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АКАДЕМИК КИРИЛ МИЦЕВСКИ
(По повод 90-годишнината од раѓањето)

Владо Матевски

Македонска академија на науките и уметностите, 1000 Скопје, Република Македонија

Оваа година се навршија 90 години од раѓањето на академик Кирил Мицевски, долгогодишен професор на Институтот за биологија на Природно-математичкиот факултет во Скопје и основоположник на современите флористички и вегетациски истражувања на територијата на Република Македонија.

Академик Кирил Мицевски е роден во Скопје на 29 април 1926 година, каде што го завршил основното и гимназиското образование. Во 1946 година се запишал на Филозофскиот факултет во Скопје – група биологија, каде што дипломирал во јануари 1951 година, како прв дипломиран студент од неговата генерација. По дипломирањето е избран за асистент во Ботаничкиот завод по предметот Систематика и филогенија на вишите растенија. Во 1954 година оди на специјализација во Загреб, кај познатиот фитоценолог, проф. д-р Стјепан Хорватиќ, каде што ја усовршува методиката на фитоценолошките истражувања. Од таа област е и неговата докторска дисертација „Типолошки истражувања на вегетацијата на низинските ливади и блата во Македонија“, која ја одбранил во 1958 година на Филозофскиот факултет во Скопје. За доцент е избран во 1958 година, за вонреден професор во 1964 година, а за редовен професор во 1970 година. Во меѓувреме престојува три месеци во хербариумот на Природнонаучниот музеј во Виена, а потоа речиси секоја година по десетина дена, работи во овој хербариум, во врска со разрешување на некои флористичко-таксономски проблеми сврзани со флората на Македонија.

Во 1974 година е избран за дописен член на Македонската академија на науките и уметностите, а во 1979 година за редовен член. Во 1987 година е пензиониран по силата на законот за предвремено пензионирање, со наполнети 60 години. За резултатите од неговите флористички истражувања, значајни за Македонија и Балканскиот Полуостров, во 1995 година е избран за дописен член на Словенечката академија на науките и уметностите.

Во текот на својот работен век, акад. Кирил Мицевски активно учествувал и бил ангажиран во разни органи и тела на Факултетот. Во два наврата бил раководител на Биолошкиот институт, раководител на Ботаничкиот завод, претседател на Советот на Природно-математичкиот факултет и др. Бил претседател на проектниот совет “Вегетациска карта на Југославија”, претседател на координациониот совет на макропроектот “Заштита на човекова околина” при МАНУ, претседател на Друштвото на биосистематичарите на Југославија, член на Советот за заштита на Охридското, Преспанското и Дојранското Езеро, член во редакциски одбори на повеќе списанија, (Годишен зборник – биологија, АСТА, „Разгледи“, „Прилози“ – МАНУ и др.).

Наставно-педагошката активност на академик Кирил Мицевски е обемна, многу плодна и содржајна. Како многу талентиран студент бил веднаш забележан од страна на проф. д-р Роко Вуковиќ, од кого, како и од проф. д-р Борис Китанов и проф. д-р Миховил Грачанин, ги добива основните сознанија од ботаниката, а подоцна и од пионерите на европската фитоценологија, професорите Стјепан Хорватиќ и Иво Хорват од Загреб. Од неговото назначување на Природно-математичкиот факултет, па сè до неговото пензионирање, има бројни наставни задолженија. Уште како асистент учествува во изведувањето на практичната настава на повеќе биолошки дисциплини, а делумно се вклучува и во теоретската настава на предметот за кој беше избран – Систематика и филогенија на вишите растенија. Од изборот за доцент ја превзема целокупната настава по предметите Систематика и филогенија на вишите растенија и Фитогеографија со фитоценологија.

Академик Кирил Мицевски учествуваше и во наставата на постдипломските студии на Институтот за биологија и на некои други факултети, држејќи настава или консултации од областа на Систематиката и филогенијата на вишите растенија и Фитоценологијата. Беше ментор или член на комисија на голем број магистерски трудови и докторски дисертации.

Покрај редовните задолженија на Природно-математичкиот факултет во Скопје, тој држел настава на Вишата педагошка школа во Скопје, на Вишата земјоделска школа во Приштина и на Филозофскиот факултет во Приштина.

Научноистражувачката дејност на академик Кирил Мицевски се одвиваше во доменот на две научни дисциплини – флористиката и вегетацијата, односно фитоценологијата. Од тие области се сите негови досега објавени (над 120) научни трудови кои се често цитирани во европската ботаничка периодика.

Вегетациските истражувања заземаат посебно место во научноистражувачкиот опус на академик Кирил Мицевски. Со неговите истражувања е опфатена целокупната територија на Република Македонија, така што се обработени повеќе вегетациски типови. Во неговите трудови комплетно е истражена водната вегетација на Охридското, Преспанското и Дојранското Езеро, како и водната вегетација на некогашните Катлановско и Моноспитовско Блато, која денес е речиси сосема уништена или пак од неа се останати само мали фрагменти. Комплетно е истражена и блатната вегетација на некогашните големи блатни површини како што се Катлановското Блато, Пелагониското Блато, Моноспитовското Блато, Струшкото и Охридското Блато, од кои денес, од некои од нив, нема ниту остатоци. Нивниот флористички состав и фитоценолошката припадност денес можат да се сретнат само во објавените студии на академик Кирил Мицевски.

Во текот на своите вегетациски истражувања академик Кирил Мицевски ги обработи и низинските ливади во сите котлини на Македонија, при што има опишано 5 нови за науката заедници.

Посебен придонес секако претставуваат резултатите на неговите истражувања на халофитската вегетација која се развива на засолените почви во Македонија, која дотогаш не беше воопшто проучувана. Притоа се опишани 2 нови за науката сојузи и 8 нови асоцијации.

Во истражувањата на вегетацијата академик Кирил Мицевски ги опфати и степоликите површини во централните делови на Република Македонија (помеѓу Велес, Штип и Неготино), притоа докажувајќи дека тука воопшто не се работи за вистинска степска вегетација, туку за една „степолика” вегетација која само физиономски многу потсетува на една степа. Оваа т.н. „културна степа” се одликува со некои свои специфичности. Имено во нејзиниот состав влегуваат пред сè, стари степски реликтни видови кои егзистирале во поранешните геолошки периоди, а тука се одржале поради поволните климатски и педолошки услови.

Академик Мицевски, за да даде една поцелосна слика на вегетацијата на Македонија, своите истражувања ги прошири и на вегетацијата на брдските пасишта, притоа, опишувајќи неколку нови за науката растителни заедници, 1 ред и 2 сојуза.

Особено значење во неговите вегетациски истражувања имаат и двете монографии кои се однесуваат на вегетацијата на две интересни подрачја од Македонија, и тоа на Малеш и Пијанец, како и на планината Бистра.

Основна преокупација во научноистражувачката дејност на академик Кирил Мицевски сепак претставува **истражувањето на флората на Република Македонија**. Како нејзин неуморен истражувач, ва периодот од 50 години, заедно со своите соработници, повеќекратно ги има обиколено речиси сите наши планини, котлини и клисури, со што хербариумската збирка на Ботаничкиот завод на Институтот за биологија при Природно-математичкиот факултет во Скопје ја збогати со огромен флористички материјал, чиј број денес изнесува околу 180.000 хербариумски примероци. Тоа му овозможи да пристапи кон пишувањето на делото „**Флора на Република Македонија**“ и кон монографска обработка на повеќе родови, секции и видови. Академик Кирил Мицевски опиша голем број таксони нови за науката – видови (45), подвидови, варијетети и форми, откриени за прв пат на територијата на Република Македонија. Тој го констатира присуството на некои родови кои дотогаш воопшто не беа познати за флората на Македонија. Такви се на пр. родовите *Isoetes, Sisyrinchium, Acorus, Drosera* и други, а посебно е голем бројот на видовите кои се нови за флората на Македонија, од кои некои се многу ретки и претставуваат посебен интерес за толкување на генезата на флората, односно вегетацијата.

Академик Кирил Мицевски беше првиот ботаничар кој уште пред 35 години укажа на неколку локалитети во Македонија кои се од посебно флористичко и вегетациско значење. Притоа предложи неколку од нив, во својство на природни реткости, да бидат заштитени. Тоа се однесува на блатото со *Osmunda regalis* кај с. Банско (Струмичко), блатото кај Негорска Бања (Гевгелиско), блатото „Студенчиште“, покрај Охридското Езеро, шумата со *Alnus glutinosa* помеѓу Гостивар и Тетово и други.

Ореол на сите негови флористички истражувања претставува делото „**Флора на Република Македонија**“, во нив, детално, современо и критички, е обработена флората која се развива на територијата на Република Македонија, при што критички се обработени, односно ревидирани сите дотогашни податоци кои се наведуваат во флористичката литература за Македонија.

Академик Кирил Мицевски беше еден од водечките балкански флористи, таксономи и фитоценолози, креативен и неуморен истражувач, кој со зрелоста на своите научни потфати и добиените резултати ја афирмира македонската наука и на светската научна сцена.

За својата дејност на наставното, научното и општественото поле акад. Кирил Мицевски е одликуван со Медал на трудот (1957), Наградата на град Скопје „13 ноември“ (1961), Орден на трудот со златен венец (1969), Златна плакета на Универзитетот „Кирил и Методиј“ (1984), Спомен-плакета по повод 25 години на Природно-математичкиот факултет во Скопје, Повелба од Универзитетот „Кирил и Методиј“ (1988), Повелба на Природно-научниот музеј во Скопје, Благодарница на Хидробиолошкиот завод во Охрид (1985), како и на наградата „Гоце Делчев“ во 1999 година.

Името на академик Кирил Мицевски засекогаш ќе остане како пример на професионален, ангажиран, доследен, принципиелен и максимално одговорен пристап кон работата и обврските, кои произлегуваа од неговата обемна наставна и научноистражувачка дејност.

ACADEMICIAN KIRIL MICEVSKI
(On the occasion of the 90th anniversary of his birth)

Vlado Matevski

Macedoniana Academy of Sciences and Arts, 1000 Skopje, Republic of Macedonia

This year, it has been 90 years since the birth of Academician Kiril Micevski, full professor for many years at the Institute of Biology of the Faculty of Natural Sciences and Mathematics in Skopje and the founder of modern floristic and vegetation studies on the territory of the Republic of Macedonia.

Academician Micevski was born on 29th April 1926 in Skopje where he accomplished his primary and secondary school education. In 1946 he enrolled in the Faculty of Philosophy – Department of Biology wherefrom he received his university degree in 1951, becoming so the first graduate student in his class. After his graduation he was appointed as assistant in the field of *Systematics and phylogeny of upper plants* at the Botanical Institute. In 1954 he went to Zagreb to specialize in the methodology of phytosociological research under the guidance of the eminent phytocoenologist Prof. Dr. Stjepan Horvatić. His doctoral thesis *Typological studies of the vegetation of lowland meadows and marshes in Macedonia*, defended at the Faculty of Philosophy in Skopje in 1958, also treated this research topic. In 1958 he was appointed a docent, in 1964 – associate professor, and in 1970 he became a full professor. In the meantime he spent three months in the Herbarium of the Museum of Natural History in Vienna, continuing to practise ten-day study visits and work in this herbarium in subsequent years in order to resolve certain floristico-taxonomic problems regarding the flora of Macedonia.

Acad. Micevski was elected a corresponding member of the Macedonian Academy of Sciences and Arts in 1974, and a regular member in 1979. In 1987 he retired in accordance with the Law on early retirement. Owing to the significant results of his floristic studies of Macedonia and the Balkan Peninsula, he was elected a foreign member of the Slovenian Academy of Sciences and Arts in 1995.

During his career at the university Acad. Kiril Micevski was actively engaged in the work of many organizations and bodies. He was twice Head of the Institute of Biology, Head of the Botanical Institute, President of the Council of the Faculty of Natural Sciences and Mathematics, etc. He was president of the project council for *The Vegetation Map of Yugoslavia*, president of the coordinative council of the macro project *The Protection of the Human Environment* at the Macedonian Academy of Sciences and Arts, president of the Yugoslav Society of Biosystematics, a member of the Council for the Protection of Ohrid, Prespa and Dojran Lakes, a member of editorial boards of several journals such as the Biology Yearbook, ACTA, *Razgledi*, Contributions of MASA, etc.

The educational activity of Acad. Kiril Micevski was very abundant and successful. Being a very gifted student he was soon noticed by Prof. Dr. Roko Vuković, who, together with Prof. Dr. Boris Kitanov and Prof. Dr. Mihovil Gračanin, introduced him to the basic of botany. The pioneers of European phytocoenology, the professors Stjepan Horvatić and Ivo Horvat from Zagreb, also contributed to his knowledge of botany later on. From his appointment at the Faculty of Natural Sciences and Mathematics in Skopje, and until his retirement, Acad. Micevski had many educational engagements. Even as an assistant he taught practical courses in several biological disciplines, and participated to a certain extent in the theoretical instruction on the subject to which he was elected. After his appointment as a docent he undertook the complete theoretical and practical courses of *Systematics and phylogeny of higher plants*, and *Phytogeography with phytocoenology*.

Academician Kiril Micevski also participated in postgraduate study courses at the Institute of Biology and some other faculties holding lectures or consultations in the area of systematics and phylogeny of higher plants and phytocoenology. He was a mentor and a member of the commissions for many masters' and doctoral theses.

Besides his regular obligations at the Faculty of Natural Sciences and Mathematics in Skopje, he held courses at the Teachers' College in Skopje, and in Prishtine at the Agricultural College and at the Faculty of Philosophy.

The research activity of Acad. Kiril Micevski was focused on two scientific disciplines – floristic and vegetation studies, i.e. phytocoenology. These fields are the subject of research of all his published articals, which are over 120 in number and are frequently cited in European botanical journals.

Vegetation studies occupy a special place in the research opus of Acad. Kiril Micevski. He explored several vegetation types in his research that encompassed the whole territory of the Republic of Macedonia. Thus, in his works, he completely investigated the water vegetation of the Ohrid, Prespa and Dojran Lakes, as well as the water vegetation in the former marshes in Katlanovo and Monospitovo which are almost totally destroyed today or are present only in small fragments. He also investigated completely the marsh vegetation of former large marshy terrains such as, for instance, the marshes of Katlanovo, Pelagonija, Struga and Ohrid, from some of which not even remains can be found today. The structure of their flora and their phytocoenological affiliation can be met today only in the published studies of Acad. Kiril Micevski.

During his researches into vegetation Acad. Kiril Micevski also elaborated the lowland meadows of all valleys of Macedonia describing thereby five communities which were new to science.

Particular significance should be assigned to the results of his investigation of the halophytic vegetation which grows on saline soils in Macedonia, and which had not been investigated at all before. In addition, he described two new alliances and eight new associations for science.

In his vegetation's studies Acad. Kiril Micevski included the steppe-like region in the central part of the Republic of Macedonia (between Veles, Štip and Negotino) proving that we did not have here a true steppe vegetation but some "steppe-like" vegetation that only physiognomically resembles a steppe. This so-called "cultural steppe" has its peculiarities, namely its composition includes, above all, old steppe relict species which had existed in the previous geological periods, and survived here because of the favorable climatic and soil conditions.

In order to give a more comprehensive picture of the vegetation of Macedonia, Acad. Micevski broadened his studies to the vegetation of dry grasslands describing several new plant communities, one order and two alliances.

Two monographs describing the vegetation of two interesting regions in Macedonia – Maleš and Pijanec, and Mount Bistra – are of particular importance among his studies on vegetation.

The basic scientific preoccupation of Acad. Kiril Micevski, however, was **his research into the flora of the Republic of Macedonia.** Being its tireless explorer in the course of fifty years, Acad. Micevski, accompanied by his collaborators, made many rounds of almost all our mountains, valleys and gorges, enriching the herbarium of the Botanical Institute at the Institute of Biology of the Faculty of Natural Sciences and Mathematics in Skopje with immense floristic materials which number today about 180,000 herbal specimens. All that enabled Acad. Micevski to begin writing his work *The Flora of the Republic of Macedonia* and to elaborate in monographs several genera, sections and species. Acad. Kiril Micevski has described a large number of taxons which were new to botanical science – species (45), subspecies, varieties and forms, discovered for the first time on the territory of the Republic of Macedonia. He confirmed the presence of certain genera which were unknown in the flora of Macedonia until then such as, for example, *Isoetes*, *Sisyrinchium*, *Acorus*, *Drosera*, etc.; there is a particularly large number of species which are new in the flora of Macedonia, some of which are very rare and specially important for the explanation of the genesis of the flora, i.e. the vegetation.

Acad. Kiril Micevski was the first botanist who, as early as 35 years ago, pointed out certain localities in the Repulic of Macedonia which are extremely important from the aspect of their flora and vegetation. In this connection he proposed that some of them be protected as natural rarities. This refers to the marsh with *Osmunda regalis* near the village of Bansko (Strumica region); the marsh near Negorska Banja (Gevgelija region), the marsh "Studenčište" near the Ohrid Lake, the forest with *Alnus glutinosa* between Gostivar and Tetovo, etc.

The volumes of his work *The Flora of the Republic of Macedonia* present the crown of his floristic studies. They elaborate the flora that grows on the territory of Macedonia in detail and critically, by means of modern methodology, analyzing critically and revising all the data known so far and cited in the floristic literature about Macedonia.

Acad. Kiril Micevski was one of the leading Balkan florists, taxonomists and phytocoenologists, a creative and tireless researcher who brought affirmation and world recognition to Macedonian science through the maturity of his scientific performance and the results achieved.

For his merits in the field of science, education and social engagement, Acad. Kiril Micevski was awarded the Order of Labour (1957), the 13th November Award of the city of Skopje (1961), the Order of Labour with Golden Wreath (1969), Golden Plaquette of the Ss.Cyril and Methodius University (1984), the memorial Plaquette on the occasion of the 25th Anniversary of the Faculty of Natural Sciences and Mathematics in Skopje, the Charter of the Ss. Cyril and Methodius University (1988), the Charter of the Museum of Natural Sciences in Skopje, the Certificate of Gratitude from the Hydrobiological Institute in Ohrid (1985) and the Goce Delčev National Award in 1999.

The name of Acad. Kiril Micevski will remain for ever in our memories as an example of a highly professional, engaged, consistent, principled and responsible approach to the work and to the obligations stemming from his voluminous research and educational activities.

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Review

SOIL MAPS OF THE REPUBLIC OF MACEDONIA

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The paper gives an overview of the history of preparation of 63 soil maps in printed and digital form, out of which 62 in a scale of 1 : 50 000 for a specific sections of the topographic maps, and one in a scale of 1 : 200 000 for the whole of the Republic of Macedonia. The Project for Preparation of Soil Map in a scale of 1 : 50.000 lasted almost seven decades (from 1947 to 2015). In the final phase of this process, within a FAO project, soil maps in hard copy and digital format were edited, together with corresponding study books for soil properties and soil forming factors for 10 regions of the country. A similar study book was written for the soils of the whole country. In addition, a common legend has been developed for all soil maps with 63 cartographic units. All classifications used during this long period of soil survey have been described and served as a basis for compiling of all legends. The areas of all cartographic units have been presented. The contents of all 11 soil studies have been described. Digitalization of all maps and the data base of soil characteristics were accomplished. For this purpose, an internet web-portal has been created (www.maksoil.ukim.mk). The results of the Project implementation were promoted and presented to the local scientific and professional public. The final works on the Project completion were financed by the FAO, UN Organization.

Key words: soil maps of the Republic of Macedonia; legend of the soil maps; areas of cartographic units; digitalization of project results

INTRODUCTION

Soil survey and soil mapping in the Republic of Macedonia started soon after the liberation (after World War II), in 1947. This process started with the survey of soils of Strumica valley. The Soil Survey Study, including a soil map of this valley in a scale of 1:50 000, was published in 1951 (Gj. Filipovski [1]). These soil survey activities, in parallel to the preparation of **soil maps and soil studies** for our country, continued up to 2015. They lasted almost to seven decades. Only the author of this text took part in these researches over the entire period. All other contributors to the preparation of the soil maps (most of whom were collaborators of Prof. Gj. Filipovski) took part only during shorter or longer periods of time. Eight of these contributors, who are still active in this field, completed the soil map of the Republic of Macedonia including the soil survey in 2015. The other contributors to the soil mapping activities, regretfully, are not with us any longer. We remember them with great love, respect and gratitude for their contribution.

With the finalization of the Project for preparation of soil maps of the Republic of Macedonia, 62 maps were published (in printed and digital form) over the topographic elements of the topographic maps in a scale of 1:50 000 and one for the entire territory of the Republic of Macedonia in a scale of 1 : 200 000. In addition, 11 soil studies have been published: 10 studies for particular regions and one for the whole territory of the country comprising 1028 pages in total.

The eight authors who participated in this task (including the retired soil scientists) are professors at the Faculty of Agricultural Sciences and Food, Institute of Agriculture and the Faculty of Forestry, all being parts of the Ss. Cyril and Methodius University in Skopje. The authors of these maps and studies (in alphabetical order) are as follows: Andreevski [3, 4], Vasilevski and Markoski [5], Markoski *et al*. [6], Mitkova *et al*. [7], Mitrikeski *et al*. [8, 9], Mukaetov [2], Petkovski [10] and Filipovski [11, 12].

Besides the study of one particular region, Filipovski [12] wrote the study for the whole of the Republic of Macedonia. The other authors wrote the soil studies for 9 separate regions.

IMPORTANCE AND IMPLEMENTATION OF THE PUBLISHED SOIL MAPS AND STUDIES

The Project for preparation of soil maps and the studies have a fundamental and applicable character. They present our soils as an important natural and hard to renew resource, and as an important component of the natural ecosystems. Therefore, the results of these researches are being used in many basic sciences: botany (especially phytocoenology), ecology, zoology, geography, etc.

Soil maps are widely used in the construction industry (urban planning, infrastructure projects), spatial planning and creation of spatial plans, environmental projects, etc.

The results from soil survey and soil mapping are used by other soil related sciences: plant nutrition, soil microbiology, agrotechnics, hydrotechnics, etc.

Their use in agriculture is particularly wide, especially in agro-ecological zoning, cultivation of different crops, cultivation of perennial crops in viticulture and fruit growing, implementation of different agrotechnical and ameliorative measures (especially in irrigation and drainage), etc.

Their importance is also notable in forestry: cultivation and exploitation of forests, afforestation, implementation of anti-erosion measures, etc.

MAIN CHARACTERISTICS OF THE PROJECT

The Project for preparation of soil maps and studies has several specific characteristics which make it different from other projects in the field of soil science. These are:

1. Particularly long project duration. It started in 1947 and, with interruptions, lasted until 2015 or for a total of 68 years. This can be explained with its specifics: soil mapping requires that ‘every foot of land’ is examined. Besides, sometimes problems occurred with project funding. That resulted in work interruptions, time gaps or slowing down of the pace of work. And lastly, the great changes and turbulent times that our country went through during this long period of time inevitably had an impact on the project completion.

2. Involvement of a particularly large number of researchers. As described above, it was necessary to engage a particularly large number of contributors to the soil mapping. The soil study that is published together with the Soil Map of Macedonia (Filipovski [12]) lists the names of all 24 researchers.

3. Participation of a large number of institutions in the creation of the project. Those were the institutions that employed these 24 researchers: MASA, Faculty of Agricultural Sciences and Food, Institute of Agriculture and Faculty of Forestry within the Ss. Cyril and Methodius University and the Tobacco Institute in Prilep, the Republic Institute for Water Management, the Rise Institute in Kočani, the Forestry Institute, the laboratories of some companies (‘Agromehanizacija’) and agricultural organizations. Some of these institutions do not exist any longer.

4. Expensive project. Due to the project research specifics, substantial financial resources had been used from different sources. The total amount is unknown. All the above mentioned institutions participated in the financing with budget funding. Beside them, financial support came from: the Directorate for Water Management, the Institute for Spatial Planning, agricultural complexes, water management companies, local councils and especially from the Federal and Republic Funds for Scientific Research. It should be particularly noted that without the expertise and the financial support provided by FAO (UN organization) in the amount of $ 340,000, the Project could not have been completed. Also, some of these institutions that took part in the financing of the Project do not exist any longer.

5. The use of numerous different soil classifications for preparation of legends for the cartographic units of soil maps. During the long period of the Project implementation, several national soil classifications were used, which reflected the level of the soil science at the time. Those classifications were based on different principles and criteria. As a result of that, the created maps had different legends. This caused a serious problem. Focusing all my efforts and knowledge on this problem, in 2008 I managed to compile one common legend from all these different ones. That enabled the creation of all 63 soil maps in 2015. This was achieved in correlation with all cartographic units of numerous legends with the **taxonomic units** from the last version of our soil classification of 2006 (Filipovski [13]). This common legend was used in the creation of the soil maps published in 2015.

6. Digitalization of the soil maps and of the soil characteristics data base. During the first dec-

ades of soil mapping, digitalisation was not possible. Digitalisation was achieved with FAO assistance and with the implementation of the soil information system (SOTER) prepared by FAO [14].

CONDITIONS FOR PROJECT COMPLETION

The final Project activities took place between 2013 and 2015 when 63 soil maps in their final form were completed together with 11 study books on soil properties.

This work was successfully completed as a result of several conditions being previously fulfilled, among others most notable being the following:

1. As a result of the soil mapping, there was a large number of field soil maps drawn by hand, some of which were even in a printed form. There were soil studies and reports for these maps.

2. MASA financed and completed several projects which enabled or facilitated the creation of the common legend and the creation of the 11 study books on soils. The completion of these projects was crowned with the publishing of several **monographs on the soils of Macedonia** (Filipovski [13, 15–23]). Some of these monographs are of vital importance for the completion of the Project, such as the monograph **Soil Classification of the Republic of Macedonia** published in 2006 (Filipovski [13]), and the monograph on the **Soils of the Republic of Macedonia** in six volumes (Filipovski [15–20]), which were used for the creation of the 11 study books on soils published in 2015. Two more monographs were used for the creation of these studies: **Soil degradation as a component of the environment in the Republic of Macedonia** (Filipovski [21]) and **The Characteristics of the Climate Vegetation Soil Zones (Regions) in the Republic of Macedonia** (Filipovski *et al*., [22]).

3. It should be noted that after the publishing of the monograph on the **soils of Macedonia**, which presented all research results of the soils until its publishing, we had access to the most recent results from the doctoral and masters studies prepared by: Andreevski [24], Vasilevski [25], Markoski [26, 27], Mitkova [28], Mukaetov [29] and Jovanov [30]. These results were also used in creating of the 11 studies in 2015.

