zeiss M1 light microscope with an AxioCam MRC5 camera and AxioVision 4.9 software. Photographs were taken with a Canon PowerShot g9 camera. Species identification was based on Kumano (2002), Eloranta & Kwandrans (2007), Eloranta et al. (2011), Knappe & Huth (2014) and Vis & Necchi (2021). Nomenclature follows Algae Base (Guiry & Guity 2023). Species are listed in alphabetical order, starting with the systematic class level. Locality, geographic coordinates, date of collection, and collector (leg.) / identifying (det.) author are given for taxa collected during the fieldwork. Historical records from the literature are listed with year and locality from the respective references.

3. Results

The analysis of the relevant literature published in the period from 1901 to the present, as well as the new field research on freshwater red algae in the territory of Bosnia and Herzegovina, has resulted in 15 species, which are divided into five families and eight genera.

Phylum Rhodophyta Wettstein, 1901
Class Bangiophyceae Wettstein, 1901
Order Bangiales Nägeli, 1847
Family Bangiaceae Duby, 1830
Genus Bangia Lyngbye, 1819

Bangia atropurpurea (Mertens ex Roth) C.Agardh 1824 (Figure 3: A–B)

Literature data

- Fojnica River, near Fojnica (Protić 1901)
- Vukovići Stream (Protić 1903)

- Koševo Stream, near Mošćanica village (Protić 1904)
- Neretva River (Kosorić et al. 1977; Redžić 1988)
- Vrbas River: downstream from Jajce Power Plant, near Pivalić luka and near Švrkava (Aganović 1981)
- Una River (Hafner 1991; Redžić 1991)
- Current research
- Osovica Stream, near Živanići village (45°01'59"N; 17°43'32"E); 213 m a.s.l.; 4 April 2019; leg. Fužinato I./det. Šovran S.
- Una River, near Japodski otoci (44°43´25´´N; 15°55´51´´E); 347 m a.s.l.; 16 May 2021; 6 August 2021; 22 June 2022; leg./det. Šovran S.
- Una River, near Štrbački buk (44°39'25"N; 16°01'10"E); 307 m a.s.l.; 5 August 2022; leg./det. Šovran S.
- Volar River, near Donji Volar village (44°59'15"N; 16°35'27"E); 130 m a.s.l.; 5 August 2022; leg./det. Šovran S.
- Vrbas River near Krupa na Vrbasu (44°38'00"N; 17°09'07"E); 209 m a.s.l.; 7 August 2022; leg. Šovran S./det. Knežević A.
- Vojskova River, near Arapuša village (44°52'35"N; 16°16'34"E); 245 m a.s.l.; 7 August 2022; leg./det. Šovran S.

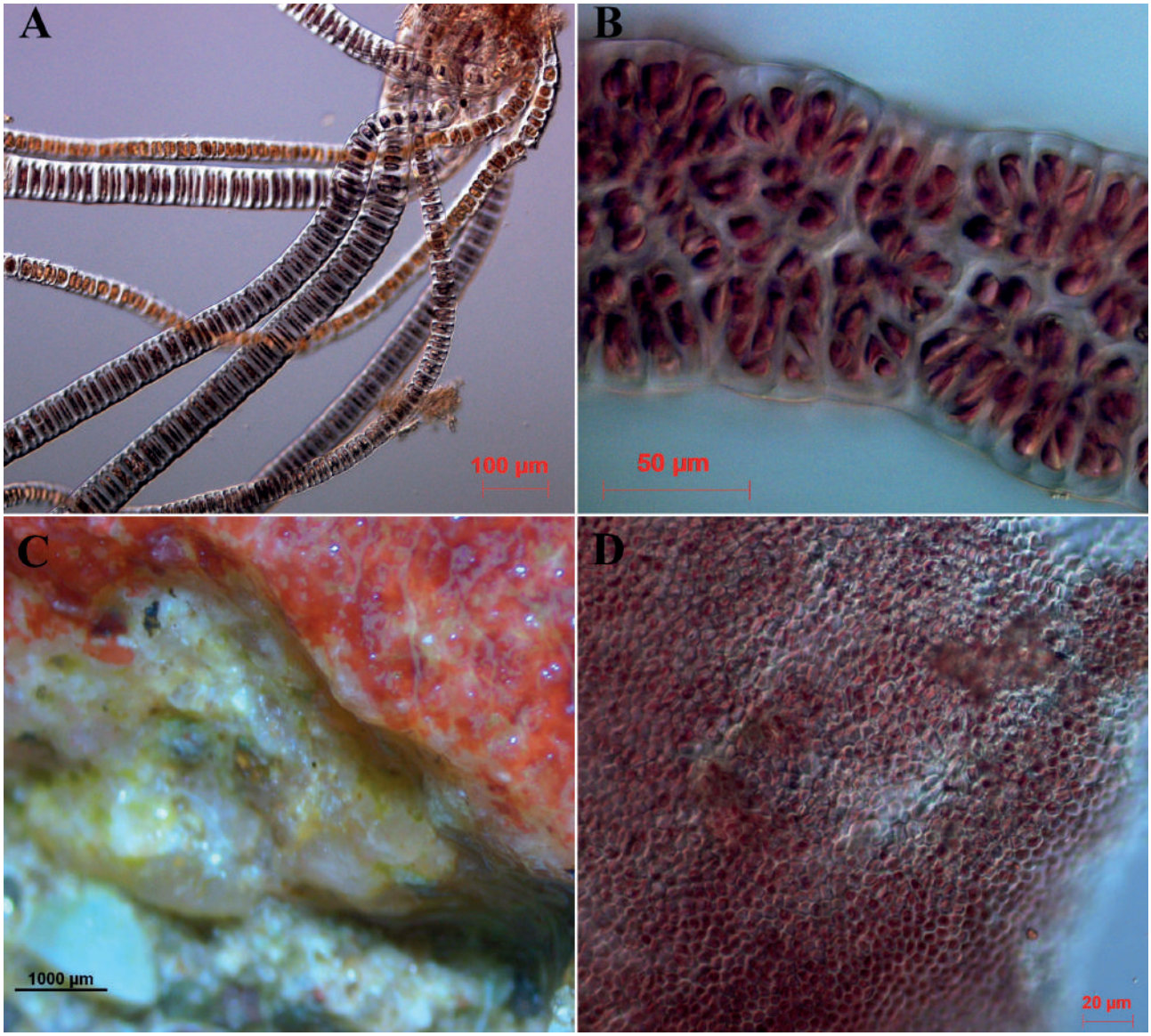

Figure 3

A) *Bangia atropurpurea* – filaments with rhizoidal part of plant; B) *Bangia atropurpurea* – multiseriate thread; C) *Hildenbrandia rivularis* – patches on the surface; D) *Hildenbrandia rivularis* – surface views of thallus.

Class Florideophyceae Cronquist, 1960
Order Acrochaetiales Feldmann, 1953
Family Acrochaetiaceae Fritsch ex W.R. Taylor, 1957
Genus Audouinella Bory, 1823, nom. cons.

Audouinella chalybea (Roth) Bory 1823 (Figure 4: A)

Literature data

- Fojnica River and Korči Stream (Protić 1901) as *Chantransia chalybaea*
- Rajkovac Stream and Bukovica Stream (Protić 1903) as *Chantransia chalybaea*
- Poriče Stream (Protić 1906) as *Chantransia chalybaea*
- Doljanka River (Protić 1908) as *Chantransia chalybaea*
- Krivaja River near Boganovići, near Careva ćuprija and near Vozuća (Blagojević & Hafner) 1979 as *Chantransia chalybaea* var. *leibleini*
- Bosna River upstream from Zenica, downstream and upstream from Modriča, upstream from Doboj (Kaćanski 1980) as *Chantransia chalybaea*
- Vrbas River near Pivalić luka, near Bočac, near Krupa na Vrbasu, near Rekavice, near

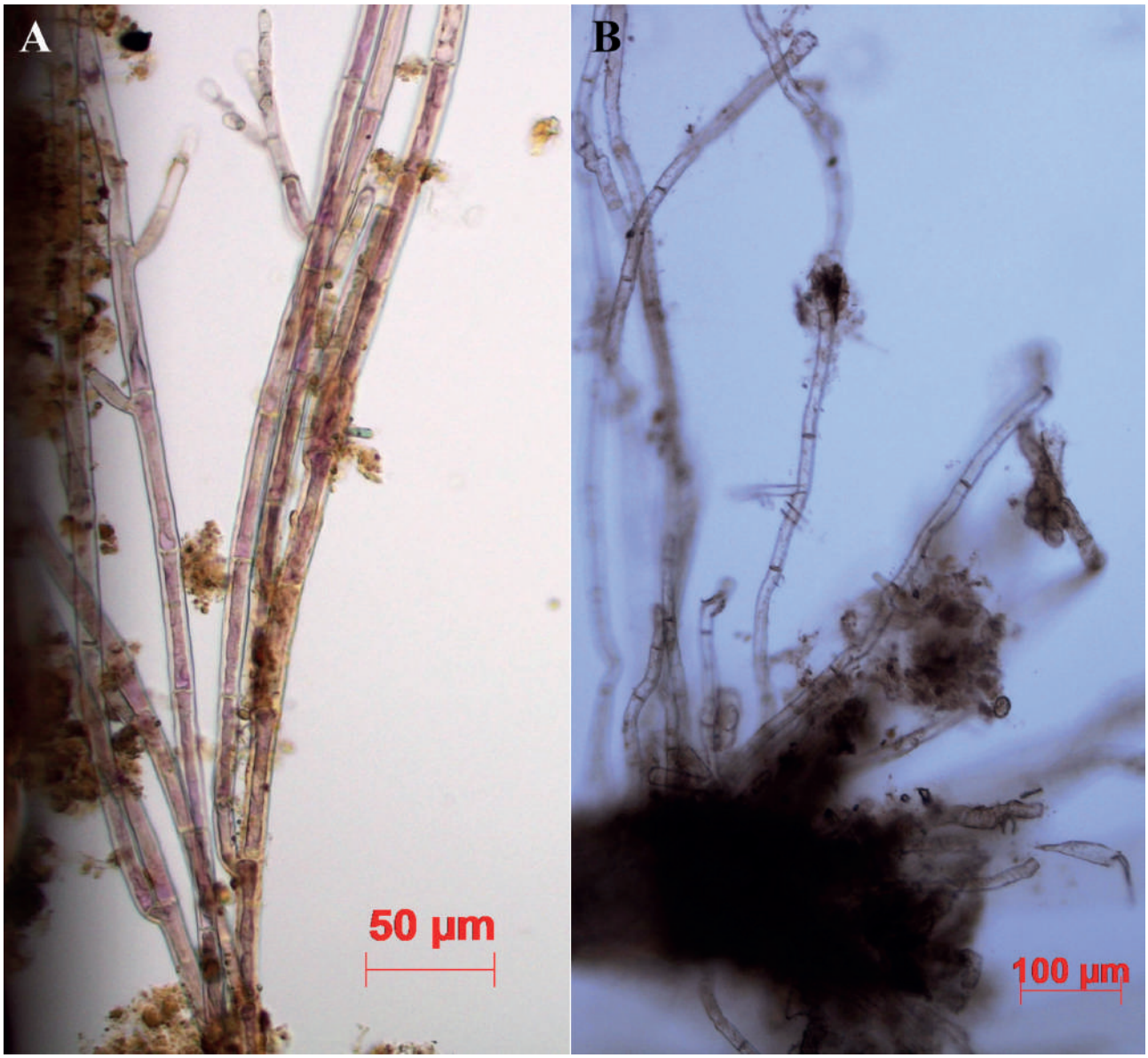

Figure 4

A) *Audoinella chalybea* B) *Audoinella hermannii.*

Karanovac (Aganović 1981), upstream from Banjaluka [28] as *Chantransia chalybaea*
- Neretva River [Kosorić 1976; Redžić 1988) as *Chantransia chalybaea*
- Una River (Hafner 1991; Redžić 1991) as *Chantransia chalybaea*

Current research

- Lake Šator (44°09´54´´N; 16°36´01´´E); 1487 m a.s.l.; 17 July 2021; leg. Kovačević B./det. Šovran S.
- Una River, near Štrbački buk (44º39'25"N; 16º01'10"E); 307 m a.s.l.; 5 August 2022; leg./ det. Šovran S.

Audouinella hermannii (Roth) Duby 1830 (Figure 4: B)

Literature data

- Stream near Vareš (Protić 1903) as *Chantransia violacea*
- Stream near Vučija luka (Protić 1904) as *Chantransia violacea*
- Krivaja River near Bioštica, near Zeleni vir, near Boganovići, near Careva ćuprija, near Vozuća and near Skroze (Blagojević & Hafner 1979) as *Chantransia violacea*
- Bosna River, upstream from Zenica, upstream from Zavidovići, upstream from Modriča, upstream from Doboj and downstream from Maglaj (Kaćanski 1980) as *Chantransia violacea*
- Vrbas River near Krupa and near Rekavice (Aganović 1981) as *Chantransia violacea*
- Vrbas River downstream from Razboj (Ratković 1985) as *Chantransia violacea*
- Una River (Redžić 1988) as *Chantransia violacea*
- Kajtaz spring (Dedić et al. 2014)

Current research

- Lake Drenova (44°48´20´´N; 17°37´03´´E); 169 m a.s.l.; 10 May 2022; leg. Fužinato I./det. Šovran S.
- Vrbas River near Krupa na Vrbasu (44º38'00"N; 17º09'07"E); 209 m a.s.l.; 7 August 2022; leg. Šovran S. / det. Knežević A.