4. The final works in 2008 were of great importance for the Project completion. With the support of three of my collaborators (Petkovski, Mukaetov and Andreevski), at the Institute of Agriculture, all the existing 140 field soil maps in a scale of 1 : 50 000 were gathered and stored, together with their legends and soil studies. A large number of these maps were in handwritten form. These data were kept in a number of institutions, funds or by the authors themselves. The collecting of this material was a hard and long process. Besides, the cartographic units indicated in the map legends were based on different classifications which used different criteria. After a long and hard work all these 140 legends with their cartographic units were correlated with the taxonomic units of the **Soil Classification** from 2006 (Filipovski [13]) with an aim to achieve a common legend. The whole completed work was presented in a handwritten text of 102 pages. The text contained a list of all collected soil studies for the 140 soil maps. Without this work the Project for the soil maps of the Republic of Macedonia could not has been completed.

5. During this period of seven decades, the soil mapping was also made possible with the classification of the Macedonian and the former Yugoslav soils, made by several authors. The classification criteria from these soil classifications were used as a base to define the cartographic units and legends. A separate chapter will be dedicated to the problems related to soil classifications.

6. After 1963, the work on the creation of the soil maps was made easier thanks to the published monograph on the soils of Yugoslavia (Filipovski *et al*. [31]). It resolved many questions related to soil classifications. In this monograph West European approaches in adoption of objective and measurable criteria for defining the taxonomic and cartography units were incorporated. This monograph motivated the process of creation of new versions of national soil classifications in former Yugoslavia, inspired by the international understandings and criteria of that time.

SOIL CLASSIFICATIONS USED FOR COMPOSING LEGENDS FOR SOIL MAPPING DURING 1947 – 2015

In certain periods within these 70 years of soil surveying different classifications were used. In this respect, we can distinguish 5 periods:

1. The period between 1947 and 1959. During this period the scientific soil classification was not at a very high level. No international classification existed, and the soils in Yugoslavia had not been significantly researched to enable establishment of a good national soil classification. During this period Russian classifications were used (Rozov [32]) which were hard to implement in our conditions. Legends were compiled using descriptions of Yugoslav soil types in the books of Stebut

[33] and Gračanin [34]. The first national soil classification published by Gračanin [35], was inaccurate as it was done at the time when the soils of Yugoslavia were not adequately researched. Therefore, soil mapping during this period was quite difficult.

2. The period between 1959 and 1963. Till the beginning of this period the soils in the valleys of Macedonia were thoroughly researched for 12 years, and a substantial amount of scientific data was collected. This enabled the creation of the first version of the soil classification of the Republic of Macedonia (Filipovski [36]). It encompassed two categories of taxonomies (types and subtypes of the systematically researched soils in the valleys), and types for the mountainous soils, surveyed only with reconnaissance which is in fact an initial step in soil survey.

3. The period between 1963 and 1995. During this period the soil classification in the former Yugoslavia swayed considerably. An important contribution to this was the detailed soil monograph on the Yugoslav soils (Filipovski *et al*. [31]) published in 1963. It presented all the known research results of the Yugoslav soils till then. The same year, a group of authors wrote the first version of the national classification of the Yugoslav soils up to the level of type (Neigebauer *et al*. [37]). Later, again a group of authors compiled two new versions: in 1973 (Škorić *et al*. [38]) and in 1985 (Škorić *et al*. [39]). These two versions, as per the recommendation of the *Yugoslav Soil Research Society*, were used across all the republics of Yugoslavia for the purpose of creation of their soil maps. These classifications were based on measurable criteria and were detailed as they contained several categories of taxonomies (*orders*, *classes*, *types*, *subtypes*, *varieties*, and *soil forms*). It can be stated that with these classifications the soil mapping was made much easier as during field measurements they could define the taxon without any problems.

4. The period between 1995 and 2006. The monograph on our soils written during this period (Filipovski [15–20]) modifies and adjusts the last version of the Yugoslav soil classification (Škorić et al. 39) in accordance with the specifics of the soils in our country. It is used not only in the monograph but also in the research and soil mapping of the Macedonian soils during this period.

5. The period between 2006 and 2015. In 2006 the last version of the Macedonian Soil Classification was published (Filipovski [13]). It applies contemporary criteria: 21 *diagnostic horizons*, 23 *diagnostic characteristics* and 27 *diagnostic soil materials*. All diagnostic horizons are quantitatively defined with specific parameters and therefore easily recognisable. They serve as a base for creation of our soil classification with precisely and measurably defined taxons out of the five categories (*big soil group*, soil types, subtypes, varieties and forms). That is why it was easily applicable. It is in essence a national classification based on the results of our well researched soils. This classification is also correlated with the international FAO classifications (Driessen *et al*. [40], Dudal [41]) and WRB (ISSS *et al*. [42], IUSS *et al*. [43]). As previously said, our classification was used for the soil mapping during this period. It also served for composing the common legend of all 63 soil maps that were published in 2015.

COMMON LEGEND FOR ALL MAPS

The process of creation of a common legend for all 63 printed maps in 2015 was described previously. Cartographic units from the national soil classification (2006) are presented in Table 1, while the correlation of the national classification with the international classifications of WRB (ISSS et al. [42], IUSS et al. [43]) is presented in Table 2.

Table 1 below shows the common legend with all its cartographic units and areas covered with each unit.

The table shows that the common legend contains a total of 63 cartographic units. 17 of them contain only one soil type, and 46 are complexes, i.e. comprising several soil types.

The cartographic units are given by relief forms separately. There are 20 in mountainous relief forms, 28 in a hilly relief, 3 on sloppy terrains and 12 cartographic units in flat landforms. There are only few of the same cartographic units in several relief forms.

The Table 1 also represents the geography of our soils as it contains their surface areas in hectares. From the figures, it can be concluded that the surface areas of soils in the mountainous relief form represent 1.434.070 ha or 57,37%, in the hill land forms 698.159 ha or 27,93%, in hilly relief 160.394 ha or 6,42% and in flat relief forms 163.020 ha or 6,52% of the total surface area of our soils.

The cartographic units of the Table 1 are corelated with the international soil classification of WRB. This is represented in Table 2.

Table 1. Soils of the Republic of Macedonia (legend with cartographic units according to the soil classification of Gj. Filipovski)

Cartographic soil units		Hectares
I. Soils of mountainous relief		
Leptosol		38.502
Leptosol on hard limestones and dolomites		1.128
Complex of Regosol and Leptosol		70.898
Complex of Mollic and Umbric Ranker		154.747
Complex of Mollic and Umbric Ranker and Regosol		34.889
Complex of Mollic and Umbric Ranker and Leptosol		1.124
Complex of Mollic and Umbric Ranker, Regosol and Leptosol		80.603
Complex of Mollic and Umbric Ranker and Luvisol		930
Rendzina on hard limestones and dolomites		146.229
Complex of Rendzina on hard limestones and dolomites and Leptosl		13.979
Complex of Rendzina and Brown Soil on hard limestones and dolomites		35.050
Red Soil (Terra Rossa)		260
Complex of Red Soil (Terra Rossa) and Brown Soil on hard limestones and dolomites		1.471
Brown Soil on hard limestones and dolomites		82.879
Brown Forest Soil		395.957
Complex of Brown Forest Soil and Regosol		86.831
Complex of Brown Forest Soil, Leptosol and Regosol		127.721
Complex of Brown Forest Soil and Mollic and Umbric Ranker		54.437
Complex of Brown Forest Soil, Mollic and Umbric Ranker and Leptosol		98.780
Complex of Brown Forest Soil and Leptosol		7.555
	TOTAL	1.434.070
II. Soil of rolling relief and lake terraces		
Regosol		102.310
Complex of Regosol and Smolnitza		28.962
Complex of Regosol and Colluvial Soil		584
Pararendzina		47.616
Complex of Pararendzina, Regosol and Leptosol		9.071
Complex of Pararendzina, Regosol and Smolnitza		6.385
Complex of Pararendzina and Leptosol		3.362
Vertisol		60.537
Complex of Smolnitza, Regosol and Leptosol		47.305
Complex of Smolnitza and Pararendzina		32.833
Complex of Smolnitza, Pararendzina and Regosol		9.906
Complex of Smolnitza, Cinnamonic Forest Soil and Regosol		40.181
Complex of Luvisol and Regosol		7.130
Complex of Chernozem and Pararendzina		2984
Complex of Chernozem, Pararendzina and Smolnitza		9.906
Complex of Pararendzina and Regosol		68.926
Cinnamonic Forest Soil		96.030
Complex of Cinnamonic Forest Soil and Regosol		45.860
Complex of Cinnamonic Forest Soil, Pararendzina and Regosol		14.538
Complex of Cinnamonic Forest Soil, Pararendzina and Colluvial Soil		1.324
Complex of Cinnamonic Forest Soil, Regosol, Pararendzina and Smolnitza		8.500
Complex of Cinnamonic Forest Soil and Smolnitza		14.539
Complex of Cinnamonic Forest Soil, Pararendzina and Smolnitza		6.823
Complex of Cinnamonic Forest Soil and Luvisol		2.188
Complex of Cinnamonic Forest Soil, Luvisol and Regosol		751
Luvisol		13.942
Rigosol		15.612
Depasol		84
	TOTAL	698.189
III. Soils of slopy relief		
Colluvial Soil		159.132
Colluvial Rigosol		735
Colluvial Hortisol		527

Table 1. (continuation)

	TOTAL	160.394
IV. Soils of flat relief		
Alluvial Soil		109.645
Complex of Alluvial and Colluvial Soil		2.540
Complex of Alluvial Soil and Swampy Gley Soil		1.197
Complex of Alluvial Soil and Fluviative Meadow Soil		309
Fluviative Meadow Soil		18.295
Complex of Fluviative Meadow Soil and Hydromorphic Black Soil		1.015
Swampy Gley Soil		10.061
Complex of Swampy Gley Soil and Histosol		934
Hydromorphic Black Soil		6.883
Complex of Solonchak and Solonetz		10.806
Planosol		1. 160
Histosol		175
	TOTAL	163.020
Populated areas		44.172
	TOTAL	2.499.845

Table 2. Soils of the Republic of Macedonia (legend with cartographic units according to the soil classification of WRB

Cartographic soil units		Hectares
I. Soils of mountainous relief		
Leptosol		38.502
Leptosol calcaric		1.128
Complex of Regosol and Leptosol		70.898
Complex of Humic Eutric and Umbric Regosol (Umbrisol)		154.747
Complex of Humic Eutric and Umbric Regosol (Umbrisol) and Regosol		34.889
Complex of Humic Eutric and Umbric Regosol (Umbrisol) and Leptosol		1.124
Complex of Humic Eutric and Umbric Regosol (Umbrisol), Regosol and Leptosol		80.603
Complex of Humic Eutric and Umbric Regosol (Umbrisol and Albic Luvisol		930
Rendzic Leptosol		146.229
Complex of Rendzic Leptosol and Leptosol		13.979
Complex of Rendzic Leptosol and Chromic Leptic Luvisol on hard limestones		35.050
Rhodic Leptic Luvisol on hard limestones		260
Complex of Rhodic Leptic and Chromic Leptic Luvisol on hard limestones		1.471
Chromic Leptic Luvisol on hard limestones		82.879
Cambisol		395.957
Complex of Cambisol and Regosol		86.831
Complex of Cambisol, Leptosol and Regosol		127.721
Complex of Cambisol, Humic Eutric and Umbric Regosol (Umbrisol)		54.437
Complex of Cambisol, Humic Eutric and Umbric Regosol (Umbrisol) and Leptosol		98.780
Complex of Cambrisol and Leptosol		7.555
	TOTAL	1.434.070
II. Soil of rolling relief and lake terraces		
Regosol		102.310
Complex of Regosol and Vertisol		28.962
Complex of Regosol and Fluvisol		584
Humic Calcaric Regosol		47.616
Complex of Humic Calcaric Regosol, Regosol and Leptosol		9.071
Complex of Humic Calcaric Regosol, Regosol and Vertisol		6.385
Complex of Humic Calcaric Regosol and Leptosol		3.362
Vertisol		60.537
Complex of Vertisol, Regosol and Leptosol		47.305
Complex of Vertisol and Humic Calcaric Regosol		32.833
Complex of Vertisol, Humic Calcaric Regosol and Regosol		9.906
Complex of Vertisol, Chromic Luvisol on saprolite and Regosol		40.181

Table 2. (continuation)

Complex of Albic Luvisol and Regosol		7.130
Complex of Chernozem and Humic Calcaric Regosol		2984
Complex of Chernozem, Humic Calcaric Regosol and Vertisol		9.906
Complex of Humic Calcaric Regosol and Regosol		68.926
Chromic Luvisol on saprolite		96.030
Complex of Chromic Luvisosl on saprolite and Regosol		45.860
Complex of Chromic Luvisosl on saprolite, Humic Calcaric Regosol and Regosol		14.538
Complex of Chromic Luvisosl on saprolite and Fluvisol		1.324
Complex of Chromic Luvisosl on saprolite, Regosol, Humic Calcaric Regosol and Vertisol		8.500
Complex of Chromic Luvisosl on saprolite and Vertisol		14.539
Complex of Chromic Luvisosl on saprolite, Humic Calcaric Regosol and Vertisol		6.823
Complex of Chromic Luvisosl on saprolite and Albic Luvisol		2.188
Complex of Chromic Luvisosl on saprolite, Albic Luvisol and Regosol		751
Albic Luvisol		13.942
Aric Regosol		15.612
Spolic Regosol		84
	TOTAL	698.189
III. Soils of slopy relief		
Fluvisol (Colluvial soil)		159.132
Aric Regosol		735
Hortic Anthrosol		527
	TOTAL	160.394
IV. Soils of flat relief		
Fluvisol		109.645
Fluvisol (Alluvial and Colluvial soil)		2.540
Complex of Fluvisol and Gleysol		1.197
Complex of Fluvisol and Mollic Fluvisol		309
Mollic Fluvisol		18,295
Complex of Mollic Fluvisol and Mollic Vertic Gleysol		1.015
Gleysol		10.061
Complex of Gleysol and Histosol		934
Mollic Vertic Gleysol		6.883
Complex of Solonchak and Solonetz		10.806
Planosol		1.160
Histosol		175
	TOTAL	163.020
Populated areas		44.172
	TOTAL	2.499.845

THE CONTENTS OF SOIL STUDY BOOKS

The 11 soil study books mentioned in the introduction of this paper, contains same chapters in the same order. It was an agreement between the authors of the study books. The first written study (Filipovski [11]) was used as a sample.

The results of the soil surveys for each of the 10 regions and for the whole of the Republic of Macedonia are presented in the following chapters:

1. Introduction, history and research goals
2. Literature review
3. Research results

3.1. Factor influencing: *formation, evolution* and *characteristics* of the soils

3.1.1. Geographic location and relief

3.1.2. Hydrographical characteristics and erosion (surface water, flooded areas and wetlands, ground water, irrigation water, erosion)

3.1.3. Parent material

3.1.4. Climate

3.1.5. Vegetation

3.1.6. Human influence

3.2. Soils of the valleys

3.3. Soils of the sloppy terrains

3.4. Soils of the undulated and hilly terrains and lake terraces

3.5. Soils of the mountain terrains

3.6. Geography (spatial distribution of the cartographic units).

In every chapter on the four relief forms, research results for each soil type are presented as follows:

- **Genesis and classification**
- **Morphological characteristics**
- **Mechanical structures**
- **Chemical characteristics**
- **Production characteristics**

A list of references is given at the end of each study.

The soil study for the whole territory of the Republic of Macedonia (Filipovski [12]) contains one additional chapter on the history of soil mapping during the period of 1947–2015.

THE HISTORY OF CREATION OF SOIL MAPS OF THE REPUBLIC OF MACEDONIA (1994–2015)

The history of soil survey and soil mapping of Macedonia before 1947 have been described in other works (Filipovski [12, 15]). Till the end of World War II there was not a single institution dealing with soil surveying. At the Agricultural Experimental and Control Unit in Skopje, established between the two world wars, there was not a soil scientist or soil science unit. A very limited research data related to soil properties exists from that period, mainly done by soil scientists from Belgrade. As far as the mapping is concerned, only one scheme-like soil map of the Skopje valley (Todorović [45]) has remained, however without any laboratory analysis.

During World War II the Agricultural Experimental and Control Unit in Skopje was renamed as Agriculture Research Institute, however, still without a soil scientist or a soil science unit. There were no soil researches performed during this period. It can be said that until 1947, soil survey of Macedonian soils did not exist in practice. This means that soils were unknown in terms of their properties and spatial distribution.

Three periods can be distinguished in the creation of the soil maps of Macedonia (Filipovski 12):

1. The period between the liberation and the proclamation of state independence (1944–1991).

2. The period from the proclamation of state independence to 2012 (1991–2012).

3. The period of finalization of the soil maps (2012–2015).

1. The period between the liberation and the proclamation of state independence (1944–1991). In December 1944, when Prof. Gj. Filipovski was appointed as Head of the Institute of Agriculture in Skopje, Macedonia got the first soil scientist. Still, during the first two years after the liberation, there were no conditions to begin with surveying and mapping of our soils. The Institute of Agriculture had no equipment for field research of soils, there were neither means of transport nor financial means. The chemical laboratory within the Institute had supplies for regular functioning. The necessary conditions were met in 1947. It was then when Prof. Filipovski started with the surveying and mapping of the soils of Strumica valley. Research results were published in 1949 (Filipovski [1]). Those were the first data on our agricultural land to be published after the liberation.

This period preceding the proclamation of state independence can be recognised as the most productive in mapping of our soils. Only a small part of the soils of the country remained unresearched and unmapped. With regards to soil mapping, this period can be divided into two subperiods: the first between 1947 and 1963, and the second between 1963 and 1991.

In the first period (1947–1963) mainly the agriculture soils of our valleys were surveyed. For this purpose, adequate financial means were allocated from the government budget, as the rapid development of the country required the necessary research of soils. The results of these soil surveys were used for the needs of hydrotechnical ameliorations (irrigation and drainage). They were also necessary for improving the agricultural production (cultivation of perennial plantations of vineyards and orchards, in the implementation of different agrotechnical and ameliorative measures (especially in irrigation and drainage), etc.

These researches were abundantly funded especially by the Republic Institute for Water Management and the Directorate for Water Management. During this period, institutional, personnel and financial conditions were created for a very intensive and successful research and mapping of our soils. In 1947, within the Faculty of Agriculture and Forestry, the Department of Soil Science and Agrochemistry was established, which was initiated and headed by Prof. Gj. FilipovskiI for many years after. For the time, the Department was well equipped for educational and scientific work and it became a breeding ground for new soil scientists. At the same time, it worked intensively on the research and mapping of our soils.

During this subperiod, the other above mentioned institutions that took part in soil mapping, were gradually established.

During this subperiod, the research and soil mapping of the following valleys were undertaken (in alphabetical order): Belčišta, Berovo, Bitola-Gjavato, Valandovo, Veles, Gevgelija, Delčevo, Dojran, Izdeglavje, Kočani, Kirva Palanka, Kumanovo, Ljubanište, Ovče Pole, Ohrid, Pelagonija, Polog, Radoviš, Resen, Skopje, Strumica, Struga and Tikveš. The following researchers took part in these researches and soil mappings (in alphabetical order): L. Vilarov, S. Vukašinović, K. Georgievski, M. Živković, Ms L. Manuševa, D. Popovski, R. Radojević, T. Tonovski, B. Kosevski and Gj. Filipovski. These researches were done with relatively dense network of soil profiles. On the basis of the researches until 1953, Prof. Gj. Filipovski had created the first soil map of Macedonia which encompassed only the soils of the valleys. This map, in a scale of 1:500 000, was published by 'Geokarta' [46] in Belgrade.

During the second subperiod (1963–1991) the research focussed mainly on the mountainous soils, however, with substantially sparse network of profiles. Till then the mountainous soils had not been researched. This mapping of soils was done within a long-term project of that time which was launched for creation of the Soil Map of Yugoslavia. This project was funded by the Federal and later by the Republic Fund for Scientific Research. In Macedonia, the project was realised at the Institute of Agriculture in Skopje. During this subperiod, besides the mountainous soils, the soils of some valleys that had not been researched and mapped yet were researched as well. Those were the valleys of: Debar, Kičevo, Ovče Pole, Štip, Mariovo and Polog, as well as Debarca, Župa, Malesija, Dolni Drimkol, Trojačka, Žegljansko and Otčično and part of Pelagonia valley. The following people took part in these researches and soil mappings: T. Avramovski, M. Andreevski, S. Geškovski, A. Gičev, N. Miševska, T. Mitkova, J. Mitrikeski, Z. Mišiku, D. Mukaetov, D. Petkovski, D. Popovski, K. Serbinovski, J. Spirovski, Gj. Tanev, B. Kosevski and Gj. Filipovski.

During this subperiod, for the purpose of spatial planning, Prof. Gj. Filipovski and Dr D. Popovski created soil maps and wrote a study on the Macedonian soils of the Ohrid-Prespa region, Municipality of Štip, Titov Veles region and the region of Eastern Macedonia.

2. The period from the independence to 2012 (1991–2012). Unfortunately, this two-decade period is not characterized with intensive soil mapping due to lack of funding. This period is characterized by the following: a) mapping of small parts of Macedonian soils that were not researched until then; b) completion of some works that enabled the final realization of the Project in the later period; and c) search for funding for Project completion.

During this period, first of all, the mapping of the territory of the Republic of Macedonia that was not researched was completed for the following regions: Mariovo, Kičevo and Polog valley and the mountains of Galičica and Jablanica. For part of this territory the soil maps were missing, and for the other part the mapping was not with good quality. M. Andreevski, D. Mukaetov, D. Petkovski and D. Popovski took part in the mapping process.

During this period, the following tasks that enabled the completion of the Project in the later period took place: a) in 2008, with the assistance of three of Prof. Gj. Filipovski’s collaborators, all completed soil maps until then in a scale of 1:50 000 were gathered, together with the soil studies for these maps; b) a common legend for all these maps which used many different legends was prepared, c) MASA published several monographs of Prof. Filipovski that were used in writing of the text – Study book of the soil map of Macedonia (Filipovski [12]). They were also used in the writing of the texts – study books of the soils of the ten regions of the country*;* d) of particular importance was the monograph on classification of soils from 2006 (Filipovski [13]) which served as a base for composing of the common legend for all maps.

This legend was composed in correlation with all previous cartographic units, with taxonomies of that classification. This classification is also correlated with international classifications; e) following the publishing of the monograph "Soils of the Republic of Macedonia" (for the period 1995–2004), several PhD and master studies were completed, as mentioned above. They were also used in drafting the soil studies and soil maps.

During this period, and in particular after 2008, when the necessary works on the Project completion were finalized, intensive efforts were made to find funding, which were unfortunately unsuccessful.

3. The period of final Project completion (2012–2015). During this period, the following final tasks were completed: a) application for and received funding and experts' assistance from FAO; b) for the purpose of Project completion, a team of 8 experts (previous contributors to the soil mapping) was established.

Following our written request, the FAO (an organization of the United Nations) expressed interest in funding of the final works for Project completion. They sent an expert who was acquainted with all available scientific data. Following his positive feedback, an agreement was signed between the FAO and the Ministry of Agriculture, Forestry and Water Management, since the FAO as an UN organization can sign agreements only with governments or governmental bodies. In parallel with the agreement, a programme for Project completion was drawn up. The FAO approved the necessary funding, expert support and a corresponding equipment for completion of the part of the Project related to digitalization of the soil maps and creation of the data base on soil characteristics.

Subsequently, a team of 8, still active soil experts, who took part in the process of mapping of our soils, was established with the purpose of completing the Project. Their names are mentioned in the introductory part. Two more lecturers from the Faculty of Natural Sciences (Institute of Geography) joined this team: Prof. I. Milevski and Prof. S. Gorin, who helped in the process of development of topographic data set and preparation of soil maps for printing. During this period, the team of these 8 soil scientists completed the following tasks:

1. Finalization of the process of soil mapping, with soil survey of few remaining parts. This means that they completed the soil maps for the following sections: Prizren 4, Bitola 3 and 4 and Gostivar 1, 2 and 3. This task has been completed by four members of the team of soil scientists (M. Andreevski, K. Vasilevski, M. Markoski and J. Mitrikeski).

2. All non-soil digital data necessary for completion of the digital soil maps were completed.

3. A set of 62 soil maps in printed and digital form in a scale of 1: 50 000 and one for the whole territory of the country in a scale of 1: 200 000, was completed

4. The digital geo-database on soil characteristics was designed and created.

5. Previously completed common legend with cartographic units for all soil maps was adopted.

6. All soil study books containing soil survey results of all 10 regions and one for the whole of the Republic of Macedonia, were finalised.

7. All soil maps with soil study books were published.

8. An internet Web Portal was created in order to enable the use of the soil maps and soil properties data to broader audience.

DIGITALIZATION OF SOIL MAPS AND OF DATA BASE ON SOIL CHARACTERISTICS

Within the process of digitalisation of all soil survey results and soil maps, the Macedonian Soil Information System (MASIS) was created. MASIS is a soil information system that was established in accordance with the EU standards (EUCBN). It represents a modern digital geo-database where soil data as a whole (numerical and graphical) are integrated with the other natural variables. Data base organized in such a way represents a good source of information for the final users, and at the same time the system allows further development and upgrades of stored data.

Besides integrating of soil data, their characteristics and their spatial distribution, MASIS's main role is, by implementing of models and various geostatistical procedures, to produce:

- Various thematic maps that facilitate the localization of the spatial distribution of certain soil characteristics.
- Initial maps on soil suitability for cultivation of particular crops.
- Maps on risks associated with soil degradation in order to identify regions subject to different risks, to quantify different risks, and to estimate their impact on the agricultural production and the environment.
- Maps on spatial distribution of: pH, CaCO, organic matters, clay, dust and sand.

The vision of the MASIS system is to become an integrated electronic system, for efficient management of farms and agricultural production, with the aim of sustainable use of natural resources and environmental protection.

The soil maps that are integrated within MASIS are in a scale of 1 : 50 000 and represent the spatial distribution of the soils and borders among different soil mapping units and complexes. Beside this, the system contains soil characteristics data. In the frame of the interlinked data MASIS gives the spatial distribution of the soil types by hectares and percentages in a network of maps in a scale of 1 : 50 000, by municipalities and river basins. D. Mukaetov and M. Markovski were the major contributors to the process of digitalization.

PROJECT PROMOTION

The Project results were presented to our professional and scientific community in the spring of 2015 at the Ministry of Agriculture, Forestry and Water Management, and in spring 2016 at MASA. The history of the research and the difficulties during Project completion, the research results and the results from the mapping of our soils, as well as the digitalisation of these results, were presented by Acad. Gj. Filipovski, Prof. Dr. J. Mitrikeski and Prof. Dr. D. Mukaetov.