Audouinella pygmaea (Kützing) Weber Bosse 1921

Literature data

- Korči Stream (Protić 1901) as *Chantransia pygmea*
- Stream near Vučija luka, Skakavac Stream, Koševo Stream, near Mošćanica village (Protić 1904) as *Chantransia pygmea*

Order Batrachospermales Pueschel & K.M.Cole, 1982
Family Batrachospermaceae C.Agardh, 1824
Genus Batrachospermum Roth, 1797

Batrachospermum gelatinosum (Linnaeus) De Candolle 1801 (Figure 5: A-B)

Literature data

- Stream near Tarčin and bog near Predeoci (Protić 1901) as *Batrachospermum moniliforme*
- Poriče Stream, Milacij Stream and bog near Glamoč (Protić 1906) as *Batrachospermum moniliforme*
- Lake Kukavica and stream near Buško Blato (Protić 1907) as *Batrachospermum moniliforme*
- Doljanka River, Drežanka River and Bog near Rama (Protić 1908) as *Batrachospermum moniliforme*
- Pond Velika Tišina (Protić 1928) as *Batrachospermum moniliforme*
- Buna River near its source (Kosorić 1977) as *Batrachospermum moniliforme*
- Krivaja River near Bioštica, Žeravice, Stupčanica (Kaćanski 1980) as *Batrachospermum moniliforme*
- Una River (Hafner 1991) as *Batrachospermum moniliforme*
- Kajtaz spring (Dedić et al. 2014)

Current research

- Vrbas River near Zvečajska klisura (44º40'08"N; 17º09'32"E); 205 m a.s.l.; 10 July 2021; leg. Šovran S. / det. Knežević A.
- Buna river near its source (43º15'24"N; 17º54'12"E); 99 m a.s.l.; 27 July 2021; 3 June 2022; leg. Šovran S. / det. Knežević A.
- Neretva River, upstream from Grabovica Power Plant (43º35'24"N; 17º43'14"E); 177 m a.s.l.; 3 June 2022; leg./det. Šovran S.
- Bastaško spring (44º23'29"N; 16º19'38"E); 549 m a.s.l.; 10 October 2022; leg. Šovran D. / det. Šovran S.

Batrachospermum skujae Geitler 1944 (Figure 5: C-D)

Current research

- Crna River (45º02'26"N; 16º54'38"E); 561 m a.s.l.; 27 May 2022; leg. Šovran S. / det. Knežević A.

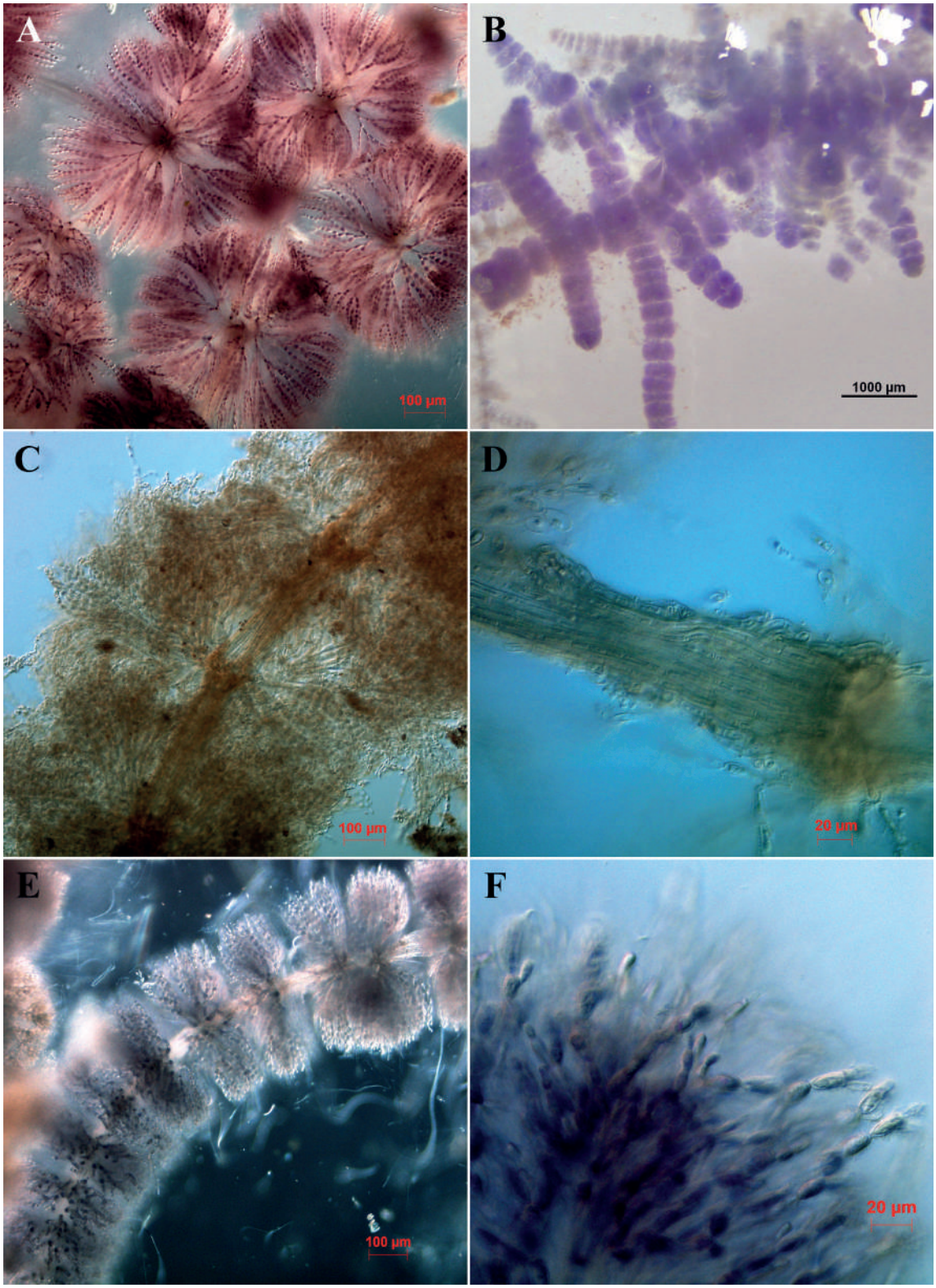

Figure 5

A and B) *Batrachospermum gelatinosum* – thallus habitus; C) *Batrachospermum skujae* - thallus habitus; D) *B. skujae* – main axis with regular cortical filaments; E) *Shaethia confusa* - thallus habitus; F) *S. confusa* – carpogonium-bearing branches.

Genus Paludicola Necchi & M.L.Vis 2020

Paludicola turfosa (Bory) M.L.Vis & Necchi 2020

Literature data

- bog between Pogari and Duboštica (Protić 1901) as *Batrachosperumum vagum*
- bog near Koševo (Protić 1904) as *Batrachosperumum vagum*
- Trebižat River (Kosorić 1977) as *Batrachosperumum vagum*
- Bioštica spring (Blagojević & Hafner 1979) as *Batrachosperumum vagum*

Genus Sheatia Salomaki & M.L.Vis 2014

Sheathia confusa (Bory) Salomaki & M.L.Vis 2014 (Figure 5: E-F)

Current research

- Janj River (44°13'07"N; 17°07'20"E); 557 m a.s.l.; 27 May 2022; leg. Šovran S. / det. Knežević A.

Family Lemaneaceae C.Agardh, 1828
Genus Lemanea Bory, 1808, nom. cons.

Lemanea fluviatilis (Linnaeus) C.Agardh 1811 (Figure 6: A-F)

Literature data

- stream near Tarčin and stream near Bugojno (Protić 1901)
- Trebižat River (Protić 1904)
- Šator stream (Protić 1901; Protić 1906)
- Doljanka River and Rama River (Protić 1908)
- Bosna River upstream from Zenica, upstream from Maglaj (Kačanski 1980)
- Vrbas River downstream from Jajce Power Plant, near Pivalić luka, near Rekavice, near Karanovac and near Švrkava (Aganović 1891)
- Una River (Redžić 1991)

Current research

- Ribnik spring (44°24'12"N; 16°47'53"E); 318 m a.s.l.; 15 May 2020; leg. Šovran S. / det. Knežević A.
- Veganac River, near Babići village (44°10'39"N; 17°11'00"E); 683 m a.s.l.; 7 July 2022; leg. Fužinato I. / det. Šovran S.
- Una River (44°52'13"N; 16°06'11"E); 170 m a.s.l.; 18 May 2021; leg./det. Šovran S.
- Sutjeska River (44°18'19"N; 18°39'03"E); 715 m a.s.l.; 18 August 2021; leg. Šovran S. / det. Knežević A.
- Sana River, upstream from Medna Power Plant (44°20'37"N; 16°50'25"E); 376 m a.s.l.; 5 September 2022; leg./det. Šovran S.

Lemanea fucina Bory 1808 (Figure 7: A–F)

Current research

- Una River, near Japodski Otoci (44°43´25´´N; 15°55´51´´E); 347 m a.s.l.; 06 August 2021; leg./ det. Šovran S. (Sabovljević et al. 2022)

Lemanea rigida (Sirodot) De Toni 1897 (Figure 8: A–F)

Current research

- Vrbas River (44°25´58´´N; 17°14´20´´E), near Vlasinje village; 416 m a.s.l.; 07 August 2021; leg./det. Šovran S. (Tomović et al. 2022)

Lemanea sudetica Kützing 1845

Literature data

- Vrbas River downstream from Jajce Power Plant (Aganović 1981)

Genus Paralemanea (P.C.Silva) M.L.Vis & Sheath, 1992

Paralemanea annulata (Kützing) M.L.Vis & Sheath (Figure 9: A-F)

Literature data

- Bregava River near Stolac (Kosorić 1977) as *Lemanea annulata*
- Buna River near spring (Kosorić 1977) as *Lemanea annulata*
- Una River (Redžić 1991) as *Lemanea annulate*

Current research

- Drina River (43°35´17´´N; 18°49´05´´E); 370 m a.s.l.; 2 August 2021; leg. Šovran D. / det. Šovran S.

Paralemanea torulosa (Roth) C. A. Agardh (Figure 10: A-F)