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ПЕДОЛОШКИ КАРТИ НА РЕПУБЛИКА МАКЕДОНИЈА

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Во овој преглед е опишан историјатот на изработката на 63 педолошки карти во печатена и дигитална форма, од кои 62 во размер 1 : 50 000 за одделните листови на топографските карти и една во размер 1 : 200 000 за целата Република. Проектот траеше близу 7 децении (од 1947 до 2015). За 10 подрачја заедно со педолошките карти се напишани и студии за почвите. Исто така, таква студија е напишана и за почвите на целата Република. За сите педолошки карти е составена заедничка легенда со 63 картографски единици. Опишани се сите користени класификации во тој долг период. Тие беа основа за составување на многуте легенди. Дадени се и површините на сите картографски единици. Опишана е и содржината на сите 11 студии за почвите. Извршена е дигитализација на сите карти и на базата на податоци за почвените својства. За таа цел на интернет е поставена web-страница (www.maksoil.ukim.mk). Резултатите од реализацијата на проектот се промовирани и претставени пред нашата научна и стручна јавност. Завршните работи за реализацијата на проектот се финансирани од FAO – организација на Обединетите нации.

Клучни зборови: педолошки карти на Р. Македонија; легенда на педолошки карти; површини на картографски единици; дигитализација на резултати од проект

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Original scientific paper

FORMATION CONDITIONS, GENESIS, EVOLUTION, CLASSIFICATION AND SOME FEATURES OF SOILS FORMED ON GYPSUM ROCKS IN THE REPUBLIC OF MACEDONIA

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The current paper studies the formation conditions, genesis, evolution, classification, morphological features, mechanical composition and chemical properties of soils formed on gypsum rocks in the Republic of Macedonia. The soils have been formed on mountain relief with steep slopes upon gypsum and anhydrite. Warm continental climate with inconsiderable impact of the Mediterranean climate prevails in the area. The soils occur underneath hill pastures, which are rather poor from a floristic point of view and they are characterized by minor canopy closure. Destruction of the natural forest vegetation and intensive grazing on the hill pastures that have remained following the destruction thereof have caused heavy soil erosion. Our research has ascertained that gypsic rendzic leptosol and gypsic pararendzina have been formed on gypsum rocks. Both soil types are distinguished by a light mechanical composition dominated by physical sand. Carbonates are present in both soil types in all soil assays while in certain soil assays the gypsum has been fully washed.

Key words: formation conditions; genesis; evolution; classification; gypsum rocks; gypsic pararendzina; gypsic rendzic leptosol

INTRODUCTION

Soils upon gypsum rocks in our country have not been studied yet; hence, there is not any data available from field and laboratory research. The aim of the current research is to provide initial data on the aforesaid soils in our country and wider in the Balkan Peninsula. We have observed the natural conditions of their formation, their genesis, evolution, classification along with their physical and chemical properties, with particular emphasis on the exchangeable ions composition and humus composition. Only a portion of the yielded results have been rendered here.

The current study is a part of a project within the framework of the MASA programme, which has funded the study. Field research and laboratory analyses have been conducted in line with the known methods [1–5].

Soils on gypsum rocks do not bear great significance for our agriculture and forestry given that they are underneath poor pastures. Due to their small-range distribution and specific features, in a number of countries these soils are specially protected and listed in the red book of natural rarities.

In former Yugoslavia, their presence was referred to in 1963, when they became part of the first version of soil classification as gypsic pararendzina [6]. In the subsequent versions of this classification they were eradicated due to their scarce distribution. In our literature, there is data that gypsic pararendzina have been formed upon gypsum rocks above the Radika River valley [7]. A definition of gypsic horizon [8] has also been provided, which used to be defined as gypsum [9], whereas the taxonomic unit containing gypsic horizon was labeled as gypsic [8]. Gypsic soil material was defined in our regosols [8]. Information on research into soils on gypsum rocks have been published in foreign literature [10–15].

RESEARCH RESULTS

In the vicinity of the villages of Dolno and Gorno Kosovrasti (Debar area), 7 soil profiles on gypsum rocks (Map 1) were excavated, studied and morphologically described, whereof four profiles were gypsic rendzic leptosol with A-R profile and three profiles were gypsic pararendzina with A-AC-C profile.

In the field, we observed the soil-forming factors determining the formation of these soils, their evolution, morphology and classification.

Map 1. Profile location

Soil-Forming Factors

Geographic position and relief

The relief characteristics of gypsum from Kosovrasti have been described before [16–18]. Those papers underscore the considerable solubility of gypsum $CaSO_4 \times 2H_2O$ and anhydrite $CaSO_4$, which results in subaerial erosion and pile-up forms in the relief similar to karst forms in limestone areas. Gypsum karren are such forms – vertical fractures through which water passes thereby dissolving the rock and creating fissures and diastromes. These soils are formed on mountain relief, distinguished by steep slopes, which is the reason why a larger section of the gypsic soils are eroded, the bare rock remaining on the surface. The small areas where these soils were found are characterized by mosaic microrelief. It comprises micro-indentations and micro-elevations. Soils occur in the micro-indentations.

Parent material

The rocks where the gypsic soils were formed have been geologically mapped on a scale of 1:25.000. In the geological map 1:100.000 [19], gypsic forms have been presented as gypsum and anhydrite. Anhydrite occurs in the inner section of the gypsic mass, where it gradually turns into alabaster. Organic matter, limestone fragments, hornstone mass and virgin sulphur are often found in the gypsic mass. In the field, we established that gypsum rocks contained $CaCO_3$ and silica residuum.

During field research, we took gypsum rock fragments from the excavated profiles (Table 1).

Table 1. Content of $CaSO_4$ and $CaCO_3$ in gypsum rocks from the studied profiles

Number of profile	$CaCO_3$ %	$CaSO_4 \times 2H_2O$ %
1 and 2	2.02	95.43
3	1.54	96.38
5	5.12	89.77
6	4.04	93.15
7	2.36	95.33

Climate

The data about Debar [20], which is in close proximity to the area of concern, will be utilized for climate description. Warm continental climate prevails in the area, coupled by minor impact of the Mediterranean climate coming from the Adriatic Sea, which is felt along the Radika River, where the profiles were excavated. The said impact is more intensely reflected on the pluviometric regime rather than on the heat regime. The average annual temperature in Debar is 11.8 °C. The lowest average monthly temperature in January is 0.7 °C, and the highest in July is 22.2 °C, with an amplitude of 21.5 °C. The absolute monthly maximum was measured in July, which is 38 °C, and the absolute monthly minimum in January –23.9 °C. The sum of temperatures in the vegetation period (above 10 °C) amounts to 3.627 °C. The total annual precipitation equals 890 mm. Most of the rainfall occurs in autumn and wintertime. December is the rainiest month of all with 120.8, then follows November with 115.2, October with 85.8, January with 84.2 and February with 81.6 mm. July is the most arid month with 33.9 mm. This timetable of precipitation is distinctive of the Mediterranean pluviometric regime. The annual drought index according to De Martone totals 40.8 whereas the annual precipitation factor according to Lang amounts to 75.4. Consistent with the latter, the climate is semi-humid while based on the heat indicator, the climate is moderately warm. In the course of the year, the moist and the arid periods give way to each other.

Such climate conditions accompanied by other soil-forming factors have an influence on the soil processes. The significant precipitation intensity and the frequent occurrence of downpours triggers erosion. The relatively high precipitation brings about washing of gypsum and $CaCO_3$ (degypsization and decarbonatization). The relatively high temperature is a reason for stronger mineralization of organic residues. Mull humus is formed in the soil and biogenic elements are produced.

Vegetation

These soils are distributed underneath hill pastures. Hill pastures are secondary vegetation formations derived from gradual and long-term degradation of the once widely distributed forest phytocenoses.

Hill pastures developing on gypsum on the territory of the Republic of Macedonia are still considered as a vegetation type that has not been studied sufficiently from a syntaxonomic aspect.

The field research into soils proceeded simultaneously with the vegetation research. The team included a phytocenologist – Academician V. Matevski. He studied the vegetation of the soils on gypsum rocks in the region of the village of Dolno Kosovrasti village. He made 8 vegetation records and described the plant communities in line with the commonly accepted methodology [21]. These communities develop at an altitude ranging between 625 and 735m. Hill pastures on soils upon gypsum rocks comprise a single plant community only: *Thymus ciliatopubescens* var. *poliothrix – Silene spegulifolia* subsp. *soskae* comm. The quoted community is of limited distribution and rather scarce from a floristic perspective. It does not occur on any other locality in the Republic of Macedonia. It belongs to the class *Festuco-Brometea* Br. Bl. et Tx. 1943, order *Astragalo-Potentilletalia* Micevski 1970 and the alliance *Saturejo-Thymion* Micevski 1970 [22].

The vegetation does not cover the soil surface in its entirety. The canopy closure totals 60–85%. The grass vegetation share in the biological accumulation of mature humus is with a narrow ratio of C : N. The humus is loaded with Ca-salts of humic acids and argillohumins, and it contributes to the creation of a fine granular structure. Its mineralization prompts a pile-up of biogenic elements.

Time impact

The duration of soil-forming processes is pivotal for the soil alterations generated by the processes thereof. In our circumstances, washing of easily-soluble matter and accumulation of organic matter take least time; therefore it is those processes that happen first [23]. Washing of $CaCO_3$ and $MgCO_3$ is slower provided they are present in the parent material. Given that time-consuming processes (clay formation, clay washing) do not occur in these soils, one may deduce that the soils are young from a temporal perspective as well as evolutionally young since they solely contain hor.A and C (or A and R) without hor. (B) or Bt, for whose formation a longer period of time is required.

Anthropogenic factor

The human activities have engendered large-scale modifications of the ecosystems and soils. The destruction of natural forest vegetation and the intensive grazing on the hill pastures that have remained after the destruction have caused heavy soil erosion. Sizable areas are now deprived of soils, and biological accumulation of organic matter and biogenic elements has diminished.

The enclosed Table 2 renders a number of soil-forming factors and the external soil morphology.

Table 2. Some soil-forming factors of soils formed on gypsum rocks in the Republic of Macedonia

Profile No	Parent material	Altitude	Exposure	Inclination	Stoniness	Occurrence of outcrops	Plant community
		m		%	%	%	
1	gypsum/anhydrite	735	southern	0–3	15–35	15–50	*Thymus ciliatopubescens* var. *poliothrix* – *Silene spegulifolia* subsp. *soskae* comm.
2	gypsum/anhydrite	735	southern	0–3	15–35	15–50	
3	gypsum/anhydrite	725	southern	>45	35–60	0.1–3	
5	gypsum/anhydrite	700	southeastern	>45	15–35	15–50	
6	gypsum/anhydrite	690	southeastern	>45	15–35	15–50	
7	gypsum/anhydrite	800	southeastern	>45	15–35	15–50	
8	gypsum/anhydrite	740	southeastern	>45	15–35	15–50	

Genesis, Evolution, Classification and Morphology

Genesis and evolution

The soil-forming processes in these soils depend on the elaborated array of soil-forming factors, whereof the following are worth underpinning: presence of rock rich in gypsum, $CaCO_3$ and silica residuum; then, presence of grass vegetation that is not heavy; rather substantial precipitation and relatively high temperature attributable to the low altitude. These conditions are different from those where rendzina on hard limestone and dolomites are formed (compact pure limestone, negligible residual remnants, absence of gypsum, high altitude, heavy grass vegetation, low temperature, greater precipitation).

The following processes take place within gypsic rendzic leptosol: (1) physical decay of rock, normally to the depth of the humus horizon; (2) gypsum dissolution and washing (degypsization); (3) dissolution and washing of $CaCO_3$ and $MgCO_3$ (decarbonatization, decalcification), and (4) pile-up of organic matter and formation of humus horizon.

The physical decay is of diverse intensity and it may be determined by the presence of skeleton particles in hor. A (up to 40%). It does not usually occur in rendzina on hard limestone and dolomites where only decarbonatization happens; therefore, skeleton particles are rarely found in them in hor. A. In addition, gypsum rocks are softer than limestone and more prone to physical decay resulting in regolith for formation of hor. A.

In contrast to $CaCO_3$, gypsum is much more soluble (20 parts anhydrite and 25 parts gypsum in 10.000 parts water), and solely water is essential for its dissolution. The dissolution of $CaCO_3$ necessitates the production of H_2CO_3 in the soil, which is the reason why its dissolution and washing are both much slower. Therefore, gypsum content in the profile rapidly plummets and the content of silica residuum increases (in %). Thus, water retention augments and plant population is facilitated along with the launch of the process of organic matter accumulation. The intensity of gypsum washing depends on the soil-forming duration. It may be washed by hor. A entirely, as in the case of two of the four studied profiles of gypsic rendzic leptosol.

The washing of $CaCO_3$ occurs at a later stage, together with accumulation of organic matter and its mineralization resulting in formation of H_2CO_3, which dissolves $CaCO_3$ yielding $Ca(HCO_3)_2$. The process is much more protracted; hence, the solum comprises much more $CaCO_3$ than $CaSO_4$.

With all of the aforementioned processes, soil genesis proceeds concurrently with regolith formation and relative enrichment with silica residuum. This facilitates plant population and emergence of the next process, i.e. accumulation of organic matter and its humification and mineralization with pile-up of biogenic elements. The solid rock is first inhabited by lichens and mosses. Regolith deepening allows for creation of prerequisites for inhabiting by grass and forest vegetation and by fauna representatives. The soil is enriched with humifying organic residue. The resulting humic acids bond with Ca and the clay of silica residuum. Thus, humus is formed, constituted of Ca-humates and argillohumins (1.6–6.3% humus in hor. A). Mineral acids (H_2CO_3) are also neutralized by bonding with $CaCO_3$, so there is not any soil acidification whatsoever (pH of water from 7.4 to 7.6). Accumulation of mull humus facilitates engendering of stable fine granular structure.

From this elucidation it becomes evident that gypsic leptosol is a prior stadium of gypsic rendzic leptosol, and that regolith formation proceeds simultaneously with soil genesis.

The processes of rendzina formation are herein marked as rendzinization [7]. These processes also develop in our gypsic pararendzina, the difference being that $CaSO_4$ washing also takes place in the latter and that gypsic regosol occurs as a previous stage. Contrary to gypsic rendzic leptosol, regolith formation does not proceed concurrently with soil genesis because it has been completed earlier during the formation of gypsic regosol. The genesis of gypsic pararendzina is distinguished by the following processes: (1) gypsum dissolution and washing (degypsization), thereby conducting its redistribution in the solum; (2) $CaCO_3$ and $MgCO_3$ dissolution and washing (decarbonatization, decalcification) initiated in the preceding stage of gypsic regosol; (3) melanization and mineralization of organic matter and establishment of a dark ("melanos") humus horizon and enrichment with biogenic elements.

Gypsum washing is done faster and more intensely owing to its greater solubility compared to $CaCO_3$, resulting in a big difference in its content between horizons A and AC. In one of its profiles hor. A is wholly degypsized.

$CaCO_3$ washing is enabled via mineralization of organic residues, which yields H_2CO_3. The process is lengthier, it is more time-consuming. $CaCO_3$ is washed only partially and the soil remains calcareous. This averts the evolution of these soils into the subsequent A-(B)-C stage.

The melanisation process, under the influence of grass vegetation, produces humic acids, which bond with Ca ions and secondary minerals from silica residuum (illite), thereby yielding Ca salts of huminic acids and humic-clay complexes (argillohumins). Mollic horizon and a stable granular structure are formed with the aforementioned process. Humification is accompanied by mineralization of organic residues from the easily-decomposable part of the humus, resulting in nutrients.

Rendzinization creates differences between gypsic regosol and gypsic pararendzina: a humus accumulative hor. A is formed, abundant in humus, darker, with more distinct structure, richer in biogenic elements, more fertile. Rendzinization does not alter the mechanical composition; there is neither clay formation nor clay transportation.

Gypsic rendzic leptosol and gypsic pararendzina as young soils loaded with $CaCO_3$ do not evolve into the next stage by hor. (B) formation, as it is the case with some other rendzina formed on friable calcareous rocks.

Classification

The latest classification of soils in the Republic of Macedonia [8] does not include again soils formed upon gypsum in view of the fact that they occupy minor areas. If the principles underlying the quoted classification are applied, it could be supplemented by the subtype gypsic pararendzina, which would fall into the type rendzina in the great soil group of mollisols. This subtype would comprise the variety on gypsum rocks and the form based on texture.

Pertaining to gypsic rendzic leptosol, from classification perspective, they are the closest ones to rendzina on hard limestone and dolomites but they are different from them given that they are formed on another parent material; they contain gypsum, carbonates and skeleton particles in the solum. Consequently, they might be separated as an independent type of gypsic rendzic leptosol in the great soil group of mollisols.

According to the criteria of World *reference base for soil resources* 2014 [24], gypsic rendzic leptosol would fit in the referential soil groups of leptosols, while gypsic pararendzina would belong to regosols. We have attempted to classify the studied soils in compliance with the aforesaid classification. On the basis of this classification, prof. 1, 3 and 5 will be classified as Humic-Calcaric-Leptosol, prof. 8 as Gypsiric-Calcaric-Leptosol, prof. 2 as Leptic-Calcaric-Regosol and prof. 6 and 7 as Gypsiric-Calcaric-Regosol.

Morphology

By their external morphology, gypsic rendzic leptosol and gypsic pararendzina are similar to rendzina on hard limestone and dolomites. They cover only a single section of the gypsum rock surface, in the depressions. The microrelief resembles a mosaic, and it features micro-depressions and micro-elevations that give way to each other at a small distance. Vegetation does not cover the surface soil in its entirety.

Gypsic rendzic leptosol sets itself apart with a profile shallower than gypsic pararendzina. The observed gypsic rendzic leptosol possesses a mollic horizon, lithic properties, calcareous soil material, and one profile contains gypsic soil material, too. The mollic horizon in the studied gypsic rendzic leptosol is 16-21cm in depth. Horizon A exhibits intense variation in depth at a small distance due to the uneven ground. Gypsic rendzic leptosol has a profile of the A-R type. The colour of the mollic horizon has been identified according to Munsell colour system in dry and moist condition (Table 3). In dry condition, the soil is gray-brown or dark gray-brown or light brown. Mollic horizon is friable, loose; it is non-coherent and easy to dig. The skeleton is always present to a lesser or higher extent.

Table 3. Soil colour, according to Munsell colour system

No of profile	Horizon and depth (cm)	Colour in dry condition	Colour in moist condition
Gypsic rendzic leptosol			
1	A 0–18	10YR 4/2 dark grayish-brown	10YR 3/2 very dark grayish-brown
3	(A) 0–16	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
5	A 0–21	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
8	(A) 0–17	10 YR 6/2 light brownish-gray	10YR 4/2 dark grayish-brown
Gypsic pararendzina			
2	A 0–19	10YR 4/2 dark grayish-brown	10YR 3/2 very dark grayish-brown
2	AC 19–32	10YR 6/2 light brownish-gray	10YR 4/2 dark grayish-brown
6	A 0–15	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
6	AC 15–24	5Y 7/2 light gray	2.5Y 5/2 grayish-brown
6	C1 24–50	2.5Y 8/2 white	2.5Y6/2 light brownish-gray
6	C2 50–80	2.5Y 8/0 white	2,5Y 7/2 light gray
7	A 0–15	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
7	AC 15–28	10 YR 7/1 light gray	10YR 6/2 light brownish-gray
7	C 28–43	10 YR 8/1 white	10YR 6/2 light brownish-gray

In contrast to rendzina on hard limestone and dolomites, it is scarcely overgrown with grass vegetation roots, and it is less humic. In a number of profiles, gypsum is washed by solum but carbonates are present in all profiles. In certain profiles, the reaction to $BaCl_2$ is weak while in some profiles white deposit occurs. Horizon A sharply passes through the solid rock, and in one profile the solid rock is physically decayed.

We have selected prof. 5 as a profile typical of gypsic rendzic leptosol, distinguished by the following morphological properties: A 0–21 mollic horizon with gray-brown colour in dry condition and a very dark gray-brown in moist condition; humic, calcareous, arid, friable, easy to dig, skeletal, permeated by scarce grass vegetation roots. Its structure is granular, very fine to fine, and distinctive. The addition of $BaCl_2$ results in emergence of white deposit. It harshly penetrates the solid rock via a sub-horizon of physically decayed gypsum.

The observed gypsic pararendzina have a mollic horizon, leptic properties, calcareous soil material, and in a number of profiles they have gypsic soil material. They possess a A-AC-C-R type of profile. The horizon colour is identified in line with the Munsell colour system (Table 3). The mollic horizon depth ranges between 15 and 19 cm, while the transitional AC horizon depth ranges between 9 and 13 cm. We have established carbonates in all horizons. Gypsum occurs in all horizons bar hor. A of prof. 2. All horizons are arid, friable and easy to dig. We shall elaborate on the morphological properties of the typical profile – prof. 6: A (0–15) mollic horizon with gray-brown colour in dry condition and a very dark gray-brown in moist condition; hugely humic, skeletal, calcareous. The addition of $BaCl_2$ results in a slight white deposit. It is dry, friable, easy to dig, intertwined by rare grass vegetation roots. Its structure is granular, very fine to fine, and distinct.

AC (15–24) transitional horizon with light gray colour in dry condition and a gray-brown colour in moist condition. It is hardly humic, skeletal, dry, friable, without structure, calcareous. A white deposit ensues from the addition of $BaCl_2$. It gradually passes into the C horizon.

C (24–80) parental material, white in colour in dry condition and light brownish-gray in moist condition. It is dry, friable, easy to dig, calcareous. A white deposit ensues from the addition of $BaCl_2$. It harshly penetrates a physically decayed gypsum rock.

LABORATORY RESEARCH RESULTS

Mechanical Composition

The results of the mechanical composition analyses are provided in Table 4.

Judging from the results, a conclusion may be drawn that gypsic rendzic leptosol contains much skeleton (approximately 30–40% skeleton). It is only prof. 8 that comprises little skeleton. As far as fine earth fractions are concerned, fine sand (44–88%) is dominant. There is much lesser presence of silt (17–24%) and coarse sand fractions (13–23%). Clay fraction (3–17%) comes last in this respect.

Table 4. Mechanical composition of soils formed on gypsum rocks in the Republic of Macedonia (in % of fine earth)

No of profile	Horizon and depth (cm)	Skeleton >2 mm	Coarse sand 0.2–2 mm	Fine sand 0.02–0.2 mm	Coarse + fine sand 0.02–2 mm	Silt 0.002–0.02 mm	Clay <0.002 mm	Silt+ clay <0.02 mm	Texture class by Scheffer & Schachtschabel
Gypsic rendzic leptosol									
1	A 0–18	35.98	15.3	44.3	59.6	23.4	17	40.4	sandy clay loam
3	A 0–16	39.31	23.2	35.4	58.6	24.5	16.9	41.4	sandy clay loam
5	A 0–21	29.75	13	67.2	80.2	16.6	3.2	19.8	loamy fine sand
8	A 0–17	3.94	4.1	88.2	92.3	2.1	5.6	7.7	loamy fine sand
Gypsic pararendzina									
2	A 0–19	46.2	14.5	49.7	64.2	19.5	16.3	35.8	sandy clay loam
2	AC 19–32	35.88	9.8	59.4	69.2	17.1	13.7	30.8	fine sandy loam
6	A 0–15	44.79	20.5	56.6	77.1	14.5	8.4	22.9	loamy fine sand
6	AC 15–24	21.92	9.4	78.1	87.5	3.1	9.4	12.5	loamy fine sand
6	C1 24–50	13.18	10	84.4	94.4	0.3	5.3	5.6	loamy fine sand
6	C2 50–80	17.55	9.4	83.6	93	0.3	6.7	7	loamy fine sand
7	A 0–15	21.19	10	80.8	90.8	4.5	4.7	9.2	loamy fine sand
7	AC 15–28	0.51	1.9	84.1	86	2.8	11.2	14	loamy fine sand
7	C 28–43	1.79	1.4	92.1	93.5	0.8	5.7	6.5	loamy fine sand

Physical sand is much more common than physical clay. Taking into consideration that skeleton and physical sand prevail in these soils, it may be construed that physical decay is intense in gypsic rendzic leptosol. Clay content is inversely proportional to the content of $CaCO_3$ + $CaSO_4$. The greater the share of $CaCO_3$ + $CaSO_4$, the lesser the content of silica residuum comprising clay. Thus, for instance, in prof. 1 and 3 the amount of $CaCO_3$ + $CaSO_4$ ranges from 13 to 25% whereas clay constitutes 17%, and in prof. 5 and 8 that amount is around 90% with only 2–3% clay. If mechanical composition of gypsic rendzic leptosol is compared to that of rendzina on hard limestone and dolomites [7], it will be ascertained that gypsic rendzic leptosol includes more skeleton and physical sand and less silt and clay. It testifies to the rather intense physical decay within gypsic rendzic leptosol. Besides, it is likely that non-soluble residuum in gypsic rendzic leptosol comprises coarser particles.

With respect to their mechanical composition, gypsic rendzic leptosol represent loamy fine sand and sandy clay loam.

As for gypsic pararendzina, there are data on a number of solum horizons. Skeleton content is also high (in hor. A 21–46%) in gypsic pararendzina, decreasing downwards; thus, in AC it occurs less and in C at least. Regarding fine earth fractions, in gypsic pararendzina, similar to gypsic rendzic leptosol, the fine sand fraction is most common in hor. A (50–80%), followed by coarse sand (10–20%), silt (5–20%) and clay (5–17%). An analogous relation between the quoted fractions is also found in the other horizons. The physical sand share prevails over that of physical clay. The physical sand content increases in depth while the content of physical clay diminishes. This is a result of decay and dissolution in hor. A.

Two profiles of these soils belong to the class of loamy fine sand, and one profile falls into the class of sandy clay loam.

The high skeleton content, low clay content and dominance of physical sand over physical clay is a common feature of all soils formed from gypsum rocks in our country.

Chemical Properties

The results of the chemical properties of soils formed on gypsum rocks are provided in Table 5.

Content of $CaCO_3$ and $CaSO_4$

In the soils formed upon gypsum rocks, there is $CaCO_3$ (from 2.85–75.59%) in all horizons, the principal reason being that parental material (gypsum) is not pure and instead it contains $CaCO_3$.

In gypsic rendzic leptosol, $CaCO_3$ share in hor. A amounts to 13–75%. In these young soils, $CaCO_3$ is slightly washed. In gypsic pararendzina, hor. A is also very abundant in $CaCO_3$ (37–73%), and it is either unwashed or barely washed; hence,

Table 5. Chemical properties of soils formed on gypsum rocks in the Republic of Macedonia

No of profile	Horizon and depth cm	$CaCO_3$ %	$CaSO_4 \times 2H_2O$ %	pH		Humus %	Total N %	C/N	Availability of mg/100 g soil	
				H_2O	nKCl				P_2O_5	K_2O
Gypsic rendzic leptosol										
1	A 0-18	24.61	0	7.60	7.00	6.26	0.42	8.64	6.56	9.66
3	A 0-16	12.79	0	7.50	7.00	5.49	0.38	8.39	42.45	10.86
5	A 0-21	75.34	3,92	7.40	7.25	4.12	0.23	10.4	2.75	5.60
8	A 0-17	14.25	77,08	7.35	7.20	1.56	0.08	11.3	1.83	3.20
Gypsic pararendzina										
2	A 0-19	36.89	0	7.55	7.25	6.19	0.42	8.55	7.33	9.26
2	AC 19-32	75.59	1.53	7.55	7.35	3.57	0.24	8.58	23.15	4.02
6	A 0-15	73.30	2.95	7.25	7.15	6.38	0.35	10.6	2.38	7.60
6	AC 15-24	16.70	65.74	7.45	7.30	1.08	0.07	8.86	2.20	2.40
6	C 24-50	17.10	77.24	7.40	7.20	0.34	0.02	9.90	2.02	2.00
6	C 50-80	10.18	84.28	7.40	7.25	0.30	0.02	8.65	1.28	1.20
7	A 0-15	63.12	16.89	7.40	7.25	3.95	0.19	12.1	2.02	6.00
7	AC 15-28	3.34	88.92	7.50	7.45	1.19	0.07	9.86	0.18	1.60
7	C 28-43	2.85	92.72	7.40	7.25	0.57	0.04	8.27	0.18	1.20

in the lower profile section it occurs less. One of the reasons for this state could be that the lower horizons are extremely rich in $CaSO_4$, so that $CaCO_3$ percentage is rather reduced.

With reference to $CaSO_4$ content in gypsic rendzic leptosol, in two profiles it is absent from hor. A, in the third profile its presence is negligible, and it is abundant only in a single profile. Gypsum absence may be caused by its heavy washing due to greater solubility.

In gypsic pararendzina, the difference in gypsum content can be monitored along the profile depth. In prof.2 it has been washed by hor. A and in AC it is found only with 1.5%. In the remaining two profiles gypsum has been heavily washed, so its occurrence in hor. AC is multiple. The higher the gypsum content, the lesser the $CaCO_3$ content (relative depletion). It becomes apparent that hor. A has been exposed to gypsum washing for the longest period of time.

Soil reaction

The reaction in water in all soils formed on gypsum rocks ranges within narrow limits between 7.25 and 7.60. It is only hor. A of prof. 6 that has a neutral reaction whereas in all other horizons in all soils formed on gypsum rocks it is faintly alkaline.

In all studied assays, the reaction in nKCl ranges within narrow limits between 7 and 7.45. In gypsic rendzic leptosol, the interval is smaller (from 7.00 to 7.25). It is specific that the disparity between pH H_2O and pHn KCl is greater (0.5 to 0.6) in gypsic rendzic leptosol not comprising gypsum compared to that containing gypsum (0.15).

In gypsic pararendzina, pH nKCl in hor. A ranges between 7.15 and 7.25. These values ascend in depth. In hor. A of gypsic pararendzina, the difference in values of pH H_2O and pH nKCl ranges between 0.10 до 0.30. Such small variations are not the case in other soils in our country.

Humus Content

The humus content in gypsic rendzic leptosol varies from 1.6 до 6.3. It is inconsiderable (1.56%) only in prof.8 whereas in the other three profiles it is higher (4.12–6.26%).

In gypsic pararendzina, the humus content in hor. A is rather high (from 3.95 to 6.38%) in our circumstances since these soils are not cultivated. The humus content rapidly declines in depth.

Content of Nutrients

In soils on gypsum rocks rich in $CaCO_3$ + $CaSO_4$ there is less silica residuum providing water and nutrients for plants, which is the reason why the content of nutrients (except for Ca and S) in them is lower.

The total nitrogen content in gypsic rendzic leptosol varies between 0.08 and 0.42% and it is contingent on the humus content. Hor. A of gypsic rendzic leptosol is very rich (prof. 1 and 3), rich (prof. 5) and medium-rich (prof. 8) in total nitrogen. The identical horizon of gypsic pararendzina is very rich (prof. 2 and 6) and medium-rich (prof. 7) thereof.

The proportion of C/N in hor. A of gypsic rendzic leptosol varies from 8.4 to 11.3, and in gypsic pararendzina it varies from 8.6 to 12.1.

According to Al method, gypsic rendzic leptosol in hor. A is poor in easily available phosphorus (prof. 1, 5 and 8) and medium-rich (prof. 3), and all gypsic pararendzina is poor thereof.

As regards the content of easily available potassium, all profiles of soils formed on gypsum rocks are poor.

The content of exchangeable ions and the humus composition will be presented in a separate paper.

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УСЛОВИ ЗА ОБРАЗУВАЊЕ, ГЕНЕЗА, ЕВОЛУЦИЈА, КЛАСИФИКАЦИЈА И НЕКОИ СВОЈСТВА НА ПОЧВИТЕ ОБРАЗУВАНИ ВРЗ ГИПСЕНИ СТЕНИ ВО РЕПУБЛИКА МАКЕДОНИЈА

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Во овој труд се проучени условите за образување, генезата, еволуцијата, класификацијата, морфолошките својства, механичкиот состав и хемиските својства на почвите образувани врз гипсени стени во Република Македонија.

Почвите се образувани на планински релјеф со стрмни наклони врз гипс и анхидрит. Во подрачјето доминира топлата континентална клима со слабо влијание на медитеранската клима. Овие почви се јавуваат под брдски пасишта кои се флористички доста сиромашни и се одликуваат со мала покровност. Со уништување на природната шумска вегетација и со интензивна испаша на брдските пасишта што останале по тоа уништување е предизвикана силна ерозија на почвата. Од нашите проучувања констатиравме дека врз гипсени стени се образувани гипсени црници и гипсени рендзини. И двата почвени типа се одликуваат со лесен механички состав со преовладување на физичкиот песок. Карбонатите се присутни во двата почвени типа во сите почвени проби, додека во некои почвени проби гипсот е целосно промиен.

Клучни зборови: услови за образување; генеза; еволуција; класификација; гипсени стени; гипсена рендзина; гипсена црница

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Original scientific paper

NEW SPECIES FOR THE FLORA OF THE REPUBLIC OF MACEDONIA

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During floristical investigation in northen, eastern and north-eastern parts of the Republic of Macedonia four taxa of vascular plants were found which were not previously reported for the country – *Andrachne telephioides* L., *Chorispora tenella* (Pallas) DC., *Nepeta parviflora* M. Bieb. and *Marrubium pestalozzae* Boiss. The genus *Andrachne* and genus *Chorispora* are new genera for the territory of the Republic of Macedonia.

Kew words: flora; Macedonia; distribution; *Andrachne telephioides* L.; *Chorispora tenella* (Pallas) DC.; *Nepeta parviflora* M. Bieb.; *Marrubium pestalozzae* Boiss

INTRODUCTION

Floristic researches continually carried out on the territory of the Republic of Macedonia keep supplementing current data by adding new information concerning genera and species belonging to previously published families in the edition "Flora of the Republic of Macedonia", as well as families that are yet to be published in the future volumes of this edition. This paper mentions the first data regarding distribution of 4 new species on the territory of the Republic of Macedonia, which had been discovered in the past period – *Andrachne telephioides* L. (Euphorbiaceae, Phyllanthaceae), *Chorispora tenella* (Pallas) DC. (Brassicaceae), *Nepeta parviflora* M. Bieb. (Lamiaceae) and *Marrubium pestalozzae* Boiss. (Lamiaceae).

EXPERIMENTAL SECTION

Floristic researches were carried out in the northern, eastern and south-eastern parts of the territory of the Republic of Macedonia (Skopje, the surroundings of Štip, Ovče Pole and the surroundings of Kriva Palanka). Herbarium material is deposed in the Herbarium of the Institute of Biology, Faculty of Natural Sciences and Mathematics in Skopje (MKNH). When determining the herbarium material, appropriate literature was consulted (Prodromus Florae peninsulae Balcanicae, I–II [1, 2]; Flora Europaea, I–III [3]; Flora of the Republic of Macedonia, 1(3–4) [4, 5] and other regional floras), as well as some special papers and databases (Euro+Med Plant Base [6]) dealing with taxonomy, nomenclature and chorology of the taxa studied.

RESULTS AND DISCUSSION

Andrachne telephioides L.

Mk Štip: Isar, along the walkway to the top of the hill, 350 m, 15.06.2013 (leg. et det. V. Matevski) (MKNH)

Distribution range of the species *Andrachne telephioides* covers the territory of the Mediterranean, South-East Europe, Caucasus, Southern, South-Western and as far as Central Asia and East Africa. As far as European areas are concerned, this species is distributed in dry, arid and semi-arid regions of Bulgaria, Crete, Greece, Spain, Italy, France, parts of Former Yugoslavia, Crimea, Ukraine (Tutin [7]; Euro+Med Plant Base [6]).

On the territory of the Republic of Macedonia, *Andrachne telephioides* was first found in the surroundings of Štip (Figure 1), in one of the aridest regions on the territory of the Republic of Macedonia. It grows on trampled places, near the paved paths leading towards the Fortress of Isar which rises above the Bregalnica river. This river is a kind of a corridor via which modified Sub-Mediterranean climate reaches the eastern parts of Macedonia (across Ovče Pole, Štip ravine, as far as Kočani-Vinica ravine). At the same time, this river is a significant phyto-geographic corridor for a great number of Mediterranean, particularly East-Mediterranean and Sub-Mediterranean plants (*Astragalus sinaicus, Buglossoides sibthorpiana, Cachrys cristata, Centaurium spicatum, Echinophora sibthorpiana, Ephedra major, Hypericum annulatum, Malvella sherardiana, Onobrychis pindicola, Pistacia terebinthus, Saxifraga graeca, Sideritis lanata, Silene scorpilii, Trifolium stellatum* and others), thus contributing considerably to expanding their range of distribution in these regions.

This species was not registered when studying the family *Euphorbiaceae* in the edition Flora of the Republic of Macedonia (Micevski [5])

This genus and species is new for the flora of the Republic of Macedonia.

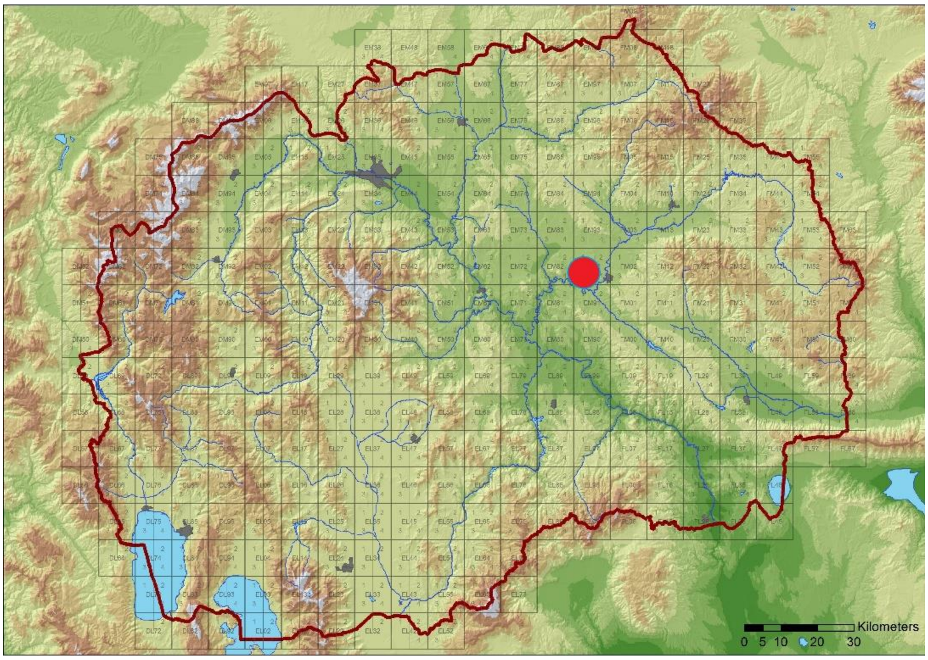

Figure 1. *Andrachne telephioides* – Map of distribution in the Republic of Macedonia

***Chorispora tenella* (Pallas) DC.**

Mk Skopje–railway station Madžari, alongside the railway line, 210 m, 17.04.1999 (leg. et det. V. Matevski) (MKNH)

According to Atlas Florae Europeae (Jalas et al. [8]), Kästner [9] and Euro+Med Plant Base [6], natural range of distribution of *Chorispora tenella* stretches from the steppes in Southern Russia (as far as Siberia) to Slovenia, Serbia – Vojvodina, Croatia, Slovakia, Romania, Bulgaria, Moldova, Crimea, Ukraine, and Trans-Caucasus region (Azerbaijan, Armenia, Georgia). In many parts of Central Europe this plant grows as weed in land farmed with grain crops, and as introduced plant (neophyte) it has been registered in Austria, Germany, Belorussia, the Czech Republic, Estonia, Finland, Latvia, Lithuania, Slovakia, Greece.

As to the territory of the Republic of Macedonia, this plant has been registered on one locality only, in the outskirts of the city of Skopje, nearby the railways in the vicinity of the railway station in Madžari (Figure 2). Relevant books state that possible habitats of this species – *Chorispora tenella* - might be places where grain crops are being unloaded either from railway freight cars or from ships. Having in mind the location this species had been registered at (nearby railway tracks, in the vicinity of a railway station), we could easily assume that on the territory of the Republic of Macedonia it is also an introduced species, which uses railway transportation as a means of expanding its range of distribution.

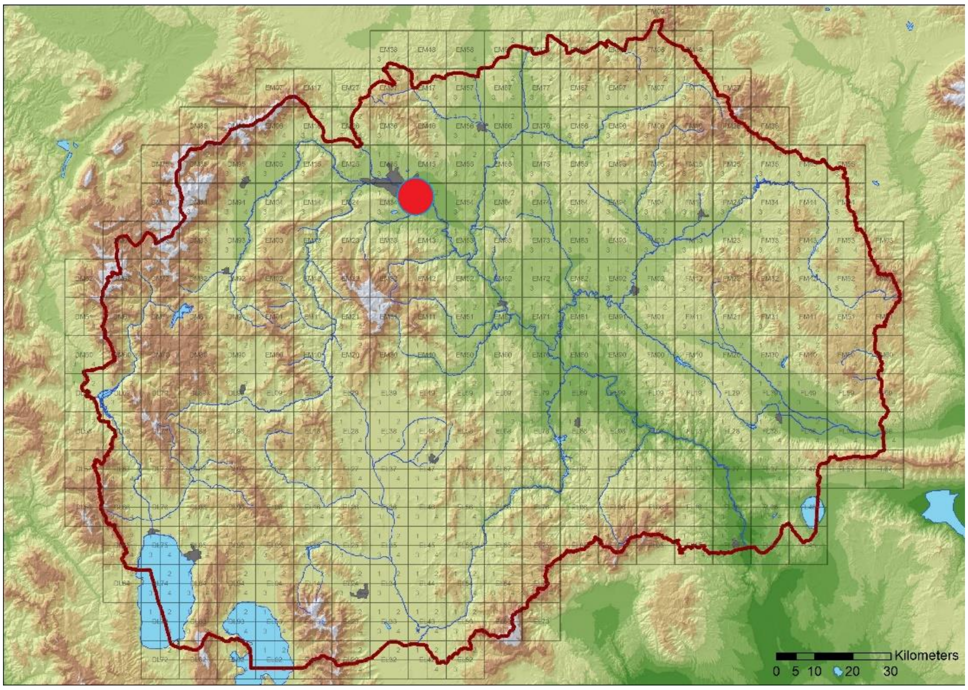

Figure 2. *Chorispora tenella* – Map of distribution in the Republic of Macedonia

This species was not registered when studying the *Brassicaceae* family in the edition Flora of the Republic of Macedonia (Micevski [4]).

This genus and species is new for the flora of the Republic of Macedonia.

***Nepeta parviflora* M. Bieb (=*Nepeta ucranica L.* subsp. *parviflora* (M. Bieb.) M. Masclans de Bolos)**

Mk Ovče Pole – between Vrsakovo village and Sudič village, 41.838445433516895 N, 22.138 16716877755 E, 23.05.2015 (leg. et det. V. Matevski) (MKNH)

Nepeta parviflora is a plant species spread in South-Eastern Europe – Bulgaria, Romania, Ukraine, Crimea, Southern Russia (Turner [10], Euro+Med Plant Base [6]). According to the report of the Ministry of Environment of Hungary [11], western border of distribution of this species is considered to be on the territory of Hungary, where it used to be considered disappeared for a long time, but has recently been registered on the territory of this country.

On the territory of the Republic of Macedonia, this species is with quite limited distribution. It has been registered on one locality only, in the aridest, steppe-like region of Macedonia, in Ovče Pole, between the villages of Vrsakovo and Sudič (Figure 3). Most of the areas where this species thrives have been turned into farmland, whereas only on small patches, mainly on the higher surrounding hills, there are still preserved fragments with steppe-like vegetation. It is exactly this type of location, predominated by paleogenic and neogenic marl grounds, where this population develops, with a host of steppe and endemic species thriving in such regions, some of which being *Anchusa italica, Anchusa macedonica, Astragalus parnassi, Centaurea finazzeri, Convolvulus holosericeus, Echinophora sibthorpiana, Ferulago macedonica, Phlomis herba-venti* subsp. *pungens, Salvia aethiopsis, Salvia jurisicii, Stipa bromoides, Ziziphora capitata*, etc.

Regarding the taxonomic status of *Nepeta parviflora*, it is still subject of additional studies, taking into consideration its high similarity to the species *Nepeta ucranica*. In Euro+Med Plant Base [6], it is added as subspecies to the species *Nepeta ucranica* L. (*Nepeta ucranica* subsp. *parviflora* (M. Bieb.) M. Masclans de Bolos). Still, despite the fact that there is similarity of this better taxon to the species *Nepeta ucranica*, the prevailing opinion is that *Nepeta parviflora* should be considered as a indipendent species (Turner [10]). This view is supported by the studies of Pădure [12], related to the morpho-anatomic features of the flowers and inflorescens of the the species belonging to genus *Nepeta* on the territory of Romania.

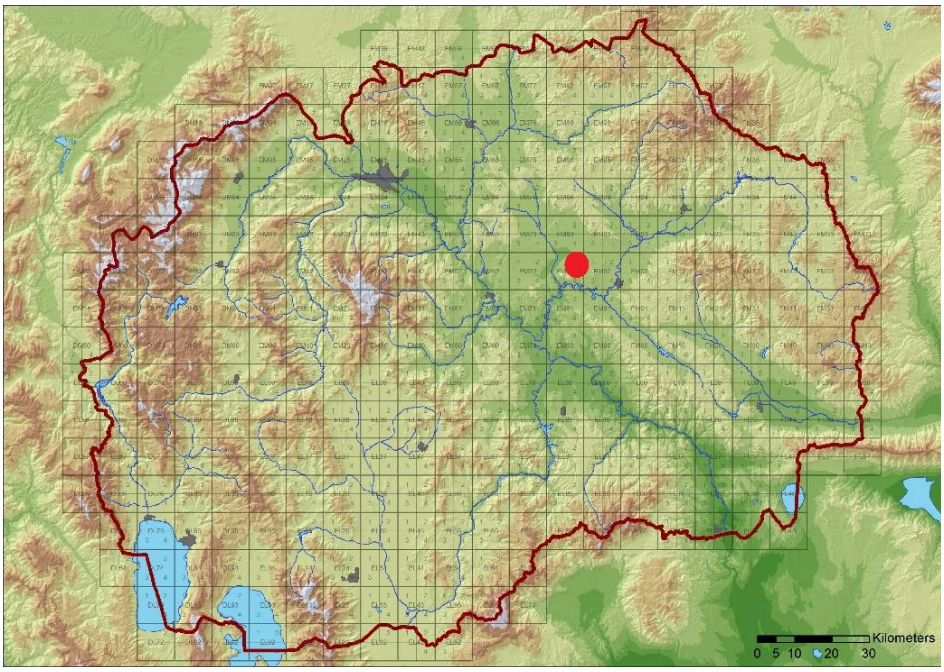

Figure 3. *Nepeta parviflora* – Map of distribution in the Republic of Macedonia

Marrubium pestalozzae **Boiss.**

Mk Kriva Palanka – Psača village, on ruderal site, 42° 10' 11'' N, 22°12' 18'' E; 514 m, 5.10.2006 (leg. et det. V. Matevski) (MKNH)

Taxonomic status and position of the taxon *Marrubium pestalozzae* is still deemed problematic and unclearly determined. Accordingly, there is a variety of opinions with reference to its taxonomic value. In the editions Flora Europaea [13] and Euro+Med Plant Base [6], its taxonomic status is clearly support its consideration as independent species, whereas in Flora of Bulgaria [14] it is considered as a synonym of the species *Marrubium parviflorum* L.

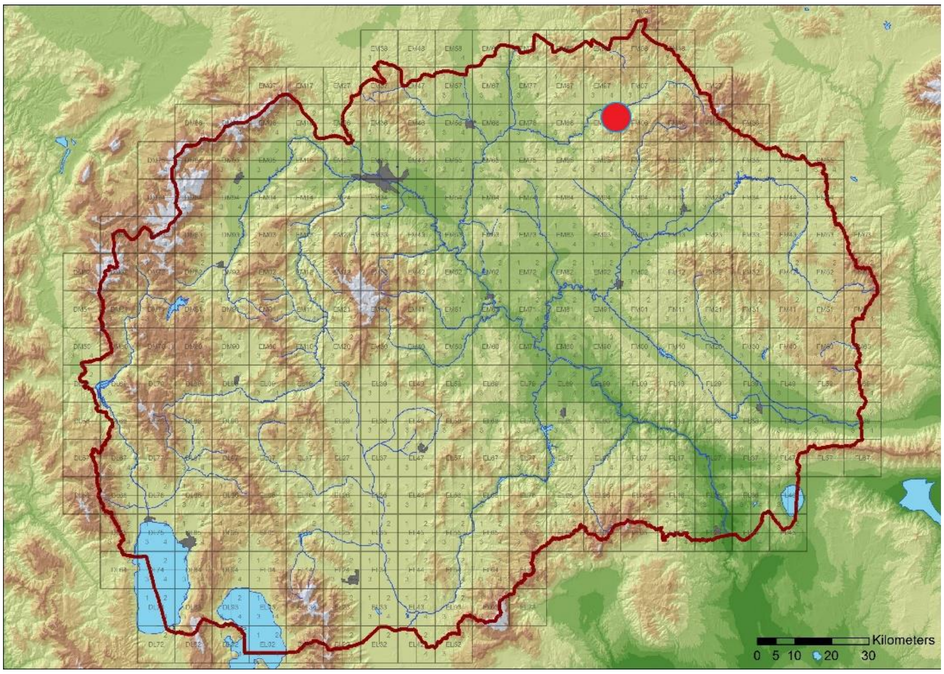

Figure 4. *Marrubium pestalozzae* – Map of distribution in the Republic of Macedonia

In Euro+Med Plant Base [6], where both species – *Marrubium pestalozzae* and *Marrubium parviflorum* – are listed, there is a note that these two species are strongly likely to be one taxon ("perhaps identical with *M. parviflorum*"). Differentiation between these two species is made based on slight morphological differences concerning the number, size and position of the calyx teeth. Analysis of the herbarium material from the territory of the Republic of Macedonia (the surroundings of Kriva Palanka) has shown that this species is more likely consistent with the diagnostic description of *Marrubium pestalozzae*.

According to the map of range of distribution presented in Euro+Med Plant Base [6], the range of distribution of *Marrubium pestalozze* covers the territories of Bulgaria, Greece, Ukraine, Crimea and central and southern parts of European part of Russia, whereas the range of distribution of *Marrubium parviflorum* stretches on the territories of Turkey and trans-Caucasus region (Azerbaijan, Armenia and Georgia).

The species *Marrubium pestalozzae* has been registered in northern-eastern parts of the territory of the Republic of Macedonia, in the surroundings of Kriva Palanka, the village of Psacha. It grows in ruderal habitats, in the centre of the settlement, alongside the asphalt road Kumanovo–Kriva Palanka (Figure 4).

Acknowledgement. The investigation was supported by the project fund of the Macedonian Academy of Sciences and Arts.

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НОВИ ВИДОВИ ЗА ФЛОРАТА НА РЕПУБЛИКА МАКЕДОНИЈА

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За време на флористичките истражувања во северните, источните и северо-источните делови на Република Македонија беа откриени 4 видови васкуларни растенија, кои претходно не беа регистрирани на нејзината територија – *Andrachne telephioides* L., *Chorispora tenella* (Pallas) DC., *Nepeta parviflora* M. Bieb. и *Marrubium pestalozzae* Boiss. Истовремено, родовите *Andrachne* и *Chorispora* претставуваат нови родови за територијата на Република Македонија.

Клучни зборови: флора, Македонија, распространување, *Andrachne telephioides* L., *Chorispora tenella* (Pallas) DC, *Nepeta parviflora* M. Bieb., *Marrubium pestalozzae* Boiss.

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Original scientific paper

THE GENUS DRYOPTERIS (PTERIDOPHYTA: DRYOPTERIDACEAE) IN THE FLORA OF THE REPUBLIC OF MACEDONIA – 30 YEARS AFTER MICEVSKI'S FLORA –

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This article presents the records about four new Buckler fern (*Dryopteris*) species for the territory of the Republic of Macedonia and new data about the distribution of some rare Buckler fern species.

Dryopteris is one of the most complex fern genera in Europe. Hybridization and apomixis among some of the species contribute to difficulties and uncertainties for identification of individual species. That, coupled with lack of research on ferns in Macedonia for the last 30 years, resulted in a low level of knowledge within this vascular plants' group.

The field research of the flora of Macedonia and thorough check of two herbaria (MKMEL and MKNH) in Skopje revealed presence of four new Buckler fern species in Macedonia: *Dryopteris affinis* subsp. *jessenii*, *D. oreades*, *D. mindshelkensis* and *D. expansa*. Additionlly, several other localities for rare species: *D. borreri*, *D. dilatata* and *D. carthusiana* were reported.

Further research is needed to fill the remaining gaps, particularly in relation to identification of hybrids and more detailed study of the distribution pattern of rare Buckler fern species.

Key words: *Dryopteris affinis*; *Dryopteris oreades*; *Dryopteris mindshelkensis*; *Dryopteris expansa*; Republic of Macedonia; rare ferns

INTRODUCTION

Buckler fern (*Dryopteris* Adans.) stands for one of the most complex genera among the European pteridophytes. According to Plant List [1], genus *Dryopteris* includes 1,458 accepted and unassessed names of species rank and 35 names of infraspecific rank worldwide (http://www.theplantlist.org/). At the same time, Euro+Med Plant Base [2] recognizes 30 *Dryopteris* species and 11 subspecies in Europe and Mediterranean region [2]. Beside the relatively high number of species in the genus, the complexity comes from the high level of hybridization among many different species and subsequent apomictic reproduction characteristics for some of the species (*Dryopteris affinis* group in particular), Fraser-Jenkins [3, 4]. Hybridization and apomixis are the main reasons for the origin of some species, morphologically separated by fine discrete characters [4]. Owing to above reasons, there was considerable confusion about Dryopteris taxonomy, thus resulting with complex synonymy and different treatment in existing standard floras, which makes identification of the particular species difficult and in some cases problematic. This particularly stands for the taxa of *D. affinis* group for which the concept of Fraser-Jenkins [4] is now accepted by the majority of researcher (see Euro+Med PlantBase) [2].