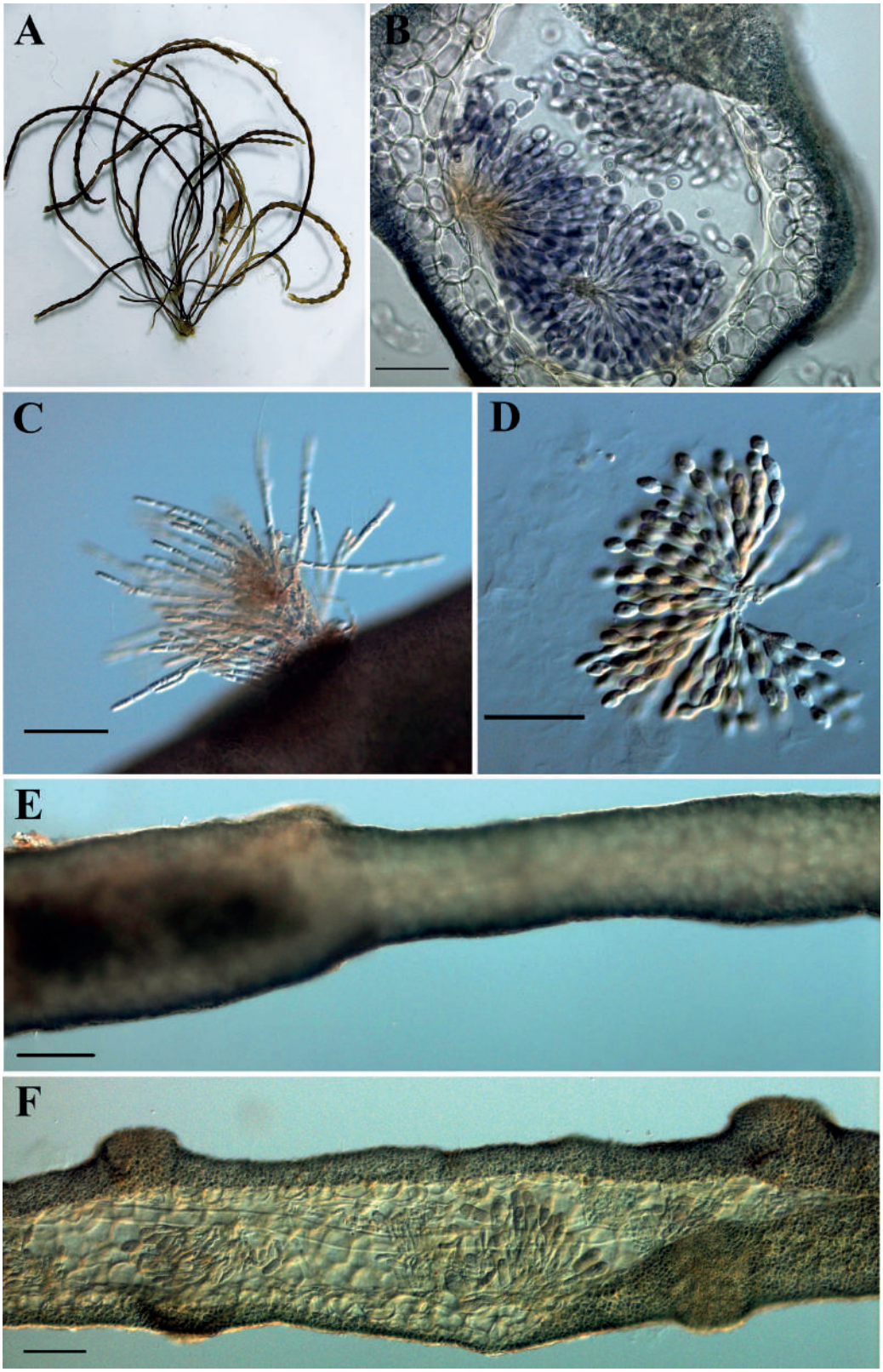

Figure 6

Lemanea fluviatilis. A) habitus of tuft; B) cross-section [scale bar-50 µm]; C) Chantransia stage [scale bar-10 µm]; D) carposporophyte [scale bar-10 µm]; E) thallus basal part [scale bar-100 µm]; F) longitudinal section [scale bar-100 µm].

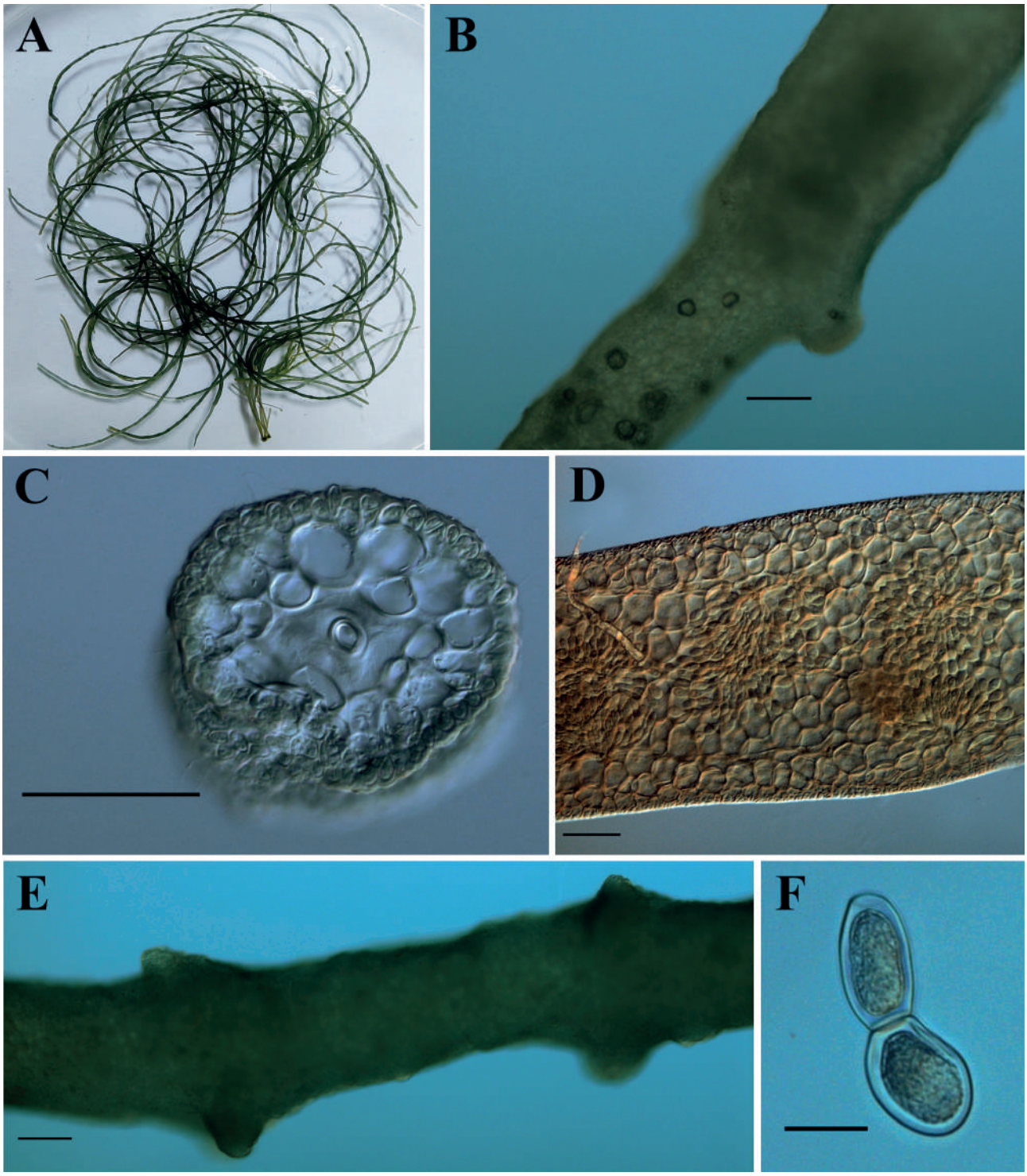

Figure 7

Lemanea fucina. A) thallus habitus; B) thallus basal part [scale bar-100 µm]; C) cross-section [scale bar-50 µm]; D) longitudinal section [scale bare-100 µm]; E) spermatangial papilae [scale bar-100 µm]; F) series of carposporangia[scale bar-10µm].