In the flora of the Republic of Macedonia six Dryopteris species are known so far, Micevski [5]: *Dryopteris filix-mas* (L.) Schott, *D. borreri* (Newman) Newman ex Oberh. & Tavel, *D. villarii* (Bellardi) Schinz & Thell., *D. pallida* (Bory) Maire & Petitm., *D. carthusiana* (Vill.) H. P. Fuchs, and *D.*

dilatata (Hoffm.) A. Gray**.** Extensive and detailed research in that time and after printing of Micevski's Flora in 1985, [3, 4, 6–18] put a new light on the knowledge about the taxonomy and chorology of this genus. These data and some recent findings in Macedonia suggest that the representation of the Dryopteris species in the country might be underestimated.

The aim of this work was to explore the Dryopteris collections in MKMEL! and MKNH! [19], to identify the species in the light of the new concept for Dryopteris taxonomy and to distinguish potential new taxa. The final goal was to assess the status of the genus Dryopteris in the flora of the Republic of Macedonia.

METHODS

The study was based on the fieldwork on the territory of the Republic of Macedonia during the last two decades and the collected and stored plant material in the Herbarium Melovskiorum (MKMEL!), as well as on the check of the Macedonian National Herbarium (MKNH!). The abbreviations of the herbaria follow Index Herbariorum [19]. Besides the field surveys, relevant literature sources were used for supplementation of the distribution records.

Identification of the specimens was performed on the basis of the keys from [10; 15], as well as Fraser-Jenkins [4] for *D. affinis* group. The detailed morphological analyses and descriptions of individual species in [20–27] were valuable for proper identification. Beside the analysis of standard morphological characters, light microscopy was applied for identification of members of the *D. dilatata* group. The spores were analyzed for perispore ornamentation rather than for dimensions of the spores. At least 10 spores from at least three herbarium specimens (*D. dilatata* and *D. carthusiana*) or two specimens in case of *D. expansa* were analyzed. An effort was done to avoid spore contamination during preparation of glycerol slides (by taking spores only directly from the sporangia). Only few spores were photographed and presented in Figure 3 for comparison.

We followed the nomenclature of the taxa used in Euro+Med PlantBase [2]. The distribution of the species was mapped on 10 × 10 km using the UTM grid system (UTM Zone 34T) and Military Grid Reference System (MGRS) projection [28], modified by Avukatov (unpublished) to 5 km × 5 km for the purpose of this paper. The quotation of the distribution locations and habitats for all records in this article follows the MAKMEL data base pattern. The regional division of Melovski *et al*. [29] was used to present the general geographic position of the localities.

RESULTS AND DISCUSSION

Among the known Buckler fern taxa in the Republic of Macedonia, *D. filix-mas* is the most frequent and abundant and *D. villarii* and *D. pallida* are frequently found on limestone mountains in western Macedonia, while *D. borreri*, *D. carthusiana* and *D.dilatata* are very rare species [5].

The present work adds four new Buckler fern species to the flora of the Republic of Macedonia and new distribution data for rare species.

Dryopteris affinis (Lowe) Fraser-Jenk. **subsp. *jessenii*** (Fraser-Jenk.) Fraser-Jenk., Fern Gaz. 18 (1): 5 (2007)

D. affinis is a diploid apomict which is nominal species of the complex *Dryopteris affinis* aggregate together with other seven species [4, 17]. Up to now, five subspecies, including the nominal one, were described [4], out of which three can be found across the Balkan Peninsula: subsp. *affinis* in Slovenia, Croatia, Greece, Bulgaria (doubtful) and Romania; subsp. *punctata* in Slovenia and Croatia and subsp. *jessenii* in Serbia and Romania [2, but on the basis of 13; 4]. The results of this article show that *D. affinis* subsp. *jessenii* is distributed in the Republic of Macedonia as well, where it was recorded only on Plačkovica Mt. (Figure 1). It was also recently reported for Poland [30].

First chorological records

Plačkovica: Selska Reka valley – above v. Laki (between Strumički Rid and Kartal – below and above the inflow of Lomska Reka), open grassy site next to the river in beech forest 930–950 m a.s.l., 24.10.2014, leg.&det. Lj. Melovski (MKMEL! 08238); Plačkovica: Selska Reka valley – above v. Laki (next to the stream Lom), next to the stream in beech forest, 1110 m a.s.l., 11.09.2016, leg.&det. Lj. Melovski (MKMEL! 08992, 08996-08998); Ibid., 1065 m a.s.l., (MKMEL! 09000-09002); Plačkovica: Selska Reka valley – above v. Laki (close to the stream of Selska Reka), at the edge of beech forest, 860 m a.s.l., 11.09.2016, leg.&det. Lj. Melovski (MKMEL! 08999).

The finding of *D. affinis* subsp. *jessenii* far from its main range is curious. However the specimens found on Plačkovica Mt. have typical morphological characteristics of *D. affinis* subsp. *jessenii* (Fig. 2) as described by Fraser-Jenkins [4]. Besides, it is not a rare case that Carpathian species spread to the south in the north-eastern Macedonian mountains (e.g. *Viola dacica* Borb., [32]). The new finding in the southern (Carpathian) part of Poland [30] shows that the subspecies is spreading its range to the north as well.

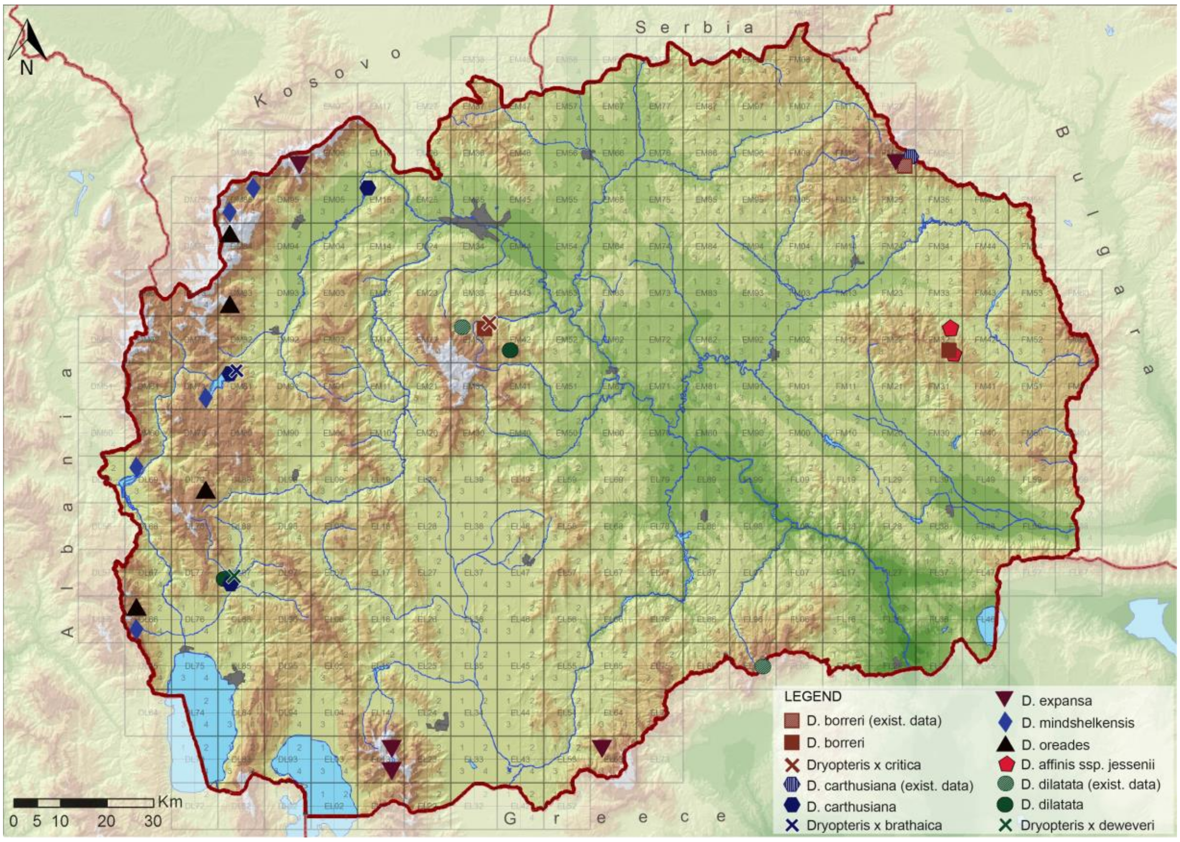

Figure 1. Distribution map of the first records, new records and literature data of the presented *Dryopteris* taxa in the Republic of Macedonia

Dryopteris borreri (Newman) Newman ex Oberh. & Tavel, Verh. Schweiz. Naturf. Ges. 118: 153 (1937)

This triploid apomict is the most widespread species in the *D. affinis* group [4]. However, it is a rare species in Macedonia – the only known locality up to now was Osogovo Mts. [5] (Fig. 1). It can be relatively easily distinguished from *D. affinis* by its indusia which look more like those of *D. filix-mas*, however in concordance with other morphological characters (Fig. 2).

Existing chorological record

Osogovo-Sasa. Beside the rocks close to the river. 1050 m.n.v. 15.VII.1967, leg. K. Micevski, det. Mayer & Micevski (MKNH! 000301, 000302, 000312).

New chorological records

Plačkovica: Selska Reka valley – above v. Laki (next to the stream Lom), next to the stream in beech forest, 1035 m a.s.l., 11.09.2016, leg.&det. Lj. Melovski (MKMEL! 09003, 09005, 09006); Mokra Planina – Golešnica: Mala Reka valley – just below the junction of the Mumdžica and Sipačan streams, close to the stream in beech forest, 950 m a.s.l., 25.09.2016, leg.&det. Lj. Melovski (MKMEL! 09026).

The species remains rare (Figure 1) which is probably realistic since Macedonia is at the southern border of its range in Europe (excluding Turkey) [2]. It is also comparatively rare in Bulgaria and was only recently reported [24] if one considers that it is a common species in Europe.

Dryopteris oreades Fomin, Monit. Jard. Bot. Tiflis 18: 20 (1910)

Mountain male fern (*D. oreades*) has interesting, rather disjunct distribution range. It can be found in west and west-central Europe, extending to N.C. Italy [10], in the Caucasus region and Turkey as well as in Romania [2]. It is possible that it has been overlooked in the past researches in the fern floras, although it is easily recognizable by its sori (high indusium which lifts slightly and remains embracing sporangia even after spores' ripening, see Figure 2). Future research can reveal new findings. Taxonomic remarks: the 'scattered minute glands' on the underside of the pinnae of Macedonian plants cannot be seen, except for the youngest fronds; some of the plants have more or less acute teeth at the tips of the pinnules instead of blunt.

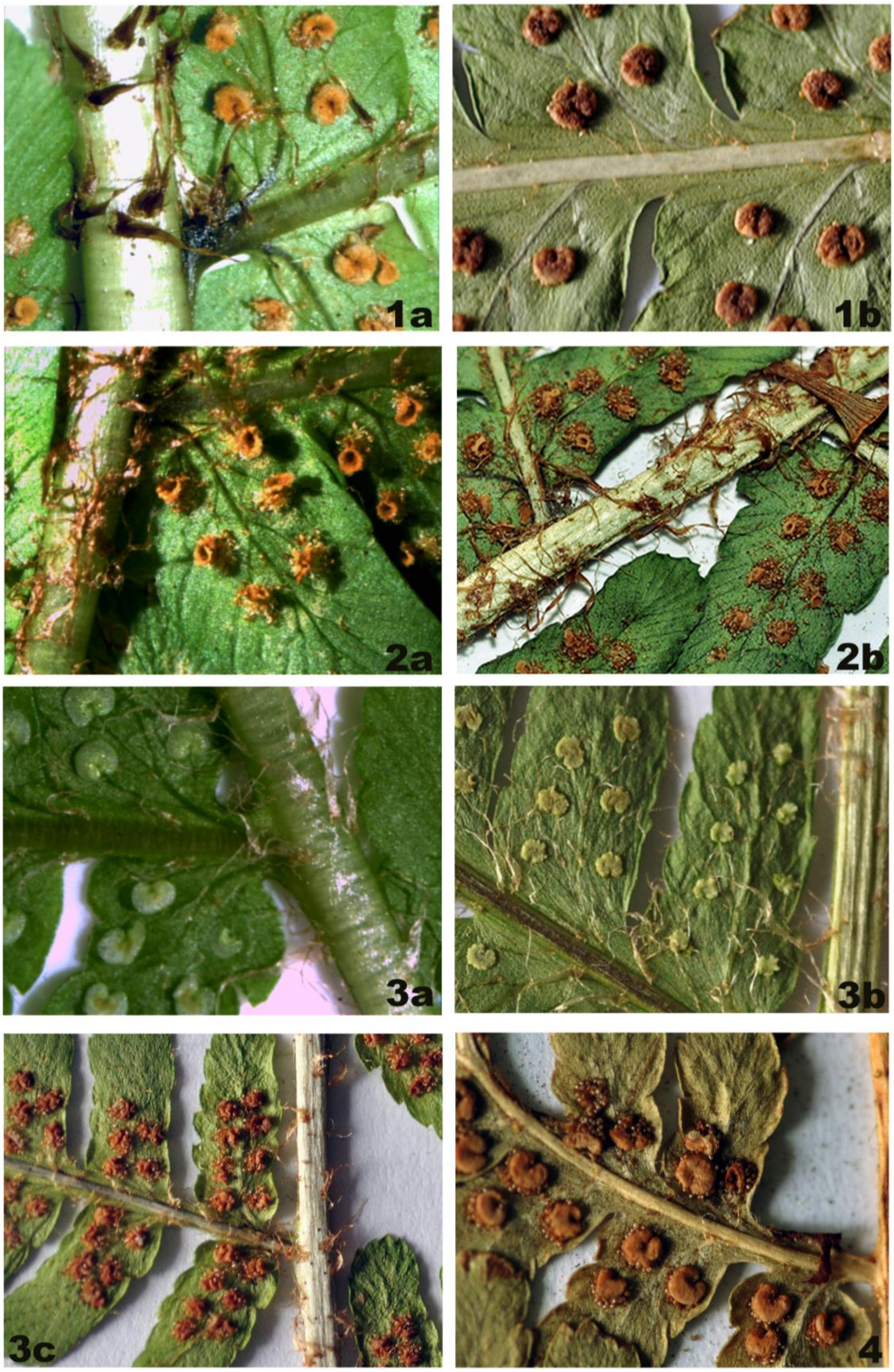

Figure 2. Sori with indusia and rachis scales of selected *Dryopteris* taxa
1) *D. affinis* subsp. *jessenii* (a – MKMEL! 08992; b – MKMEL! 08238).
2) *D.borreri* (a – MKMEL! 09006; b – MKMEL! 09005).
3) *D. filix-mas* – for comparison (a – young sori on live specimen; b – young sori on dessicated specimen, both from MKMEL! 09020; c – sori with ripe and mostly shed spores, from MKMEL! 09019).
4) *D. oreades* (MKMEL! 08215).

In the Republic of Macedonia, this species is found on silicate rocky ground on the western mountains (Figure 1).

First chorological records

Šar Planina: Mengulova Kula – above v. Gorno Jelovce (above Ramen Kamen), silicate rocks, 2000 m a.s.l., 14.07.1998, leg. IDSB-Lj. Melovski, det. Lj. Melovski (MKMEL! 08195, 08196 and 08216); Šar Planina: Central massif – Titov Vrv (Golema Smreka), silicate stony site, 1900 m a.s.l., 08.09.2004, leg.&det. Lj. Melovski (MKMEL! 08215); Jablanica: Crn Kamen massif – Krivi Virovi, silicate rocks, 1700-1800 m a.s.l., 08.06.2003, leg. Lj. Melovski, S. Arsovsa & M. Šušlevska, det. Lj. Melovski (MKMEL! 08217); Stogovo: Valavica stream valley – below Jama, open place next to the road in beech forest, 1410 m a.s.l., 31.08.2016, leg.&det. Lj. Melovski (MKMEL! 09024 and 0925).

Dryopteris mindshelkensis Pavlov, Vestn. Akad. Nauk Kazakhsk. SSR 8: 129. 1954

D. mindshelkensis is at present accepted name for widely known *D. submontana* (Fraser-Jenk. & Jermy) Fraser-Jenk. It has similar distribution range as *D. oreades*, but it is characteristic only for mountains with calcareous bedrock. Beside Romania, on the Balkan it is present in Serbia, Montenegro, Albania and Greece [2]. Micevski [5] did not list this species in his Flora. However, two years after Micevski's flora has been published, Fraser-Jenkins (during his revision of *Dryopteris* material from MKNH!) identified three specimens as *D. submontana* wrongly identified as *D. villarii* by Micevski.

In the Republic of Macedonia, *D. mindshelkensis* is found on calcareous rocky ground on the western mountains (Figure 1).

First chorological records

Šar Planina: Kobilica – Golem Kamen, limestone rocks and stony ground, 1900–2050 m a.s.l., 01.10.2006., leg.&det. Lj. Melovski (MKMEL! 08161); Šar Planina: Central massif – Krivošija (Treta Karpa – above Krivošiska Reka), limestone scree, 1740 m a.s.l., 20.07.1995, leg. IDSB-Lj. Melovski, det. Lj. Melovski (MKMEL! 08162); Jablanica: Čuma – Malo Sedlo, limestone rocks and stony ground, 1900–2000 m a.s.l., 10.08.2005, leg. Lj. Melovski & N. Angelova, det. Lj. Melovski (MKMEL! 08163); Bistra: Toni Voda – close to the sinking stream, limestone stony ground - between large stones, 1700 m a.s.l., 22.08.2016., leg.&det. Lj. Melovski (MKMEL! 08950 and 08951); Debarsko – Krčin. Above the village of Gorno Kosovrasti, on limestone rocks. 1270 m.n.v., 19.VII.1960, leg. K. Micevski, det. C. R. Fraser-Jenkins (MKNH! 000477-000479).

Dryopteris dilatata complex

The complex consists of three species (*D. dilatata*, *D. expansa* and *D. carthusiana*) which are known for difficult and uncertain identification [20, 3, 25, etc.] due to their high variability and interconnected origin. It is recommended that one should use a set of characters for identification rather than one or two usually used in standard keys. Many morphological characters were studied and involved (including dimensions and volume of the glands [33]), but still the perispore remains among the most important ones. In some keys [e.g. 10] *D. dilatata* perispore is described as being covered with dense and obtuse tubercles, and *D. expansa* perispore with sparse acute tubercles, which is not sufficient for identification of the two taxa, especially if the spores are examined by the light microscopy ("acute" and "obtuse" is not easily visible). Both *D. dilatata* and *D. expansa* have acute tubercles (or echinulae as R. L. L. Viane [33] names them) at least on light microscope images and the main difference is the density [33]; (see also Figure 3). *D. expansa* has well-spaced echinulae unlike *D. dilatata* with dense echinulae. Plants from Macedonia confirm this finding (Figure 3). Yet, traditionally accepted morphological characters used to distinguish the species in the group (particularly the length of the basioscopic pinnule) are sufficient to identify the majority of the specimens growing in Macedonia. However, in the frame of the considerable variation in fronds' morphology in this buckler fern group there are some individuals with characters that approach border values. In these cases the spores' morphology is important for proper identification.

Dryopteris dilatata (Hoffm.) A. Gray, Man. Bot. 631 (1848)

This species is distributed in the whole Europe excluding Montenegro and Albania where its presence is doubtful [2]. In Macedonia there was much confusion in regard to this species in the past. *D. dilatata* is listed in the Flora of Macedonia [5] for several localities: Pelister, Dudica, Jakupica – Kadina Reka river, Osogovo. However, the revision of Buckler ferns in MKNH! by Fraser-Jenkins in 1987 (after the Flora has been published) showed that it was not present in Macedonia (all specimens from MKNH! were identified by Fraser-Jenkins as *D. expansa*). On the other hand, the research presented in this article showed that he misidentified the specimens from Dudica (Kožuf Mt.) and Mt. Jakupica (Kadina Reka river).

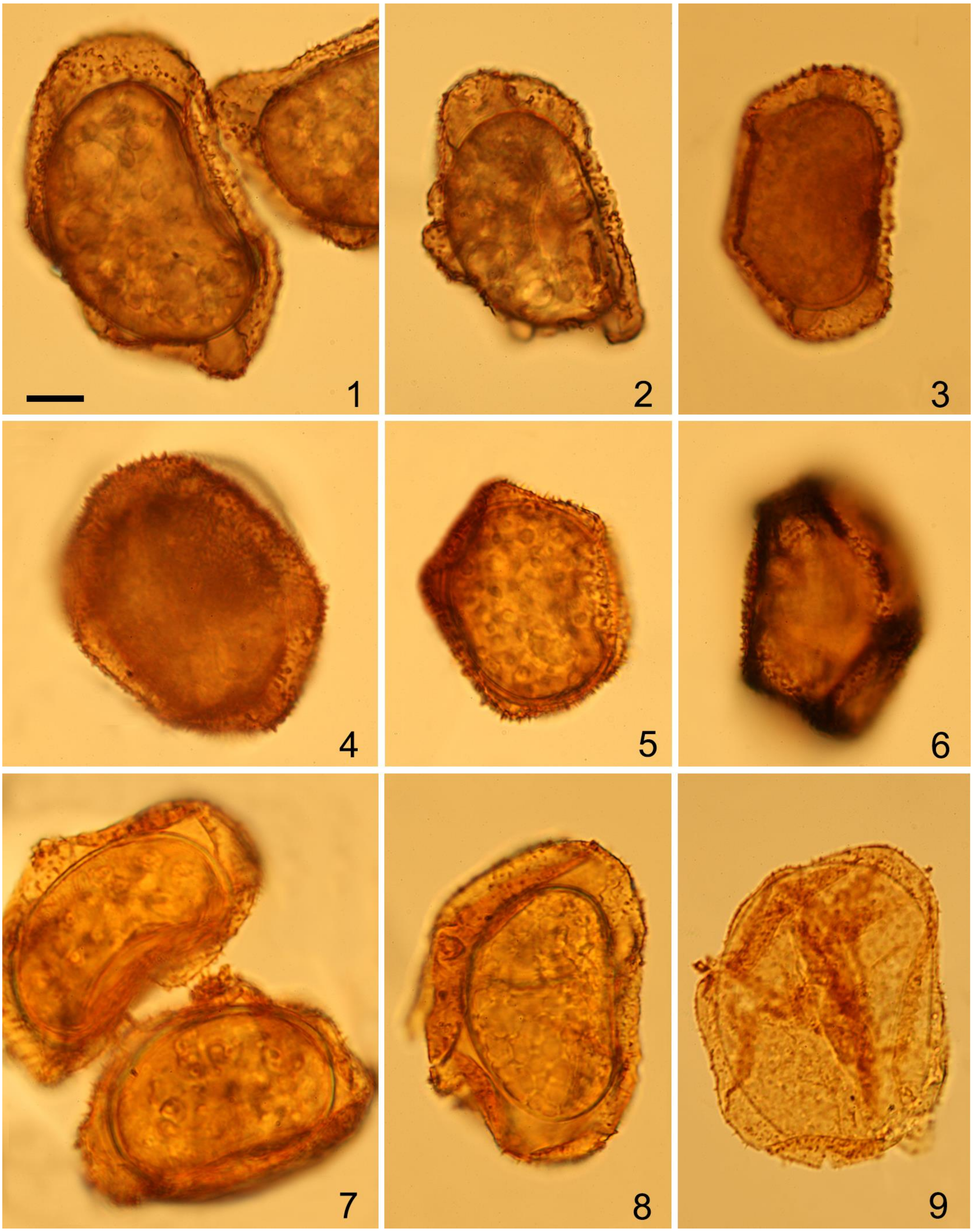

Figure 3. Spores of species of *Dryopteris dilatata* complex (×1000) (scale bar 10 μm)
1–3 *D. carthusiana*: 1 – from Debarca – Belčiško Blato (MKMEL! 01940); 2 – from Debarca – Belčiško Blato (MKMEL! 08029); 3 – from Bistra–Šar Planina – Bunec (MKMEL! 00250)
4–6 *D. dilatata*: 4 – from Dudica (MKNH! 000318); 5 – from Dudica (MKNH! 000325); 6 – from Jakupica – Kadina Reka (MKNH! 000317)
7–9 *D. expansa*: 7 and 8 – from Osogovo (MKNH! 000310); 9 – from Pelister (MKMEL! 08076)

These specimens certainly are *D. dilatata*, which was confirmed by microscopic analysis of the spores (Figure 3) and thorough analysis of the morphological characteristics, particularly the ratio between basioscopic and acroscopic pinnulae of the lowest pinna and the degree of the frond division. Spores are frequently pointed as quite certain character for separation of the two close species – *D. dilatata* and *D. expansa*, in some standard keys, including Flora Europaea [10]. Present distribution of *D. dilatata* in Macedonia is shown on Fig. 1.

Further research is needed to check the accuracy of the data given by old botanists from the beginning of 19-th century and mentioned in Micevski [5].

Existing chorological records

Dudica – on humid ground, on andesite. 1500 m.n.v., 24.VIII.1978, leg.&det. K. Micevski, confirmed by Lj. Melovski (MKNH! 000318-000325); Jakupica pl. – by the Kadina Reka river. 6.VIII.1953, leg.&det. K. Micevski, confirmed by Lj. Melovski (MKNH! 000316 and 000317).

New chorological records

Debarca: Belčiško Blato – close to the v. Novo Selo, alder forest, 763 m a.s.l., 09.06.2009, leg.&det. Lj. Melovski (MKMEL! 01941); Mokra Planina – Golešnica: Lisec – Pešterska Reka – from Klizište till the dale and higher, beech forest, 1000–1100 m a.s.l., 16.05.2007, leg.&det. Lj. Melovski (MKMEL! 08072–08074).

Dryopteris expansa (C. Presl) Fraser-Jenk. & Jermy, Fern Gaz. 11: 338 (1977)

According to Euro+Med PlantBase [2] *D. expansa* has very wide distribution in Europe. It is absent only from Macedonia, Albania, Montenegro, Croatia and Moldova. However, it seems that it is more frequent than *D. dilatata* in Macedonia (Figure 1; see also notes above, under '*Dryopteris dilatata*' subchapter). As a matter of fact, most of the specimens in MKNH! actually belong to *D. expansa*, which was proved by microscopic analysis of the spores (Figure 3), thorough morphological analysis and revision of *Dryopteris* in MKNH! by Fraser-Jenkins in 1987.