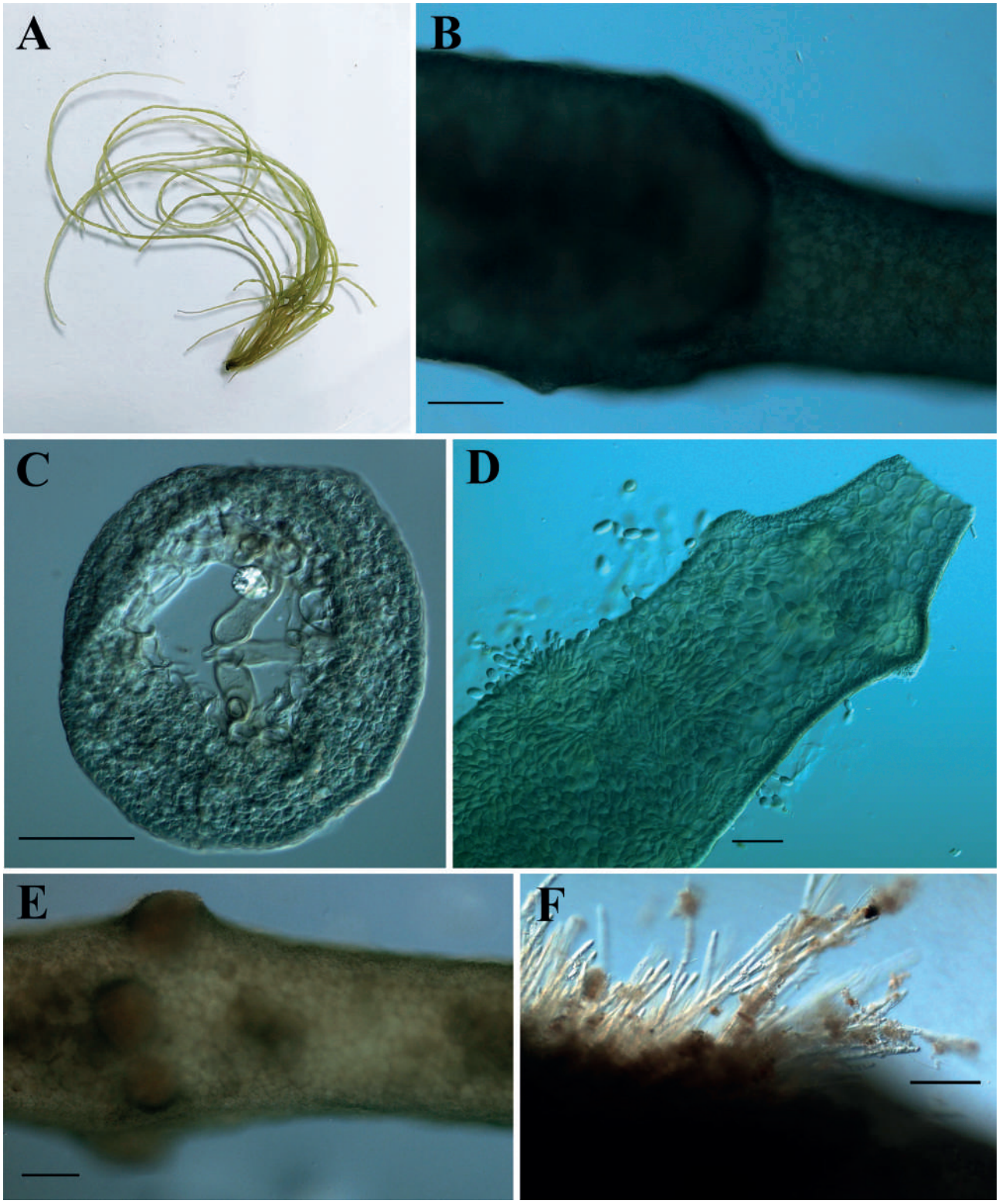

Figure 8

Lemanea rigida. A) thallus habitus; B) thallus basal part [scale bar-100 µm]; C) cros-section [scale bar-50 µm]; D) longitudinal section [scale bar-100 µm]; E) nodes [scale bar-100 µm]; F) Chantansia stage [scale bar -20 µm].

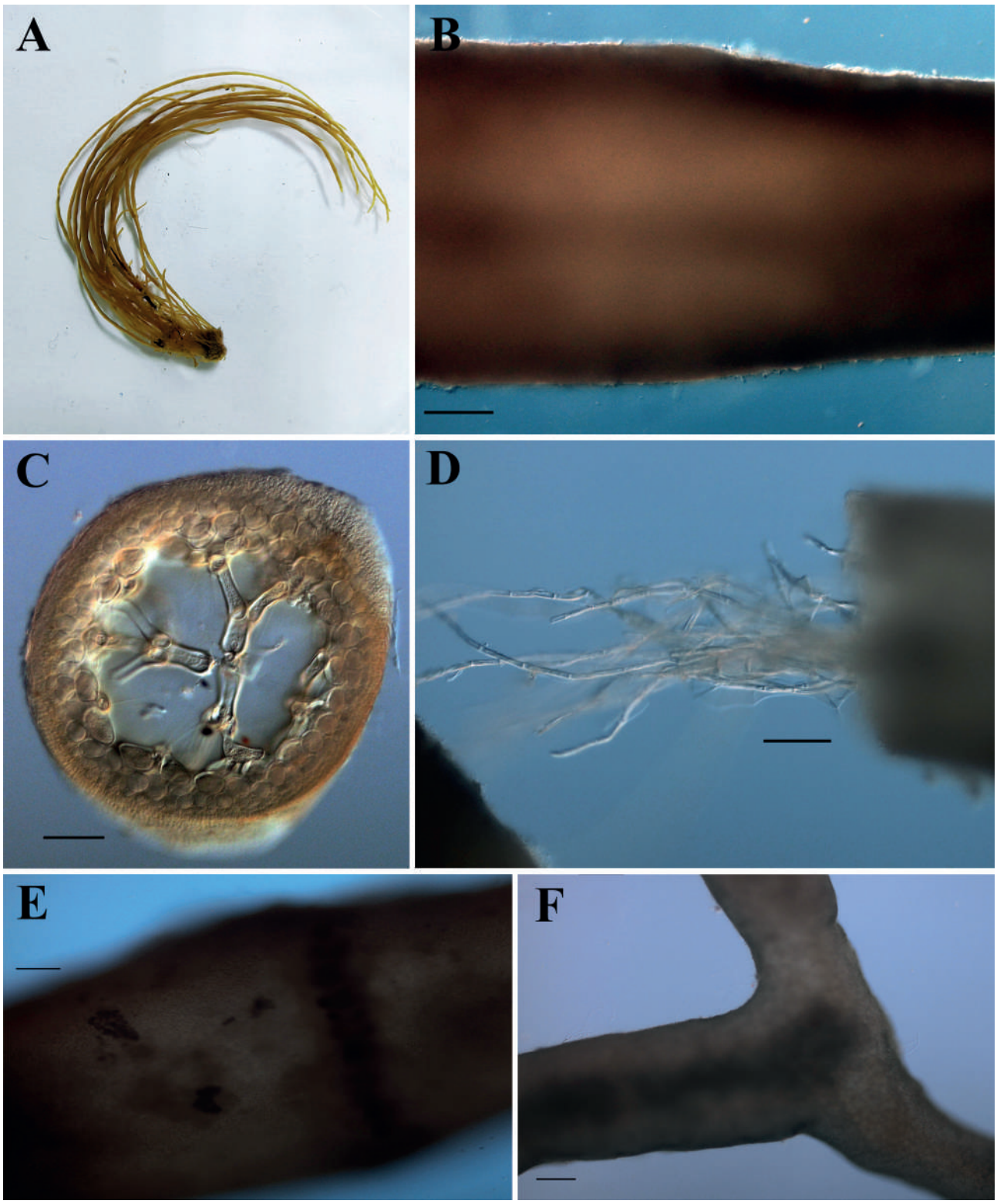

Figure 9

Paralemanea annulata. A) thallus; B) thallus basal part [scale bar-100 µm]; C) cross-section [scale bar-20 µm]; D) axial filament covered by cortical filaments [scale bar-50 µm]; E) ring scale bar-50 µm]; F) detail of branching [scale bar-200 µm].