First chorological records

Šar Planina: Čaušica–Peskovi–Bistra, in the crevices of silicate rocks, 2600 m a.s.l., 24.08.2014, leg.&det. Lj. Melovski (MKMEL! 08068–08071); Kajmakčalan (Nidže): close to Redir – Miletina Kosa, beech forest, 1500–1570 m a.s.l., 11.07.2002, leg. IDSB-Lj. Melovski, det. Lj. Melovski (MKMEL! 08075); Pelister (Baba): Debel Rid – below Golemo Ezero, among silicate blocks, 1800–2000 m a.s.l., 10.07.2003, leg. Lj. Melovski & J. Miloševski, det. Lj. Melovski (MKMEL! 08076-08081); Pelister (Baba): above v. Niže Pole – towards Debel Rid, among silicate blocks, 1260 m a.s.l., 12.06.2008, leg.&det. Lj. Melovski (MKMEL! 08082); Pelister (Baba): Partizanski Vrv – Malo Ezero, among silicate blocks, 2200–2250 m a.s.l., 27.06.2004, leg.&det. Lj. Melovski (MKMEL! 08083 and 08084); Pelister (Baba): Veternica - Golemo Ezero cirque, silicate stone blocks, 2230 m a.s.l., 14.07.2016, leg.&det. Lj. Melovski (MKMEL! 08955-08958); Osogovo–Sasa. On paleogene schists. 1600 m.n.v., 17.VII.1967 (sub *D. dilatata*), leg.&det. K. Micevski (sub *D. dilatata*), rev. C. R. Fraser-Jenkins, confirmed Lj. Melovski (MKNH! 000303-000306); Pelister – around Malo Ezero, on silicate rocks. 2100 m.n.v., 12.VII.1968, leg.&det. K. Micevski (sub *D. dilatata*), rev. C. R. Fraser-Jenkins, confirmed Lj. Melovski (MKNH! 000326, 000331, 000332 and 00336); Pelister – around Malo Ezero, on silicate rocks. 2250 m.n.v., 12.VII.1968, leg.&det. K. Micevski (sub *D. dilatata*), rev. C. R. Fraser-Jenkins, confirmed Lj. Melovski (MKNH! 000327-000330 and 000333-000335).

Dryopteris carthusiana (Vill.) H.P. Fuchs, Bull. Soc. Bot. Fr. 105: 339 (1958)

D. carthusiana is the third member of *D. dilatata* group. Same as the other species of this group, it has very wide distribution in Europe – it is not present only in Portugal and Iceland [2]. Up to this research it was considered as a very rare species in Macedonia, found only on Osogovo Mts. (Osogovski Planini) [5] (Figure 1). This research proved that it has broader distribution though it is still quite rare (Figure 1). It is confined to the localities where the last remnants of alder forests and woodlands are still preserved. Further research is needed to check the data given by old botanists from the beginning of the 19-th century and questioned by Micevski [5].

Existing chorological records

Osogovo – Sasa: On paleogene schists. 1600 m.n.v., 17.VII.1967, leg.&det. K. Micevski (MKNH! 000307-000311).

New chorological records

Bistra–Šar Planina: Children's resort "Bunec" – below the resort, swampy site in alder woodland, 1240 m a.s.l., 14.08.2007, leg.&det. Lj. Melovski (MKMEL! 00249 and 00250); Debarca: Belčiško Blato – close to the v. Novo Selo, alder forest, 763 m a.s.l., 09.06.2009 and 12.07.2009, leg.&det. Lj. Melovski (MKMEL! 01935, 01939 and 01940); Debarca: Belčiško Blato – close to v. Novo Selo, swampy forest with *Alnus glutinosa*, 763 m a.s.l., 26.06.2004, leg.&det. Lj. Melovski (MKMEL! 08028–08030); Polog: Dolni Polog – v. Jančište (Zabel), alder forest, 390 m a.s.l., 16.09.2016, leg. Lj. Melovski & M. Kostadinovski, det. Lj. Melovski (MKMEL! 08985–08991).

It can be concluded that the flora of the Republic of Macedonia consists of 10 *Dryopteris* species: *Dryopteris affinis* with one subspecies – *D. affinis* subsp. *jessenii*, *D. borreri*, *D. filix-mas*, *D. oreades*, *D. villarii*, *D. pallida*, *D. mindshelkensis*, *D. dilatata*, *D. carthusiana* and *D. expansa*. However, the knowledge of the Buckler ferns in Macedonia is still incomplete. Presence of some other species cannot be rejected. Future research is needed to prove presence of several hybrid taxa for which there are indications that they can be found in the Republic of Macedonia.

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РОДОТ DRYOPTERIS (PTERIDOPHYTA: DRYOPTERIDACEAE) ВО ФЛОРАТА НА РЕПУБЛИАК МАКЕДОНИЈА – 30 ГОДИНИ ПО ФЛОРАТА НА МИЦЕВСКИ –

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Оваа статија ги презентира првите наоди на четири нови видови машка папрат (*Dryopteris*) на територијата на Република Македонија и нови податоци за дистрибуцијата на некои ретки видови од групата на машка папрат.

Dryopteris е еден од најкомплексните родови папрат во Европа. Хибридизацијата и апомиксисот меѓу некои од видовите придонесуваат за тешкотиите и несигурноста за идентификација на одделни видови. Тоа, во комбинација со недостиг на истражување на папратите во Македонија во последните 30 години, резултира со ниско ниво на знаење во рамките на оваа група васкуларни растенија.

Истражувања од областа на флората на Македонија и темелна проверка на два хербариума (MKMEL и MKNH) во Скопје открија присуство на четири нови видови папрат во Македонија: *Dryopteris affinis* subsp. *jessenii*, *D. oreades*, *D. mindshelkensis* и *D expansa*. Покрај тоа, презентирани се неколку други локации со ретки видови: *D. borreri*, *D. dilatata* и *D carthusiana*.

Потребно е понатамошно истражување за да се пополнат преостанатите недостатоци, особено во однос на идентификување на хибридите, како и подетална студија за распространување на ретките видови од родот *Dryopteris*.

Клучни зборови: *Dryopteris affinis; Dryopteris oreades*; *Dryopteris mindshelkensis*; *Dryopteris expansa*; Република Македонија; ретки папрати

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Review

VEGETATION OF DECIDUOUS FORESTS IN THE BALKAN PENINSULA*

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The article provides an overview of deciduous forests of the Balkan Peninsula. It presents riverine, floodplain and moor forests, dominated by *Alnus incana, A. glutinosa, Fraxinus excelsior, F. angustifolia, Quercus robur, Salix alba, Ulmus laevis, U. minor*; acidophilous forests dominated by *Betula pendula, Castanea sativa, Fagus sylvatica, Quercus petraea*; thermophilous forests dominated by *Carpinus orientalis, Ostrya carpinifolia, Quercus cerris, Q. f~~a~~rainetto, Q. petraea, Q. pubescens* and mesophilous forests dominated by *Carpinus betulus, Fagus sylvatica, F. orientalis, Fraxinus excelsior, Tilia argentea, T. cordata, T. platyphyllos, Ulmus glabra*. At the same time, forests were classified into the synsystematic framework of the standard Central European system to the level of an alliance.

Keywords: Balkan; forest; vegetation; classification

Nomenclatural source: Euro+Med Plantbase (http://ww2.bgbm.org/EuroPlusMed)

INTRODUCTION

Research into vegetation in southeastern Europe has a long tradition. The first fundamental works about vegetation in the region were based on the so-called physiognomic-ecological approach and originate from the beginning of the 20th century, when Gabriel Beck-Mannagetta published his work Vegetationsverhältnisse der illyrischen Länder [1] and Lujo Adamović his work Vegetationsverhälnisse der Balkanländer [2]. At the beginning of the 20th century, a new science – phytosociology – was established [3]. Soon after its beginning in Europe, research in the Balkans began according to this method [4] and the new science was widely accepted among researchers in the region. Our presentation is based on the standard Braun-Blanquet method and its hierarchy; so we group associations (ending -etum) into alliances (ending -ion), alliances into orders (ending -etalia) and those into classes (ending -etea) [5]. As a result of long and intensive research in the region, during recent years some important surveys of forest vegetation of some parts of the region has appeared, e.g. Slovenia [6], Croatia [7], Serbia [8], Kosovo [9], Bulgaria [10] and Greece [11, 12]. These and many other studies have enabled us to make an overview of forest vegetation of the region.

The large number of publications all over Europe encouraged a group of authors guided by Ladislav Mucina to start preparation of an overview over all vegetation types of the whole of Europe to the alliance level, from the Canary Islands to the Urals and from Cyprus to Greenland [13]. It is based on a list of vegetation classes [14] and on a preliminary overview of alliances [15]. During the procedure, literature sources all over Europe have been checked and many nomenclature corrections and some revisions of individual syntaxa have been published, for instance [16, 17].

This paper is intended to give an overview of deciduous forests of the region on the alliance lev-

*The paper was presented as an inaugural lecture by the author on the occasion of his election to be a member of the Macedonian Academy of Sciences and Arts on 5th May 2016 in Skopje.

el, to synchronize regional classification schemes with the European one [13], to show the present state of knowledge and to detect some problems. At the same time, it will facilitate integration of the vegetation of deciduous forests into the wider European framework, into various overviews of forest vegetation, red lists and similar [18].

DESCRIPTION OF AREA

The Balkan Peninsula has a large altitudinal diversity, since a great part of the territory has an altitude of over 1000 m, and provides a large altitudinal range through a relatively small latitudinal range of 10°. At the same time, the Balkan Peninsula is a highly complex region in terms of geology, climate and vegetation. The diverse geology is the most important factor contributing to the diversity of flora: there are crystalline massifs, such as Rhodopes and new fold mountains, such as the Dinaric Alps or the Shar-Pindos mountain range, composed of limestone [19].

The climatic conditions are parallel its geographical position, relief and extensive coastline (Figure 1). Belgrade in the northern part, which is cut off from the influence of the Mediterranean and lies open to central and eastern Europe, is dominated by a continental climate with maximum of precipitation in May–June. Ljubljana has a mountain climatic regime, with two peaks of precipitation, in spring and autumn. Ohrid in the south is also located in mountains but is influenced by a Mediterranean climate and an autumn peak can be observed. Ljubljana has more precipitation but Ohrid and Belgrade have almost the same amount, although Belgrade has precipitation during the vegetation season, that is more propitious for flora and vegetation, and also for agriculture, whereas in Ohrid the majority of precipitation falls in the part of the year in which the vegetation cannot use it.

OBJECT

The potential vegetation of the major part of the Balkan Peninsula is represented by deciduous broadleaved forest. Broadleaved deciduous forests appear in the areas with relatively moist summers and mild winters. Forests can be divided into two subgroups: mesic and warm temperate forests. Mesic temperate forests appear in the humid sub Atlantic climate and are dominated by mesophilous deciduous tree species, such as *Fagus sylvatica*, *Carpinus betulus*, *Acer pseudoplanatus, Alnus glutinosa* etc. Warm deciduous forests appear in areas under the influence of continental and Mediterranean climates, in which summer drought is more pronounced. These forests are dominated by various species from the genus *Quercus*, *Ostyra carpinifolia, Carpinus orientalis* etc. [20].

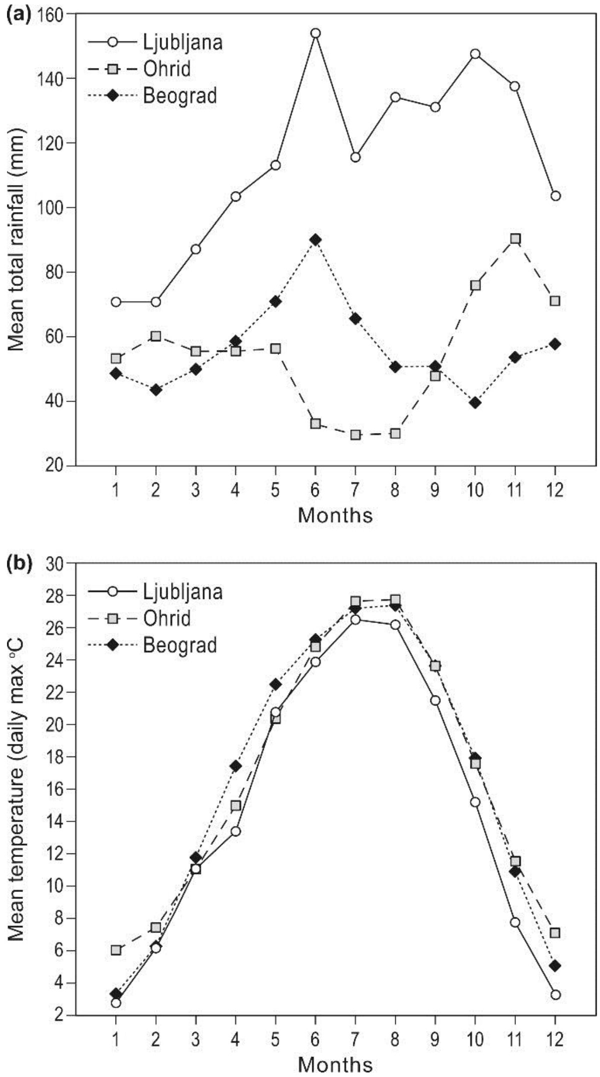

Figure 1. Mean total rainfall (a) and mean monthly temperatures (b) in the research area. Climatological information for Ljubljana, Ohrid and Belgrade (World Meteorological Organization data, http://www.wmo.int/pages/index_en.html)

CONTACT FORESTS

In the case of increased cooling or increasing drought, deciduous forests are in contact with coniferous ones. In cold and humid areas, they are in contact with forests dominated by *Picea abies* and *Abies alba*, as well as *Larix decidua*. In drier areas, two relict coniferous forests appear, *Pinus peuce* and *Pinus heldreichii*, and a hybrid between *Abies alba* and *Abies cephalonica Abies borisii-regis* forests. Deciduous forest can also be in contact with *Pinus syl-*

vestris and *Pinus nigra* but these two species do not form zonal forests and appear locally in extreme conditions (e.g. extreme drought or acidity) [21–26].

In areas under the influence of the Mediterranean climate, deciduous forests are in contact with evergreen broadleaved forests. A warm climate with mild winters is characteristic of Mediterranean evergreen vegetation dominated by evergreen tree species, such as *Quercus ilex*, *Q. coccifera,* and their substitutes, maquis, garrigues. In some cases, they can also come in contact with coniferous forests of Mediterranean mountains [27–29].

HISTORY

One of the main factors determining the present vegetation is the development of vegetation during and after the ice ages (Figure 2). This area was covered with no or relatively little ice during the last glaciation and the assumed July temperature was only 5° cooler than present, which probably provided a suitable environment for the survival of temperate tree taxa. Since most water was bound in ice, the sea level was lower and half of the Adriatic Sea was part of the mainland. From the point of view of phytogeography, the land connection to the Apennines is also important and caused the two peninsulas to share some common or closely related taxa and vegetation types. The area of common (syn)taxa could also be called the Apennine-Dinaric window in phytogeography [30–32].

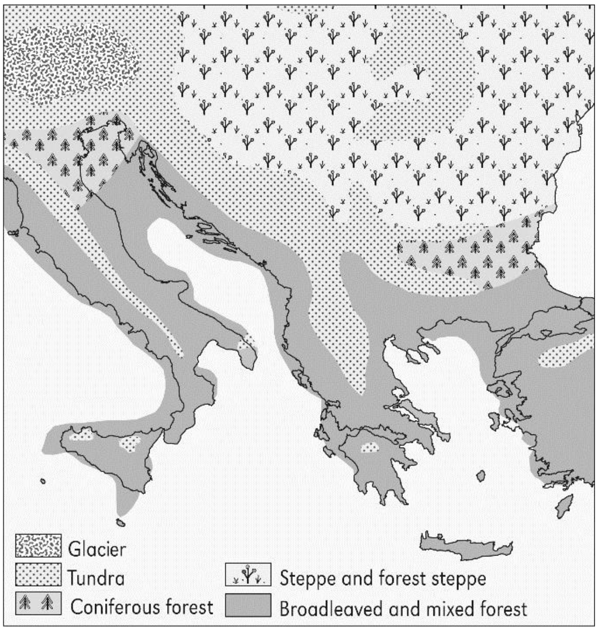

Figure 2. Vegetation cover of the Balkan during ice age (Würm) (after [33]).

The area was covered by forest, tundra and steppe and it was one of the refugial areas for tree species in Europe. Even now, the highest diversity of tree species in Europe is found in the southern part of Macedonia, where there are over 130 woody species [34].

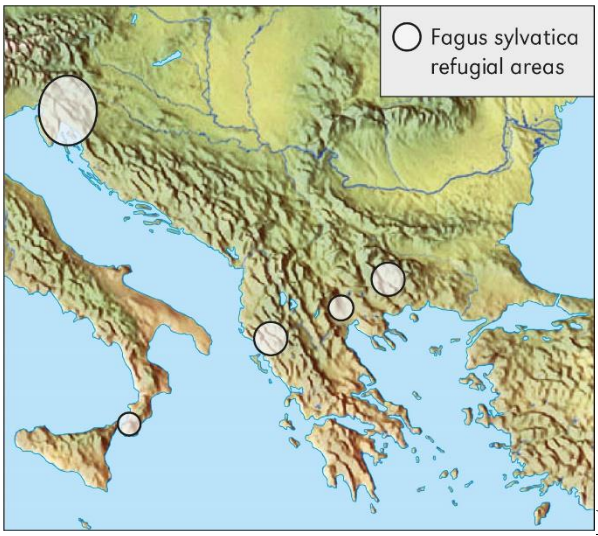

Figure 3. Refugial areas of beech (after [35]).

There were macro refugia of mesophilous forest in the northwestern part of the region (Figure 3). The major refugia of beech forests were in the northwestern part of the Balkans and beech spread out from these refugia practically all over Europe. These refugia were at an altitude between 600 and 800 m, since in the lowlands it was too dry, and at higher altitudes it was too cold. So called Illyricoid flora (e.g. *Lamium orvala*, *Omphalodes verna* etc.) (sensu Trinajstić) also survived here, i. e. mesophilous endemic species that survived in these mesophilous forests. A distinction has thus been made between Illyric species – endemics surviving on extreme habitats and Illyrioid species – mesophilous endemics [35, 36].

The situation was different with thermophilous forests; their primary refugia were in the south but in warmer periods they expanded towards the north and could sometimes survive colder periods in those areas, in so called secondary refugia (Fig. 4). Evidence exists that in the southern Balkans there were macro refugia of warm temperate forests and also cryptic (smaller) refugia of mesic temperate forests. The macro refugia were more species rich but cryptic refugia also had their floristic individuality [20, 37, 38].

Most research of the history of forests has been done by people from outside the region and the focus has been on the location of refugia and the time needed for temperate trees to migrate from these areas to northern Europe [39]. The vegetation history of the Balkans has much greater significance for the development of forests than this. If the temperate trees were present in the region during the last glacial period, then it is an important region in which we can study them in terms of understanding forest development without the arrival of any immigrant taxa. If migration was not a significant factor in the postglacial vegetation succession of the region, other factors need to be considered to explain the type and rates of postglacial vegetation change. This can include external forces such as climate change and internal factors such as soil development and forest dynamics [40, 41].

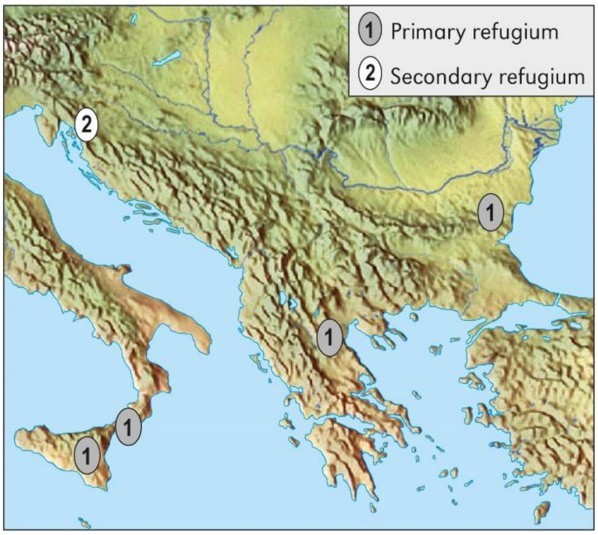

Figure 4. Refugial areas of oak species (after [37]).

The species that were present in the region could adapt to climatic and other conditions and could even genetically change in a fairly short time during the Holocene. Here there can be found, for instance, two subspecies of the species *Cistus incanus: C. incanus* subsp. *incanus* and *C. incanus* subsp. *creticus*. These subspecies can be explained by a process of adaptive radiation within *Cistus incanus* agg. Specimens found in the continental parts of the Balkans have larger leaves, a straight leaf margin and do not have glandules, whereas specimens in the coastal areas have glandules and undulated leaf margins. These differences are treated taxonomically on the level of subspecies; specimens in the continent are treated as the typical subspecies, whereas those in the coastal regions as the subspecies *creticus*. It should still be tested whether these differences are genetically fixed; what would happen if plants from the coastal region were planted in continental conditions and vice-versa [42, 43].

BIOGEOGRAPHICAL DIVISION OF THE REGION

The following biogeographical regions can be found in the area: the Mediterranean, which is linked to the coastal area; the mountain area is classified within the alpine region, while the majority of the area is connected to the continental region and there is a small part that can be attached to the Pannonian region; there is also a Black Sea region along the Black Sea coast. (European Environmental Agency: www.eea.eu.int).

This is the commonly accepted solution of the biogeographical division. However, other divisions can also be found, including that of Oberdorfer, who drew a distinction between the Mediterranean area and the Eurosibirian region in the northern part of the Balkans. This distinction is based on two factors. Evergreen vegetation can be found only in the southernmost part of Greece and there is quite a large area of submediterranean thermophilous deciduous forest there, unlike the situation in the western Mediterranean. The other factor is that the transition between evergreen and deciduous vegetation is fairly continuous; there is maquis consisting only of evergreen species, then pseudomaquis consisting of a mixture of evergreen species and deciduous species and šibljak consisting only of deciduous species. On the other hand, the division between mesophilous deciduous and thermophilous deciduous forest is fairly obvious [27, 45].

OVERVIEW OF FORESTS

Riverine, floodplain and moor forest

These forests appear in areas that are under the influence of a watercourse or underground water. The boundary of these habitats in floodplains is the line that is reached by the highest floods. The time when the highest water level is attained depends on the water regime; rivers that have their source in the mountains have the highest level during late spring, when the snow melts, while others have their maximum during high precipitation, and floods can happen unexpectedly due to sudden high precipitation, often causing destruction. When the water level is low, these forests can often be dry. Species need to be able to adapt to floods, to survive the submerged period, to have flexible branches not be broken by a water course etc. and also to survive the lack of humidity during low water levels. On the other hand, these habitats are very rich in nutrients, which the water flow brings and deposits and this makes the habitats one of the richest in the landscape. At the same time, these deposits can be carried out by the next floods and so the best position for growth is near the edge of average floods, where the fine deposits are left and are not too often carried off. In these stands, the development of a soil profile can already be found. The river brings deposits and gravel with flow, which are deposited in its bed. The river climbs above the landscape in this way and moor vegetation can be found in the hinterland. These moor forests are often dominated by *Alnus glutinosa*, since this species well supports the high ground water over the whole year. These stands can be occasionally flooded. This vegetation seems to be to a large extent azonal and does not show a special geographic pattern. In lowlands, such stands are often in contact with zonal oak-hornbeam forest in the north and with thermophilous deciduous forest in the south; pine forests can sometimes be found on old gravel deposits [46–50].

The majority of these forests are classified into *Alno-Populetea albae*, which encompass floodplain and riverine forests of the Eurosibirian and Mediterranean regions. The class is divided into two orders, which reflect macroclimatic conditions: *Populetalia albae* in the Mediterranean region and *Alno-Fraxinetalia* in the temperate region. Within the Mediterranean part, *Platanus* dominated communities can be distinguished, classified as *Platanion orientalis* and *Lauro nobilis-Fraxinion angustifoliae* encompassing other floodplain and riparian forests [51]. Forests of the temperate order *Alno-Fraxinetalia* can be divided into two alliances; *Alnion incanae* encompassing forests appearing along the upper stream of rivers and dominated to a large extent by alders (*Alnus glutinosa, A. incana*) and *Alno-Quercion*, which appear downstream and are dominated by *Fraxinus*, *Ulmus* and *Quercus*. *Alnion incanae* is in close contact with oak-hornbeam forests and, in some cases, these forests share many common species. Some authors do not recognize the individuality of the two alliances: *Alnion incanae* and *Alno-Quercion* [7, 52]. Riparian willow forests, appearing mainly on lowland alluvia, are classified within *Salicetea purpureae, Salicetalia purpuraea* and *Salicion albae*. Mesotrophic forests appearing in waterlogged sites are classified into *Alnetea glutinosae*, *Alnetalia glutionsae* and *Alnion glutinosae* [46–52].

Acidophilous forests

These forests appear on less productive soils, where more demanding species such as hornbeam, maple and others cannot thrive. Deciduous acidophilous forests are dominated by *Fagus sylvatica, Quercus petraea* and *Betula pendula*. It has been established that *Quercus robur* is rarely a dominant in such forests in the region. *Fagus sylvatica* dominated forests are classified into the group of beech forests (*Carpino-Fagetea*). Oak and birch forests are also classified into two different classes (see further). Mesic-acidophilous oak dominated forests appear only in the western part of the region, while in the eastern part acido-thermophilous oak forests belong to the group of thermophilous deciduous forests and are classified within the class *Quercetea pubescentis*. Birch forests can be found all over the region. These forests are to a large extent the result of human activities over centuries. With the abandonment of exploitation, succession is liberated and they can convert to mesic forests [7, 8, 53, 54].

Castanea sativa dominated forests need further research. *Castanea sativa* originates from the *Quercion frainetto* zone and is probably non-native in the northwestern part of the Balkans. It grows not only on acidic soils but can also appear on other substrata, so these forests can be classified into various groups: acidophilous, mesophilous, thermophilous deciduous and ravine forests [12, 55–59].

Acidophilous oak dominated forests are classified into the group of acidophilous oak and birch-oak forests on nutrient poor soils, *Quercetea roboris-petraeae* and *Quercetalia roboris*. Two alliances appear; one from temperate regions, *Agrostio-Quercion petraeae* and the other from submediterranean regions, *Castaneo-Quercion*. The division between these two alliances in the area should be reconsidered in the future. In recent years, proposals have been made to separate birch forests from oak forests on the class level and to classify them within the group of hemiboral pine and birch-pine herb rich open forests on fertile soils and relict birch-poplar forest *Brachypodio pinnati-Betuletea pendulae* and further into relict extrazonal temperate deciduous birch-poplar woods on mineral soil *Fragario vescae-Populetalia tremulae* and *Fragario vescae-Populion tremulae* [17, 60, 61].