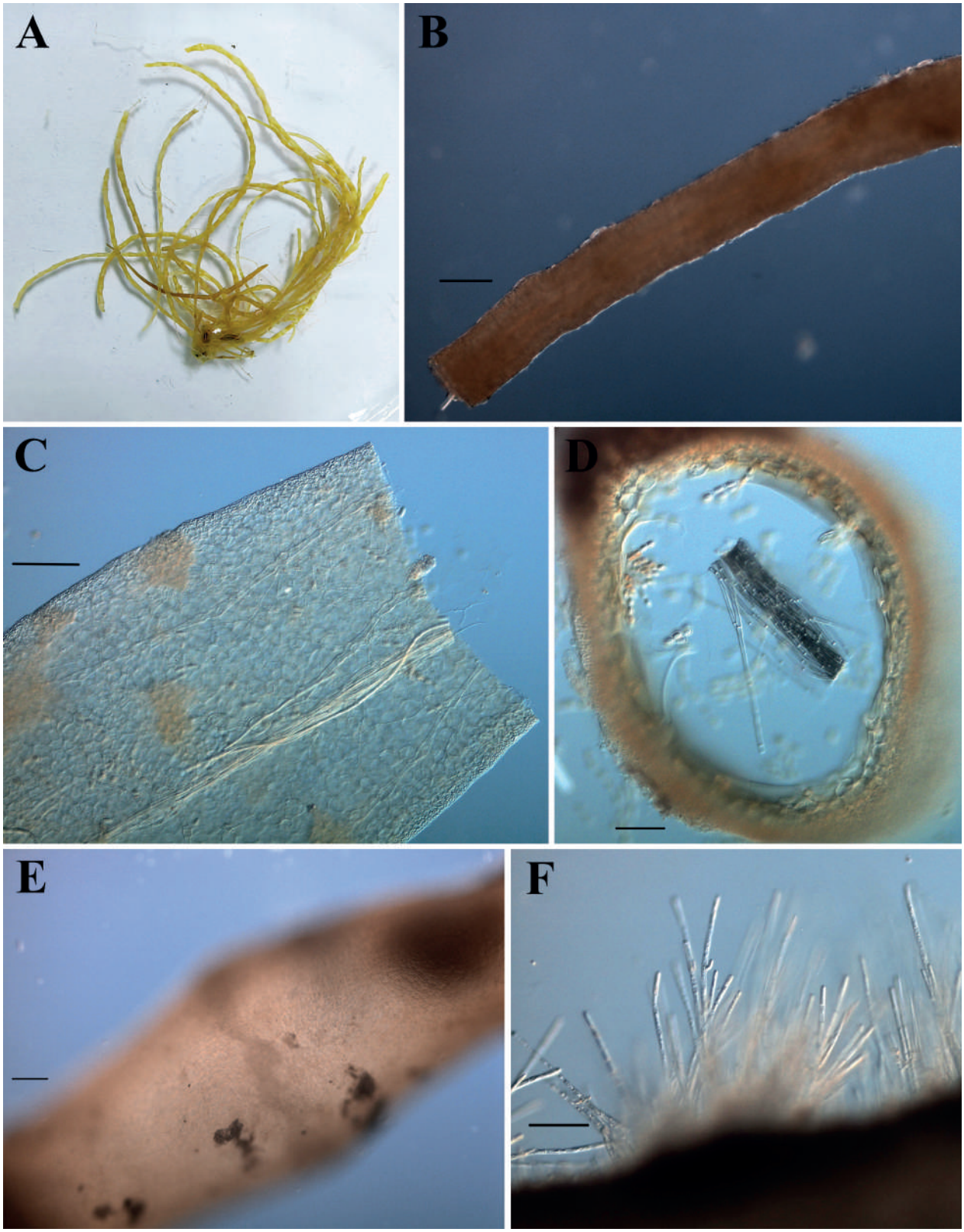

Figure 10

Paralemanea torulosa. A) thallus; B) thallus basal part [scale bar-100 µm]; C) longitudinal section [scale bar-100 µm]; D) cross-section [scale bar-50 µm]; E) ring [scale bar-50 µm]; F) Chantransia stage [scale bar-20 µm].

Literature data

- Poriče Stream (Protić 1901) as *Lemanea torulosa*
- Doljanka River (Protić 1908) as *Lemanea torulosa*

Current research

- Kozica River near Kozica waterfalls (44°00´59´´N; 17°51´35´´E); 1045 m a.s.l.; 13 July 2021; leg. Kovačević B. / det. Šovran S.
- Sušica Stream (43°18´14´´N; 18°40´39´´E); 834 m a.s.l.; 18 August 2022; leg./det. Šovran S.

Order Hildenbrandiales Pueschel & K.M.Cole, 1982
Family Hildenbrandiaceae Rabenhorst, 1868
Genus Hildenbrandia Nardo, 1834, nom. cons.

Hildenbrandia rivularis (Liebmann) J.Agardh 1851 (Fig. 3: C–D)

Literature data

- Korči stream near Tarčin village, Šator stream (Protić 1901)
- Rajčevac stream (Protić 1903)
- Skakavac stream (Protić 1904)
- stream on Šator Mt. (Protić 1906)

Current research

- Pliva River (44°14'23"N; 17°00'53"E); 508 m a.s.l.; 5 May 2021; leg. Šovran S. / det. Šovran S.
- Brzica River (44°12'00"N; 16°35'41"E); 921 m a.s.l.; 26 July 2021; leg. Kovačević B. / det. Šovran S.
- Suhalj River (44°02'12"N; 16°52'33"E); 912 m a.s.l.; 6 June 2022; leg. Fužinato I. / det. Šovran S.
- Jaruga Stream (44°01'55"N; 16°54'07"E); 894 m a.s.l.; 6 June 2022; leg. Fužinato I. / det. Šovran S.