Thermophilous deciduous forests

The most widespread forests of the region are thermophilous deciduous forests. They can be divided into two larger groups. (1) The first is dominated by various oak species. They form zonal forests in the southern-eastern part of the region and extrazonal forests on loess substratum on the edges of the Pannonian basin, as well as forests on southern slopes on carbonate bedrock in the northwestern part. Thermophilous-acidophilous oak forests appearing in the central and eastern part of the region are also attached to this group. (2) The second group is dominated by *Ostrya carpinifoila*, *Quercus pubescens* and *Carpinus orientalis*. Such vegetation can be found along the coast in the submediterranean area, on steep slopes with shallow soils on carbonate mountain chains that separate the coast and the continent, such as the Dinaric Alps or Shar–Pindos mountain range and on dry calcareous sites in the hinterland [62–65].

These forests are classified within *Quercetea pubescentis* and *Quercetalia pubescenti-petraeae*, a group of forests that are dominated by various oak species (*Q. pubescens, Q. cerris, Q. petraea, Q. frainetto, etc.*), oriental hornbeam (*Carpinus orientalis*), hop hornbeam (*Ostrya carpinifolia*), as well as Mediterranean relict fir species (*A. cephalonica*). This vegetation is fairly diverse and can be divided into several subunits. Within this framework can be distinguished submediterranean forests dominated by *Quercus pubescens* and *Carpinus orientalis Carpinion orientalis*, meso-thermophilous supra-Mediterranean and relic forests dominated by *Ostyra carpinifolia Fraxino orni-Ostryion* and continental thermophilous forests dominated by *Carpinus orientalis Syringo-Carpinion orientalis,* thermophilous continental forests of deep, neutral to slightly acidic soils dominated by *Quercus frainetto* and *Quercus cerris Quercion confertae* and those under maritime influence *Melitto albidae-Quercion*, dry acido-thermophilous (sub)montane continental forests dominated by *Quercus petraeae* and *Quercus cerris Quercion petraeo-cerridis*, acido-thermophilous northern-dinaric and southern-pannonian *Quercus petraea* dominated forests *Quercion pubescenti-petraeae*, and thermophilous oak forests on deep soils in the forest-steppe zone in the northern part of the region *Aceri tatarici-Quercion* [12, 66, 67].

Ravine forests

Broadleaved ravine forests grow especially on restricted sites with specific soil conditions. They occur on slopes, at the foot of slopes, in sinkholes, gorges and hollows with colluvial, skeletal and primarily unstable soils, which allow broadleaved trees such as *Acer platanoides*, *Acer pseudoplantus*, *Fraxinus excelsior*, *Tilia* sp. div. to settle and replace competitively stronger species, mainly *Fagus sylvatica*. These species are called noble trees, because their litter decays quickly and ameliorates the soils, and so many high stalk plants can be found in these forests, such as *Lunaria rediviva, Urtica dioica* and many others. Within the area of the southern Alps and southeastern Europe, these forests can be classified within two large groups: thermophilous scree and ravine forests dominated by *Tilia sp. div.* and *Ostrya carpinifolia* and mesophilous scree and ravine forests dominated by *Acer pseudoplatanus*, *Fraxinus excelsior* and *Ulmus glabra* [68].

These forests are classified within mesic deciduous and mixed forests *Carpino-Fagetea*, as well as scree and ravine forests *Aceretalia pseudoplatani*. In the region, this group can be divided into mesophilous ash-maple forests *Fraxino-Acerion* and thermophilous lime-hop hornbeam forests *Ostryo carpinifoliae-Tilion platyphylli* [17, 69].

Oak-hornbeam forests

Oak-hornbeam forests appear as zonal vegetation of the plains and hilly region of the northwestern part of the Balkan Peninsula, whereas in the southeastern part hornbeam forests can be found only extrazonally in valleys, along water courses and other habitats that offer humidity and mesic site conditions. In the southeastern part of the region, oak-hornbeam forests are replaced by thermophilous deciduous forests as zonal lowland forests. In the northwestern part of the region, oak-hornbeam forests are in contact with beech forests, which form the submontane vegetation belt. In the lowlands, oak and hornbeam outcompete beech because they better support summer drought and spring frosts. In the transitional zone, beech forests are often converted into oak-hornbeam coppiced forests. In natural stands, oak can be found in the upper and hornbeam in the lower tree layer. However, this vertical zonation in a stand can often be changed by forest management; pure hornbeam or oak forests can be found. Oak-hornbeam forests also appear on more humid sites. Since hornbeam is more susceptible to underground and surface water, it gradually disappears from stands and those forests are classified into floodplain forests. [57, 70–72]

Oak-hornbeam forests are classified within the class of mesic deciduous and mixed forests *Carpino-Fagetea*; specifically they belong to oak-hornbeam and mesic oak forests on deep nutrient rich soils *Carpinetalia betuli*. Oak-hornbeam forests of the Balkans are classified into *Erythronio-Carpinion betuli*; within this framework two suballiances can be distinguished, as moesian oak-hornbeam forests *Aceri tartarici-Carpinenion* and illyric oak-hornbeam forests *Lonicero caprifolii-*

Carpinenion. Hornbeam forests in the southeastern part of the Balkans can be classified into *Castaneo-Carpinion orientalis*, which has its center of distribution in northern Anatolia [49, 73].

Beech forests

Beech forests cover a large proportion of the European forest area. It has to be considered that beech gained the dominant role in European forests in the subatlantic period about 2500 years ago and in about 30 generations has formed well established forest communities. The population originating from the northwestern Balkans is the most vital, since it has settled nearly the whole continent. Beech can be found in intermediate sites that are not too wet and not too dry, not too nutrient rich nor too poor, not too warm or too cold. It has its optimum habitats in the montane belt, where it builds monodominant stands that are sometimes mixed with fir (*Abies alba*, *A. borisii-regis*). In the northwestern part of the region, beech forests occupy various sites and have a wide altitudinal range, while in the southeastern part of the region and on the edge of the Pannonian plain, in their border range, they can only be found in humid mountain areas. [11, 35, 74, 75].

During elaboration of beech forests, we treated only the taxa *Fagus sylvatica* subsp. *sylvatica* and *Fagus sylvatica* subsp. *orientalis*. The intermediate taxon Fagus *sylvatica* subsp. *moesiaca* was attached to *Fagus sylvatica* subsp. *sylvatica* [75].

Classification of beech forests has been taking place for nearly a century and a common consensus could not be reached. Three main gradients can be observed with beech forests: soil pH, temperature and geography, of which the last includes macroclimatic gradients and, at the same time, also a history of the spread of beech forests. A consensus has been achieved about acidophilous beech forests and beech forests on acid soils in temperate Europe are classified within a separate group. However, basiphilous beech forests have given rise to major discussion among researchers. It is not obvious which factor is more important, temperature or geography. If temperature is more important, units would be ecologically defined and subunits geographically, and vice-versa. A consensus has recently been achieved that both approaches can be considered equally relevant. With the European classification system, it has been accepted that the mostly well-defined alliances should be retained. [13, 76]

Acidophilous beech forests, illyric beech forests, moesian beech forests and south Balkan beech forests form individual groups in the region. All beech forests from Europe have been classified into the class of mesic deciduous and mixed forests *Carpino-Fagetea*. Acidophilous beech forests are classified into *Luzulo-Fagetalia sylvaticae* and *Luzulo-Fagion*. Basiphilous beech forests are classified into *Fagetalia sylvaticae*. These forests from the illyric floristic province are further classified into *Aremonio-Fagion*. Moesian beech forests are not well defined floristically and it was decided to attach them partly to Central European beech forests *Fagion sylvaticae* and partly to south Balkan beech forests. South Balkan beech forests are grouped into *Geranio striati-Fagion*. The latter group also comprises some acidophilous communities. [11, 13, 76]

Oriental beech forests

Fagus orientalis appears in Europe in the extreme southeastern part, in Turkey, Bulgaria and Greece. The distribution center of these forests is in the Euxinian province, which is situated in the central part of the Turkish Black Sea region. On the basis of analysis, these forests were divided into seven groups (alliances). Only two groups can be found in Europe: submontane and ravine beech forests. Within the European classification system, only one alliance is recognized, containing all oriental beech forests of Europe. Oriental beech forests are classified within the class of mesic deciduous and mixed forests *Carpino-Fagetea* and within oriental beech forests *Rhododendro pontici-Fagetalia orientalis*. Oriental beech forests appearing in Europe are classified within *Fagion orientalis* [13, 76, 77].

CONCLUSIONS

The presentation provides a brief overview of deciduous forests of the Balkan Peninsula on the alliance level. An attempt is made to put all forests of the region into a logical system that is integral within the region and corresponds to the European classification scheme. However, other classification concepts still exist, each with its own shortcomings and inconsistencies, and much effort will be needed to attain the optimal solution.

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Appendix

Synsystematic scheme (after [13]):
Alno glutinosae-Populetea albae P. Fukarek et Fabijanić 1968
  Populetalia albae Br.-Bl. ex Tchou 1949 *nom. conserv. propos.*
    Platanion orientalis I. Kárpáti et V. Kárpáti 1961
    Lauro nobilis-Fraxinion angustifoliae I. Kárpáti et V. Kárpáti 1961
  Alno-Fraxinetalia excelsioris Passarge 1968
    Alnion incanae Pawłowski et al. 1928
    Alno-Quercion roboris Horvat 1950
Salicetea purpureae Moor 1958
  Salicetalia purpureae Moor 1958
    Salicion albae Soó 1951
Alnetea glutinosae Br.-Bl. et Tx. ex Westhoff et al. 1946
  Alnetalia glutinosae Tx. 1937
    Alnion glutinosae Malcuit 1929
Quercetea robori-petraeae Br.-Bl. et Tx. ex Oberd. 1957
  Quercetalia roboris Tx. 1931
    Agrostio-Quercion petraeae Scamoni et Passarge 1959
    Castaneo-Quercion petraeae Soó 1964
Brachypodio pinnati-Betuletea pendulae Ermakov et al. 1991
  Fragario vescae-Populetalia tremulae Willner et Mucina in Willner et al. 2016
    Fragario vescae-Populion tremulae Willner et Mucina *ined.*
Quercetea pubescentis Doing-Kraft ex Scamoni et Passarge 1959
  Quercetalia pubescenti-petraeae Klika 1933
    Carpinion orientalis Horvat 1958
    Fraxino orni-Ostryion Tomažič 1940
    Syringo-Carpinion orientalis Jakucs (1959) 1960
    Quercion confertae Horvat 1958
    Melitto albidae-Quercion Barbero et Quézel 1976
    Quercion petraeo-cerridis Lakušić et B. Jovanović in B. Jovanović et al. ex Čarni et Mucina 2015
    Quercion pubescenti-petraeae Br.-Bl. 1932 *nom. mut.*
    Aceri tatarici-Quercion Zólyomi 1957
Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968
  Aceretalia pseudoplatani Moor 1976 *nom. conserv. propos.*
    Fraxino excelsioris-Acerion pseudoplatani P. Fukarek 1969
    Ostryo carpinifoliae-Tilion platyphylli (Košir et al. 2008) Čarni in Willner et al. 2016
  Carpinetalia betuli P. Fukarek 1968
    Erythronio-Carpinion (Horvat 1958) Marinček in Wallnöfer et al. 1993
    Castaneo sativae-Carpinion orientalis Quézel, Barbero et Akman ex Quézel et al. 1993
  Luzulo-Fagetalia sylvaticae Scamoni et Passarge 1959
    Luzulo-Fagion sylvaticae Lohmeyer et Tx. in Tx. 1954
  Fagetalia sylvaticae Pawłowski 1928
    Aremonio-Fagion (Horvat 1950) Borhidi in Török et al. 1989
    Fagion sylvaticae Luquet 1926
    Geranio striati-Fagion Gentile 1970
  Rhododendro pontici-Fagetalia orientalis Passarge 1981
    Fagion orientalis Soó 1964

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ВЕГЕТАЦИЈА НА ЛИСТОПАДНИ ШУМИ НА БАЛКАНСКИОТ ПОЛУОСТРОВ

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Во трудот се дава преглед на листопадните шуми на Балканскиот Полуостров. Претставени се речните, заливните и мочуришните шуми, во кои доминираат *Alnus incana*, *A. glutinosa*, *Fraxinus excelsior, F. angustifolia, Quercus robur, Salix alba, Ulmus laevis, U. minor*; ацидофилни шуми во кои доминираат *Betula pendula, Castanea sativa, Fagus sylvatica, Quercus petraea*; термофилни шуми во кои доминираат *Carpinus orientalis, Ostrya carpinifolia, Quercus cerris, Q. farinetto, Q. petraea, Q. pubescens* и мезофилни шуми во кои доминираат *Carpinus betulus, Fagus sylvatica, F. orientalis, Fraxinus excelsior, Tilia argentea, T. cordata, T. platyphyllos, Ulmus glabra*. Во исто време, шумите се класифицирани во синсистематски стандрадни рамки според Системот на Централна Европа до ниво на сојуз.

Клучни зборови: Балкан; шума; вегетација; класификација

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Original scientific paper

DRY GRASSLAND VEGETATION ON GALIČICA MOUNTAIN (SW MACEDONIA)

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This paper presents the dry grassland vegetation (*Festuco-Brometea*) on the Galičica Mountain. The research underlying this study was carried out in the period of 2009–2010 at several localities, on carbonate substrate from Ohrid and Prespa sides. Registered community of this type is subordinate to xerophilous vegetation of the *Festuco-Brometea* the order *Astragalo-Potentilletalia* Micevski [1] and alliance *Saturejo-Thymion* Micevski [2]. From the floristic composition and the detailed phytocoenological analysis of the investigated vegetation it was concluded that it is represented by ass. *Siderito montanae-Trifolietum dalmaticae* ass. nova subass. *erodietosum guicciardii* subass. nova.

Key words: vegetation, dry grasslands, Galičica

INTRODUCTION

This study deals with the syntaxonomic position and the ecological characteristics of the dry grasslands on the territory of the National Park Galičica. Dry grasslands have an important role in sustaining the biodiversity of the National Park Galičica by harboring many rare and endangered plant species (*Erodium guiciardii*, [3], *Minuartia glomerata* subsp. *macedonica*, *Centaurea grisebachii*, *Verbascum longifolium* subsp. *pannosum*, etc.) In the lowland belt to 1000 (1200) above sea level, in the belt of oak forests (*Fraxino orni-Quercetum petraeae*, *Ostryo carpinifoliae-Quercetum cerris* and *Fraxino orni-Quercetum cerris)*, and some in the lower belt of beech forest, on the altitude of 700–1200 m [4], [5], with their degradation (uprooting, burning or prolonged use of forests for firewood or other uses), these habitats are gradually transformed into dry grasslands which are secondary phytocenoses maintained through grazing and other anthropogenic activities. The communities of this vegetation type from the central and southern parts of the Balkan Peninsula belong to the class *Festuco-Brometea*, order *Astragalo-Potentilletalia* Micevski [1] Matevski [6].

Festuco-Brometea class is represented by thermophilic communities that develop mainly in the belt of hilly pastures, rocks and pastures with deeper soil layer. The communities of this class are prevalent in the area of Atlantic, Central Europe and in the sub-Mediterranean region [7]. Xerophilous vegetation of the class *Festuco-Brometea* covers large areas of the Balkan Peninsula from the sub-Mediterranean zone to subalpine belt, at an altitude between 200 and 1550–1600 m. The communities in this class find optimal conditions for their development on warmer habitats, secondary habitats that represent the final stages of degradation of forest vegetation communities of the following orders: *Quercetalia pubescenti-petraeae* Klika [8] and *Fagetalia sylvaticae* [9]. In the composition of the communities that have developed in the southern part of the Balkan Peninsula the species of Balkan, Illyrian, south Balkan, southeast-European floral elements, as well as local endemic species, are of particular significance.

For the Balkan Peninsula, two regional orders of the Festuco-Brometea have traditionally been used: *Festucetalia valesiacae* (pontic), *Astragalo-Potentilletalia* (central Balkans) and *Scorzonero villosae-Chrysopogonetalia grylli* (Illyrian region) [7].

The dry grasslands on the territory of Macedonia, according to Micevski [1, 2, 10], are subordinated to the order *Astragalo-Potentilletalia* and were divided into three alliances - *Trifolion cherleri* Micevski [11], *Saturejo-Thymion* Micevski [2] and *Armerio-Potentillion* Micevski [10].

At that time Micevski could not have an overview of the vegetation of Europe, and integrated all dry grasslands into one order that is nowadays divided into several classes. According to the latest concept of Mucina et al. [12], the alliance *Trifolion cherleri*, which includes the communities of the belt of hilly pastures that develop on silicate surfaces in the altitude belt of 100–900 m, is transferred to the class *Helianthemetea guttati*, while the communities of the alliance *Armerio-Potentillion*, which develop also on silicate substrate on the territory of Macedonia and inhabit the area between 1000–1400 m, are transferred to the class *Stipo giganteae-Agrostietea castellanae* Rivas-Mart. et al. [13], Romeo di Petro et al. [14]. In accordance with the latest sintaxonomic solutions, Matevski et al. [12] the order *Astragalo-Potentilletalia* is associated only with the communities of the belt of hilly pastures on the territory of Macedonia and northern Greece, which develop on carbonate substrate and belong to the alliance *Saturejo-Thymion*.

The order *Astragalo-Potentilletalia,* which is especially important for the southern Balkans or eastern sub-Mediterranean, unites communities from the hilly pastures that develop under the impact of the Mediterranean or modified Mediterranean climate, on carbonate geological surface [1]. As a result of the ecological conditions, the dry calcareous grassland communities on the territory of the Republic of Macedonia can be divided into two subgroups: steppe that develop on a flat surfaces with fragmented bedrock, and rocky grasslands.

This order, according to the concept of Matevski et al. [6], is represented by the alliance *Saturejo-Thymion* Micevski [2]. It should be noted that the alliance *Saturejo-Thymion* and the order *Astragalo - Potentilletalia,* which were described by Micevski [1], were validated a year later because according to the "International code of phytosociological nomenclature" [15] if a union is to be validly described, it should also include at least one validly described association. Considering that, the first association described validly from the alliance *Saturejo-Thymion* was ass. *Brachypodio-Onobrychetum pindicolae* [2], therefore, 1971 is considered as the year when the alliance and the order were validly described.

Within the order *Astragalo-Potentiletallia*, from the Republics of Serbia and Kosovo the alliances *Scabioso-Trifolion dalmatici* [16] and *Koelerio-Festucion dalmaticae* [17] were described, while from the territory of Greece, the alliance *Alyssion muralis* [18] was described, but in the light of new research, according to the concept of Mucina et al, [12], they have been transferred to other orders within the class, or within other classes.

The study area was previously an object of floristic and vegetational investigations [19–26]. The present study was thus aimed at gaining a more complete understanding of the vegetational characteristics of the dry grasslands of the investigated area, as a basis for synphytosociological studies. All this indicated the necessity of taking additional phytocoenological research, taking into account the progress in the floristic knowledge of the mountain, using modern phytocoenological methods and respecting the International code of phytosociological nomenclature.

The article is dedicated to Acad. Kiril Micevski, one of the pioneers of modern vegetation studies in Macedonia. Acad. Micevski specialized in the phytocoenological methodology according to Braun Blanquet under the mentorship of one of the well known phytocoenologists – Prof. Stjepan Horvatić. As a result of his research activities that lasted over 50 years he gave a general survey of the vegetation of Macedonia by elaborating many vegetation types. He made an outstanding contribution to the investigation of the water, marsh and halophytic vegetation, as well as of lowland meadows. His contribution to the study of dry grassland vegetation is also remarkable as he established the research principles and described an order and three alliances (*Astragalo-Potentilletalia, Trifolion cherleri*, *Saturejo-Thymion* and *Armerio-Potenillion*) on the basis of which numerous communities have been described.

AREA OF RESEARCH

The heterogeneity of vegetation cover of the Mountain Galičica, is undoubtedly a result of spatial and environmental uniqueness of the massif, its geological history and climate specifics. Mountain Galičica is a horst which was elevated by the tectonic movements in the past and which relatively clearly stands out from the surrounding mountains as a separate geo-morphostructural whole. To the east and west the mountain is clearly limited by two major natural lakes - Ohrid and Prespa (Figure 1), to the south by the valley of Korča in Albania, while to the north it is connected with Plakenska and Ilinska mountains through Preval of Bukovo [27]. Ohrid and Prespa Lakes, between which Mountain Galičica is located, are a kind of thermal regulator which regulates the climate on the broader space, not permitting extremely high or low temperatures, so that this region is under the influence of mild continental or modified (sub) Mediterranean climate. Favorable climatic circumstances and dominant limestone geological substrate, create good environmental conditions and ambient for development of a number of plant species and plant communities typical of Mediterranean or sub-Mediterranean flora and vegetation. It can be seen in all parts of the mountain, as in the valleys and in its highest parts. The geographic position, limestone relief and mild pleasant climate, allow Galičica to function during the glacial period as a part of the grid of refugial areas of the territory of Macedonia [28].

Figure 1a and b. Map of the investigated area and localities on Galičica Mountain

MATERIAL AND METHODS

Phytosociological investigations were realized during 2009 and 2010 in the framework of a broader research into the grassland vegetation. The dry grassland vegetation on Mountain Galičica was investigated as well as the most common secondary vegetation types created by gradual and long-lasting degradation (grazing and browsing by animals, fires, or mowing) of various forest phytocenoses.

Phytosociological investigations were conducted according to the standard method of vegetation surveys of Zurich-Montpellier school [29], whereby for the chosen homogeneous, representative areas lists of plant species with estimated cover values, named as relevés, were made; so, in our case, 50 vegetation relevés were prepared for this purpose.

For the preparation of the vegetation relevés representative minimal areas were selected up to 100 m². For each vegetation relevés, besides the data for the floristic composition and their quantitative participation, there were also registered the basic data for the locality and the abiogenic and physiognomical features of the habitats: the name of the investigated locality, date, altitude (m), the area of the relevé (m²), inclination (°), exposure, total cover, geological substrate, geo-coordinates anthropogenic influence, etc.

After drying and labeling the collected plant material was determined, using thereby a large number of floristic works - Flora Europaea [30–34]; Prodromus florae peninsulae Balcanicae [35–37]; Flora of the Republic of Macedonia [38–44]; Flora of Bulgaria [45–47]; Flora of SR Serbia [48], etc. The taxonomic nomenclature and the compliance of registered taxa of our vegetation relevés were done with the taxonomy and nomenclature of the species and lower taxa and their synonyms using the "online" EURO + MED PLANT BASE (database for vascular plants of Europe and the Mediterranean region – http : //www.euromed.org.uk/).

For determination of the taxa of taxonomic complicated genera there were used the latest monographs and other floristic and taxonomic notes that refer to the flora of the Republic of Macedonia, the Balkan Peninsula and Europe. For comparison, there was also used the herbarium material deposited in the herbarium of the Institute of Biology (MKNH) at the Faculty of Natural Sciences and Mathematics in Skopje.

The list of our own vegetation relevés and those that are described in the literature has been entered into the Turboveg database [49]. Vegetation relevés were exported in computer software JUICE [50] for further analysis, where for defining of plant communities, firstly, an agglomerative hierarchical cluster analysis has been made in program PC-ORD [51] with Jaccard index of similarity, using Flexible Beta method for connections within a groups with $\beta = -0.25$, and transforming the data with $b = \log (Xi, j + 1)$. For an objective selection of the cluster method and the optimal number of clusters with maximum number of "faithful" species we used the method OptimClass [52].

Additionally, the diagnostic species of the communities were identified by a fidelity measure in the JUICE program [50]. The threshold of the phi value was subjectively selected at 0.50 for species to be considered as diagnostic [53]. The species having more than 50% occurrence frequency for a given community were defined as constant species, while species attaining a cover higher than 50% in more than 30% of the relevés were accepted as dominant species.

To determine the biological range of communities we used biological (life) forms by Raunkiaer [54]: geophytes, therophytes, hemicryptophytes, chamaephytic and phanerophytes.

The results obtained from numerous numerical analyses helped us in processing of analytic and later of synthetic tables. By using the appropriate literature, and the knowledge that we possess, each of the taxa listed in the table was determined by its syntaxonomic affiliation to the appropriate syntaxonomic category.

In the last column of the analytical tables there are data of the calculated and entered percentages of occurrence of the species in the total number of relevés of vegetation community - the so-called degree of constancy.

The names of registered syntaxa and their authors are given according to the International code for phytosociological nomenclature [15].

During chorological analyses the floral elements given by Gajič [55], Pignatti [56] and other authors were used. A total of 233 taxa of vascular plants were identified during our research, characterized by high phytogeographic diversity which were arranged in 9 chorological groups: I – Balkan and sub-Balkan floral elements, II – Steno Mediterranean floral elements, III – Eurimediterranean floral elements, IV – Mediterranean mountainous floral elements, V – Eurasian floral elements, VI – Atlantic floral element, VII – Orophil-South European floral element, VIII – Boreal floral elements, and IX – floral elements with wider distribution. Through their percentile representation in the community the chorological composition of the registered phytocenoses was determined.

RESULTS AND DISCUSSION

For more precise and objective classification of the relevés made within our research of dry grassland vegetation of Mountain Galičica the latest computer numerical methods were also used besides classical methods of analysis. After the analysis was made, because of the presence of a large number of characteristic species (such as: *Koeleria splendens*, *Medicago rigidula*, *Ziziphora capitata*, *Coronilla scorpioides*, *Minuartia hamata*, *Tragopogon balcanicus*, *Tremastelma palestinum*, *Fumana procumbens*, *Hippocrepis ciliata*, *Allium flavum* subsp. *flavum* and *Minuartia glomerata* subsp. *macedonica* of the alliance *Saturejo-Thymion*) we have concluded that the investigated vegetation belongs to that alliance, which includes communities that develop on rocky and hilly pastures on limestone geological substrate. On the territory of the Republic of Macedonia within this alliance the following seven associations are described so far: *Brachypodio-Onobrychetum pindicolae* Micevski [2], *Astragalo-Morinetum* Micevski [2], *Sileno-Thymetum ciliatopubescentis* Matevski, Lozanovski et Kostadinovski [57], *Petrorhagio-Chrysopogonetum grylli* Matevski *et al*. [6], *Scorzonero-Stipetum endotrichae* Matevski *et al*. [6], *Globulario-Centauretum grbavacensis* Matevski *et al*. [6] and *Astragalo-Helianthemetum marmorei* Matevski *et al*. [6].

To determine the syntaxonomic position of the 50 vegetation relevés from the ivestigated area a base of vegetation relevés was created for the associations from the alliance *Saturejo-Thymion*, registered on the territory of the Republic of Macedonia.

This database contains 278 vegetation relevés and 580 taxa which were exported to a computer program Juice, for further analysis.