4. Discussion

The present paper provides an overview of all freshwater red algae species recorded in the territory of Bosnia and Herzegovina. The first literature data on the distribution of Rhodophyta in Bosnia and Herzegovina date back to the beginning of the 20th century (Protić 1901), but in general there are very few publications dealing with red algae. These are mostly sporadic findings during exploration of larger rivers in the territory of B&H. Comprehensive field research was conducted between 2019 and 2023, visiting more than 100 sites and finding freshwater red algae at 26 localities. A variety of aquatic habitats (streams, rivers, lakes, waterfalls, ponds, etc.) were surveyed throughout B&H, and freshwater red algae were found primarily in clear and oxygen-rich water.

Literature data initially indicated a total of 11 species of freshwater red algae in the territory of Bosnia and Herzegovina. Through additional fieldwork, we confirmed the presence of nine previously recorded species and discovered four species new to the algal flora of Bosnia and Herzegovina. To date, a total of 15 taxa, divided into eight genera and five families, have been identified in the B&H area. Comparing the size of the area and the number of surveyed sites, the total number of freshwater red algae is significant. This number is certainly higher because morphological identification of the genus *Batrachospremum* is very difficult and requires additional molecular studies (Entwisle et al. 2009; Nan et al. 2022). Some of the collected freshwater red algae material was dry herbarized and molecular analyses will be attempted in the coming period. Some data found in the literature were reconfirmed during the fieldwork: the species *Bangia atropurpurea*, *Audoinella chalybea* and *Lemanea fluviatilis* were found again in the Una River; the species *Audoinella hermannii* was found again in the Vrbas River, and *Batrachospermum gelatinosum* was found again in the source of the Buna River. The species *Audoinella pygmea*, *Peludicola turfosa*, and *Lemanea sudetica* were not found during the field research. Only literature distribution data are available for these species. They are also not stored in the collection, so verification and revision of these data is not possible. Water pollution, construction of mini hydroelectric dams, disturbance and fragmentation of habitats dominated by freshwater red algae are just some of the possible reasons why these species no longer occur in B&H waters. Future research will certainly aim to combine classical taxonomy with molecular methods to complete the list of freshwater red algae in Bosnia and Herzegovina.

During the current field research, four species of the freshwater red algae were found that are new to the B&H algal flora. These are: *Batrachospermum skujae* (Sabovljević et al. 2023b), *Sheathia confusa* (Sabovljević et al. 2023a), *Lemanea fucina* (Sabovljević et al. 2022) and *L. rigida* (Tomović 2022).

To date, the species *Batrachospermum skujae* (Figure 5: C–D) was found in clear and fast-flowing waters in some European countries: Germany, Latvia, Spain, Finland, Portugal, Sweden (Kumano 2002; Eloranta & Kwadrans 2007; Eloranta et al. 2011; Knappe

& Huth 2014). At the time of sampling, the water of the Crna Rijeka River was neutral (7.22), well aerated (9.43) and moderately cold (14.3°C). Morphoanatomical characteristics of *B.skujae* are given in Sabovljević et al. (2023b). The species is considered rare in Europe (Kumano 2002; Eloranta et al. 2011; Knappe & Huth 2014) and is included on the Red Lists of some European countries (Siemińska et al. 2006; Forstner et al. 2018).

In May 2022, *Sheathia confusa* (Figure 5: E–F) was collected in the Janj River. At the time of sampling, the water of the Janj River was alkaline (7.88), slightly cold (13.6°C), and well aerated (10.45 O_2 mg/l). The species is mainly distributed in slow-flowing waters in Europe and North America (Eloranta et al. 2011). Morphoanatomical characteristics of *S. confuse* are given in Sabovljević et al. (2023a). The species is considered rare in Europe (Kumano 2002; Cvijan et al. 2003; Eloranta et al. 2011; John et al. 2011; Chiasson et al. 2014; Forstner et al. 2018) and is protected in some European countries, such as Bulgaria (Temniskova et al. 2008), Germany (Forstner et al. 2018) and Serbia (SGRS, 2011).

The freshwater red algae *Lemanea fucina* (Figure 7) were found at a site on the Una River as macroscopic aggregates in a weakly alkaline (8.16), moderately cold (13.5°C), well aerated (10.35 O_2 mg/l), and stony substrate. Morphoanatomical characteristics of *L. fucina* are provided in Sabovljević et al. (2022). The species *L. fucina* was recorded in North America (Vis & Sheath 1992) and some European countries (Kumano 2002; Eloranta et al. 2011; Knappe & Huth 2014). Data on the distribution of *L. fucina* in Southeastern Europe are very scarce. *L. fucina* was recorded in Croatia (Koletić et al. 2020), Montenegro (Simić & Đorđević 2011), and Serbia (Mitrović et al. 2021). These findings of *L. fucina* in Bosnia and Herzegovina are very important and contribute to the knowledge of the distribution and ecology of *Lemanea* species in the Balkan region (Sabovljević et al. 2022). The species is considered rare in Europe (Eloranta et al. 2011).

The species *Lemanea rigida* (Figure 8) was found at a site in the Vrbas River in the form of macroscopic aggregates in a weakly alkaline (7.98), moderately cold (12.8°C), well aerated (9.81 O_2 mg/l) and stony substrate. Morphoanatomical characteristics of *L. rigida* are given in Tomović et al. (2022). *Lemanea rigida* was recorded in North America (Vis & Sheath 1992) and Europe (Kumano 2002; Eloranta et al. 2011; Knappe & Huth 2014). Data on the distribution of *L. rigida* in Southeastern Europe are very scarce. It was recorded in Croatia (Koletić 2020) and Serbia (Mitrović et al. 2021).

Unfortunately, freshwater red algae in the territory of Bosnia and Herzegovina are still not protected, although they are threatened due to the increasing destruction of their habitats. This first list of freshwater red algae is the first step toward establishing continuous monitoring of this extremely important group of organisms.

5. Conclusion

This work describes the first systematic and detailed research on the freshwater red algae of Bosnia and Herzegovina. A list and database of species have been created, along with their abiotic and biotic characteristics. Since red algae are extremely rare in freshwater, it is necessary to intensify their protection in the future, mainly through fundamental research, but also by establishing permanent monitoring of the habitats where this specific and unique group of organisms occurs. A review of literature data suggests that countries in the region, as well as in other parts of Europe, have done considerable work to protect red algae (e.g. the Red List), and therefore protection of this group based on European practices should be introduced within the borders of Bosnia and Herzegovina. Freshwater red algae, along with diatoms, can be used for biomonitoring the state of freshwater ecosystems.

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