The optimal level of the clustering was determined by the Optimclass 1 method [52]. Correspondingly, relevés were grouped using Jaccard index of similarity and the Flexible Beta method, as cut levels, percentage cover values of 0, 5, and 25 were defined and dendrogram was cut at the fourteen-cluster level (Figure 2).

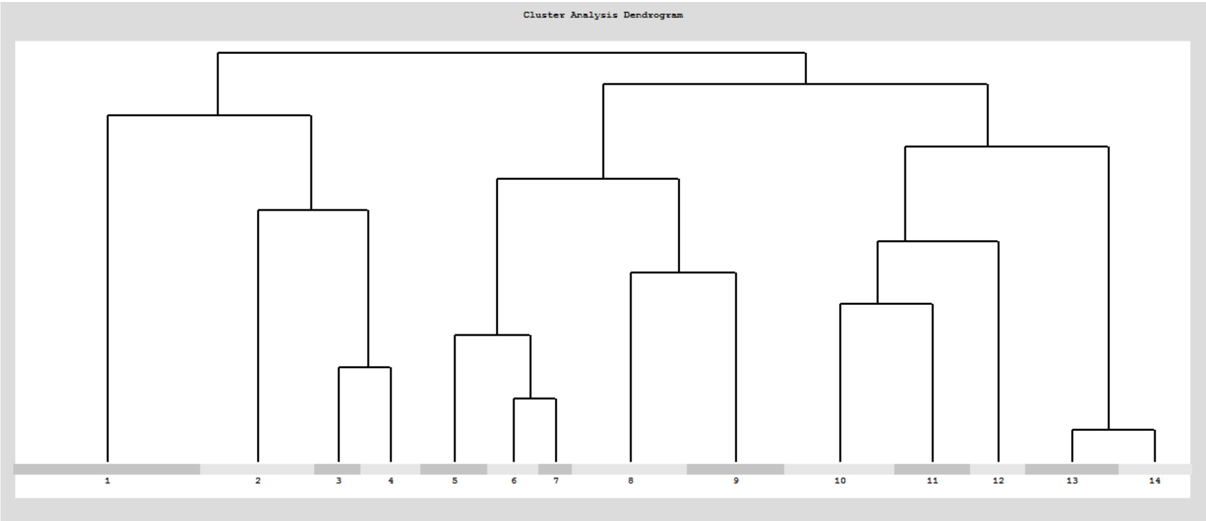

Figure 2. *Saturejo-Thymion* – Hierarchical classification in the form of dendrogram of 278 relevés in 14 clusters. Cluster 1 *Brachypodio-Onobrychetum pindicolae*; Cluster 2 – *Astragalo-Morinetum*; Cluster 3 и 4 – *Hedysaro-Convolvuletum*; Cluster 5 – unpublished vegetation relevés on limestone substrate from the locality Luben;Cluster 6 – ass. *Petrorhagio-Chrysopogonetum grylli*; Cluster 7 – unpublished vegetation relevés on limestone substrate from the locality Barbaras; Cluster 8 – ass. *Siderito - Trifolietum dalmaticae* ass. nova- subass. *typicum* subass. nova; Cluster 9 – ass. *Siderito –Trifolietum dalmaticae* ass. nova – subass. *erodietosum guicciardii* subass. nova; Clusters 10, 11 and 12 ass. *Globulario-Centauretum grbavacensis*Matevski *et al* 2014, in Cluster 11 ass. *Sileno-Thymetum ciliatopubescentis*; Clusters 13 and 14 – ass. *Scorzonero-Stipetum endotrichae* (the Cluster 14 also includes unpublished vegetation relevés on limestone substrate from the locality Pantelejmon – Mariovo).

According to hierarchical classification (Figure 2) the researched dry grasslands on Mountain Galičica are subordinated to the clusters 8 and 9. When the synoptic table with program package Juice was prepared, we received three groups of taxa - diagnostic, constant and dominant. According to them, our vegetation relevés from Galičica Mountain are separated from the vegetation relevés from other parts of Macedonia covered by the remaining twelve clusters. Below, the diagnostic, constant and dominant taxa are presented which were obtained by the analysis.

Diagnostic species: *Alyssum strigosum, Anthemis arvensis, Bupleurum gussonei, Cerastium brachypetalum* subsp. *roeseri, Clinopodium acinos, Elytrigia intermedia, Sideritis montana* subsp. *remota, Trifolium dalmaticum.*

Constant species: *Aegilops neglecta, Bromus squarrosus, Crupina vulgaris, Helianthemum salicifolium, Hypericum rumeliacum, Koeleria splendens, Medicago minima, Petrorhagia saxifraga, Poa bulbosa, Sedum urvillei, Teucrium capitatum, Valerianella coronata.*

Dominant species*:* *Anthyllis vulneraria* subsp*. polyphylla*

After the prepration of the synoptic table and the comparative analysis made between our own records and the literature data relating to known communities of the alliance *Saturejo-Thymion*, we concluded that the vegetation relevés of Mountain Galičica are characterized by a sufficient number of diagnostic species which is the basis for the separation of a new association - *Siderito montanae-Trifolietum dalmaticae* ass. nova (Table 1).

The association *Siderito montanae-Trifolietum dalmaticae* (Holotypus hoc loco: Tab. 1/21) is named after the two characteristic species - *Sideritis montana* subsp. *remota*, which is a representative of the south Balkan-Asia Minor floral element and has limited distribution on the territory of the Republic of Macedonia, in the vicinity of Dojran and Mount Galičica, and the Balkan endemic species *Trifolium dalmaticum.*

As diagnostic species the following taxa are separated, too: *Cerastium brachypetalum* subsp. *roeseri*, *Anthemis arvensis*, *Alyssum strigosum*, *Clinopodium acinos*, *Bupleurum gussonei* and *Elytrigia intermedia*.

It is a secondary community which develops at the clearings on Galičica Mountainin degraded stands in the belt of oak forests (ass. *Quercetum frainetto-cerris*, ass. *Quercetum trojanae*, ass. *Ostryo carpinifoliae-Quercetum cerris*), as well as in the lower belt of beech forest on an altitude of 700–1200 m.

The association *Siderito montanae-Trifolietum dalmaticae* is registered at several sites in the Ohrid part of Galičica Mountain: Mal Osoj, Elšani, Trpejca, over the road to Vršec, Velestovo, Pogled, also to Margarine and over the curve M from the Prespa side (Figure 3).

The biological spectrum illustrates best the environmental conditions, especially the climatic characteristics of the reaserched area. It is a therophytic-hemicryptophytic community in whose composition therophytes (49%) and hemicryptophytes (36%) dominate (Figure 4).

Figure 3. Ass. *Siderito montanae-Trifolietum dalmaticae* ass. nova – dry grassland above the v. Velestovo

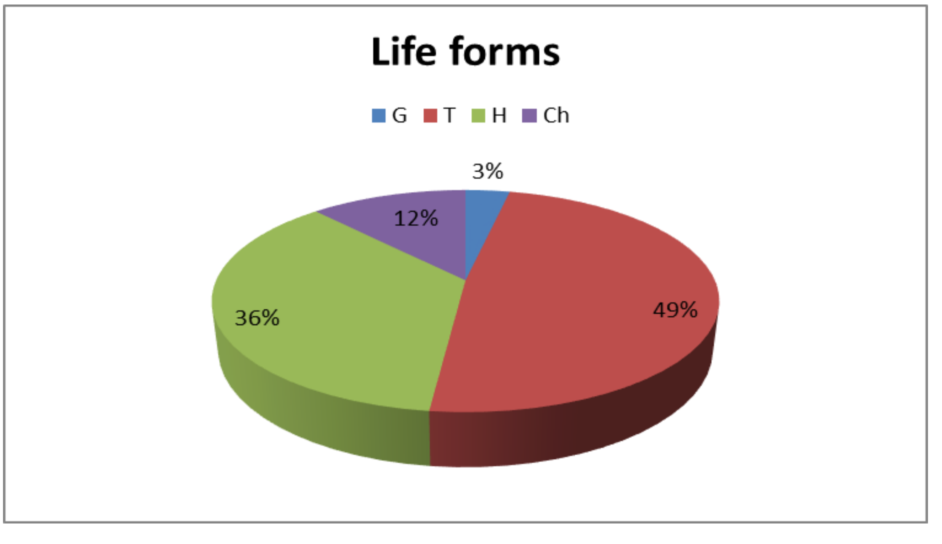

Figure 4. Ass. *Siderito montanae-Trifolietum dalmaticae* ass. nova – spectrum of life forms

Through a detailed analysis of area-spectrum, we got a rather complete phytogeographic structure of the dry grasslands of Galičica (Figures 5 and 6).

The impact of the modified Mediterranean climate which is particularly intense in the altitudinal belt where this community develops is reflected in its floristic composition, as is evident by the largest presence of taxa from the Eurimediterranean floral element (35%). Taxa belonging to Eurasian floral element are represented by 28%, while the Balkan floral element comprises 17% (Figure 5).

From the group of Balkan floral elements (Figure 6), the most dominant are the Balkan floral elements (sensu stricto) (40%).

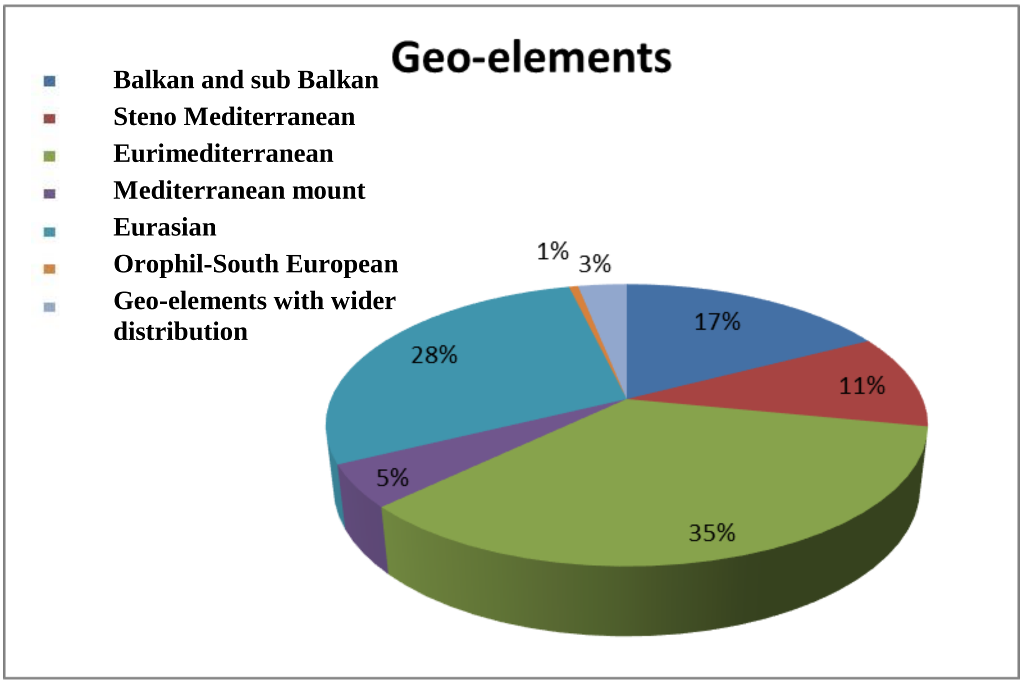

Figure 5. Ass. *Siderito montanae-Trifolietum dalmaticae* ass. nova – spectrum of geo-elements

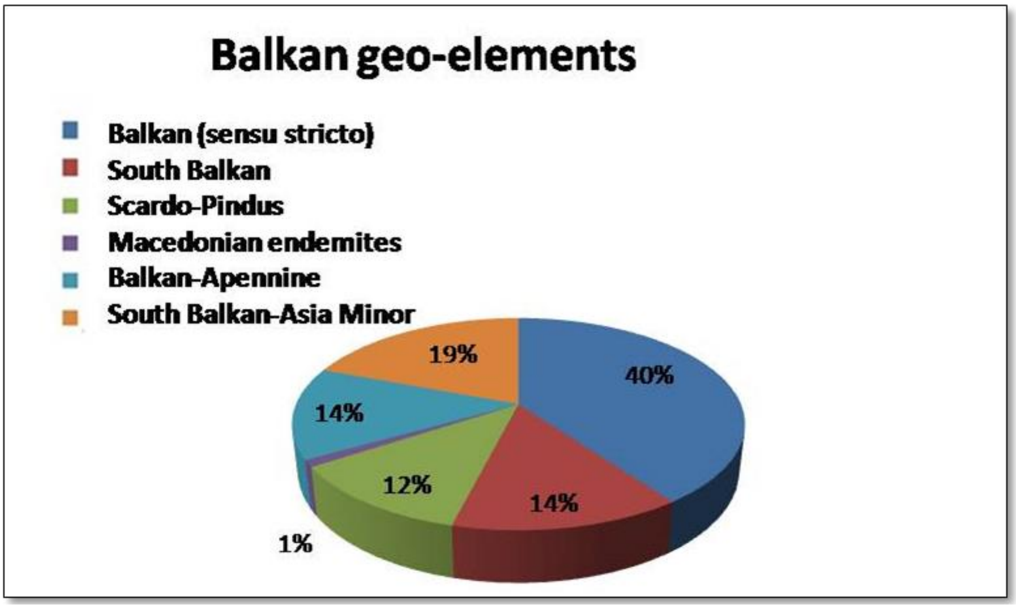

Figure 6. Ass. *Siderito montanae-Trifolietum dalmaticae* ass. nova – percentage representation of Balkan geo-elements (phytogeographic spectrum)

Using the data from "WorldClim", we received the following bioclimatic variables for the researched community:

BIO1 = Annual mean temperature (9.2), BIO2 = Mean diurnal range (mean of monthly (max temp – min temp)) (10.2), BIO3 = Isothermality (BIO2/BIO7) (0.35), BIO4 = Temperature seasonality (standard deviation *100) (64.6), BIO5 = Max temperature of warmest month (25.1), BIO6 = Min temperature of coldest month (–3,8), BIO7 = Temperature annual range (BIO5–BIO6) (28.9), BIO8 = Mean temperature of wettest quarter (–5.7), BIO9 = Mean temperature of driest quarter (17.4), BIO10 = Mean temperature of warmest quarter (17.4), BIO11 = Mean temperature of coldest quarter (–0,9)

BIO12 = Annual precipitation (854), BIO13 = Precipitation of wettest month (113), BIO14 = Precipitation the driest month (45), BIO15 = Precipitation seasonality (coefficient of variation) (28), BIO16 = Precipitation of wettest quarter (291), BIO17 = Precipitation of driest quarter (134), BIO18 = Precipitation of warmest quarter (134), BIO19 = Precipitation of coldest quarter (245);

The vegetation relevés of cluster 9 (Figure2), registered on several localities of Galičica – above Glajšo, Margarine, above the curve M – from Prespa side (Figure7), are separated from other vegetation relevés because of their floristic composition obtained at the sites where the typical form of the association *Siderito montanae-Trifolietum dalmaticae* develops. In the floristic composition of these relevés several taxa are appearing, such as: *Convolvulus althaeoides* subsp. *tenuissimus*, *Erodium guicciardii*, *Alyssum repens* subsp. *trychostachyum*, *Cynoglottis barrelieri* subsp. *serpentinicola*, *Scandix australis*, *Erysimum comatum* and *Thesium divaricatum,* which are registered in this combination on Mountain Galičica only at these sites, and are taken as diagnostic species of a new subassociation - subass. *erodietosum guicciardii* subass. nova (Holotypus *hoc loco*: Tab. 1/44) (Table 1). Special diagnostic species for this subassociation are two differential thermophilic species *Erodium guicciardii* (Figure 8) and *Convolvulus althaeoides* subsp. *tenuissimus,* which mainly develop in the southern part of the Balkan Peninsula and the Mediterranean. The most representative populations of these two species on the territory of Macedonia are found on Mountain Galičica. *Erodium guicciardii* was discovered for the first time for the territory of Macedonia by Micevski [3] on the Mountain Galičica, vicinity of Demir Hisar and Kičevo (Baba Sač, Ilinica, Suvo Pole), while *Convolvulus althaeoides* subsp. *tenuissimus* for the vicinity of Gevgelija and Galičica ([58], [44]). Other diagnostic species of the subassociation are: *Alyssum repens* subsp. *trychostachyum*, *Cynoglottis barrelieri* subsp. *serpentinicola*, *Scandix australis*, *Erysimum comatum* and *Thesium divaricatum*.

Figure 7. Ass. *Siderito montanae-Trifolietum dalmaticae* – subass. *erodietosum guicciardii* subass. nova – Margaraina above Oteševo, dry grassland

Figure 8. *Erodium guicciardii* Heldr.

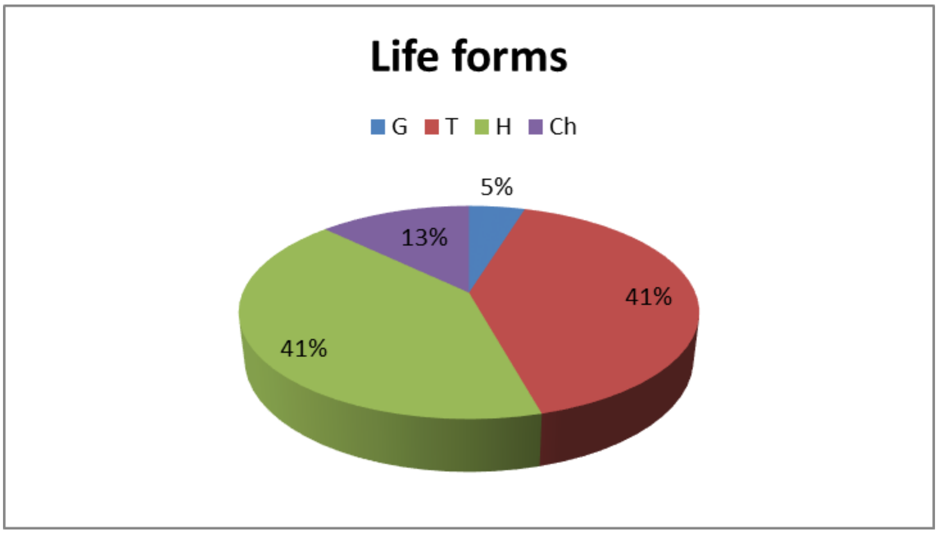

Figure 9. Ass. *Siderito* - *Trifolietum dalmaticae* ass. nova – subass. *erodietosum guicciardii* subass. nova - spectrum of life forms

From the biological spectrum (Figure 9) of the subassociation *erodietosum guicciardii*, it can be noticed that the percentages of hemicryptophytes and terrophytes are equal (41%), while the representation of the hemicryptophytes in the subassociation is higher than in the typical form of the association *Siderito montanae-Trifolietum dalmaticae.*

The spectrum of floral elements is shown for the subassociation *erodietosum guicciardii* (Figures 10 and 11).

From the spectrum of floral elements (Figures 10 and 11) of the subassociation *erodietosum guicciardii*, it can be noticed that the percentage of Balkan and sub-Balkan elements is higher (23%), and thereby the percentages of Balkan (sensu stricto) and South Balkan elements are higher too, than in the typical form of the association *Siderito montanae-Trifolietum dalmatica*.

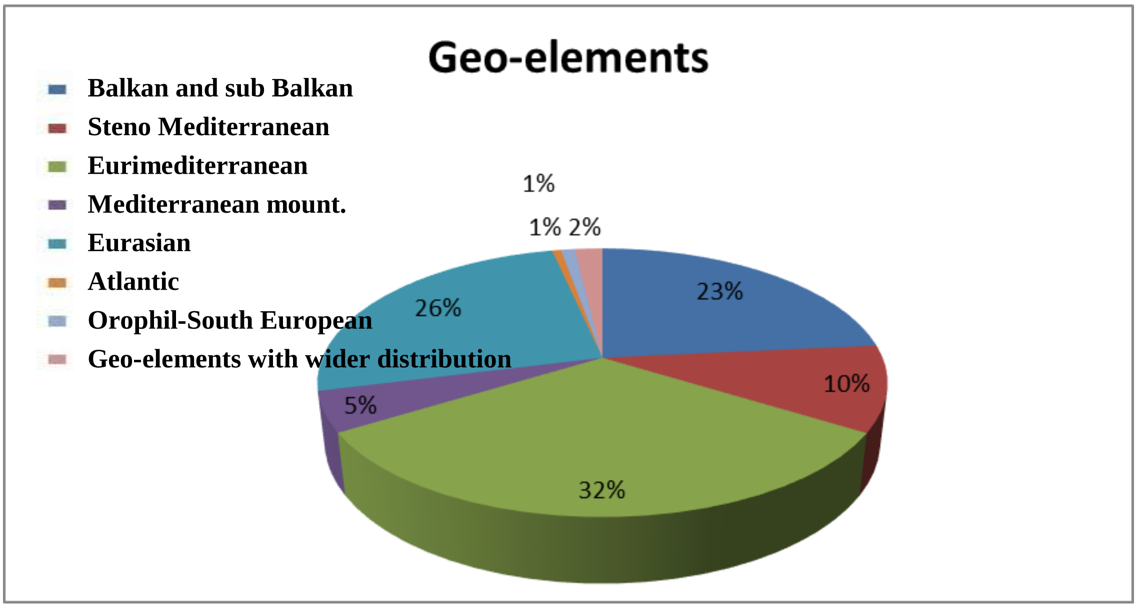

Figure 10. Ass. *Siderito – Trifolietum dalmaticae* ass. nova – subass. *erodietosum guicciardii* subass. nova. Spectrum of geo-elements (phytogeographic spectrum)

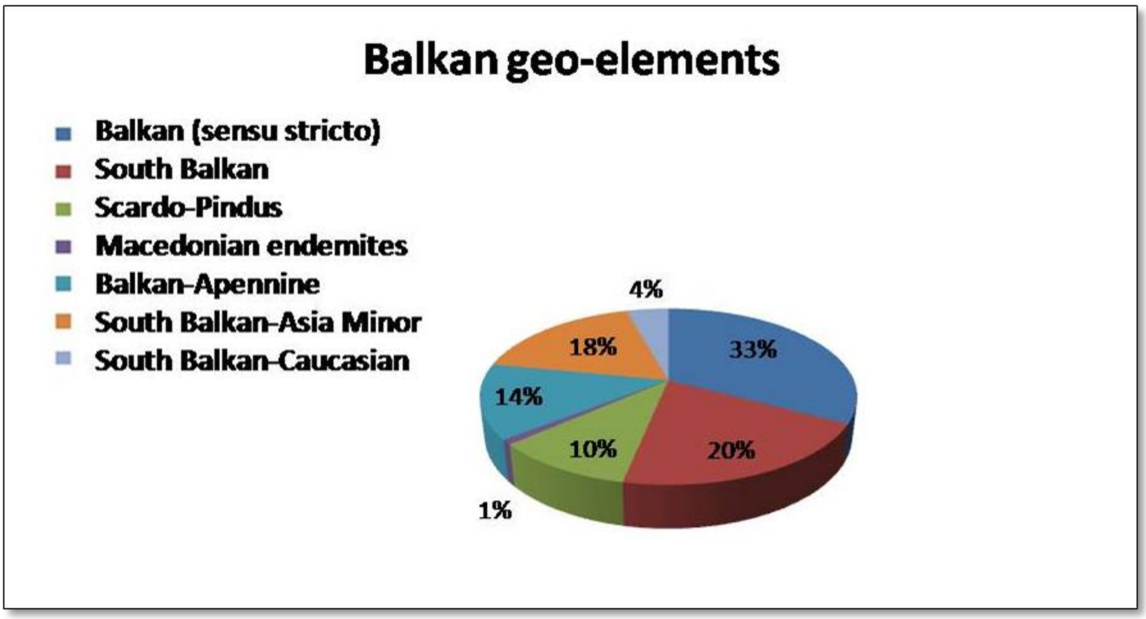

Figure 11. Ass. *Siderito montanae - Trifolietum dalmaticae* ass. nova – subass. *erodietosum guicciardii* subass. nova. Percentage representation of Balkan geo-elements (phytogeographic spectrum)

Table 1. ass. *Siderito - Trifolietum dalmaticae* ass. nova- subass. *erodietosum guicciardii* subass. nova

Releve number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
***Siderito montanae-Trifolietum dalmaticae* ass. nova**																																																			
Cerastium brachypetalum subsp. *roeseri*	1	1	+	1	+	+	+	+	+	+	+	1	1	+	+	+	+	+	1	1	1	1	1	2	1	2	1	.	1	+	.	+	1	+	1	1	1	+	+	+	1	+	+	1	1	1	1	+	+	+	V
Anthemis arvensis	+	+	+	+	+	.	.	.	.	.	.	+	+	+	1	+	+	1	1	1	1	1	1	+	+	1	1	.	.	.	.	1	+	+	+	+	+	+	1	1	1	1	.	.	.	+	+	+	+	+	IV
Sideritis montana subsp. *remota*	.	.	.	.	+	+	1	.	+	.	.	+	+	+	.	.	.	+	+	+	2	2	2	1	+	.	1	.	+	+	+	1	+	.	.	+	+	+	1	1	2	1	1	1	1	+	2	1	1	2	IV
Trifolium dalmaticum	3	2	2	2	1	+	1	+	+	1	+	2	1	1	1	1	1	1	2	2	2	1	2	1	2	2	+	.	.	.	.	.	.	.	.	.	.	.	1	+	1	1	.	.	+	+	+	+	.	.	IV
Alyssum strigosum	1	.	.	+	.	1	1	+	+	+	+	+	+	+	+	.	+	+	1	1	1	+	+	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	.	1	1	1	1	+	1	1	IV
Clinopodium acinos	.	.	+	.	.	+	1	1	.	+	+	.	.	1	.	.	.	1	+	+	.	.	1	1	+	+	+	+	+	+	+	.	.	.	.	+	+	.	+	+	+	+	+	+	+	+	+	+	+	1	IV
Bupleurum gussonei	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	1	+	+	2	1	1	1	1	1	2	.	.	.	.	.	.	+	+	+	1	+	1	III
Elytrigia intermedia	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	1	+	.	.	.	.	.	+	1	1	1	+	+	+	+	.	+	1	1	+	+	+	.	.	.	.	.	+	+	+	+	+	+	+	III
***erodietosum guicciardii* subass. nova**																																																			
Convolvulus althaeoides subsp. tenuissimus		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	1	+	.	+	+	.	.	.	+	+	+	+	+	+	+	+	+	1	1	+	+	+	1	+	+	III
Erodium guicciardii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	1	1	+	+	.	1	+	+	1	1	2	2	1	2	1	1	1	II
Alyssum repens subsp. *trychostachyum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	1	.	.	.	.	.	.	.	+	+	+	+	1	1	1	1	1	+	+	+	II
Cynoglottis barrelieri subsp. *serpentinicola*		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	+	+	+	.	.	+	+	.	.	2	1	+	.	.	+	1	1	II
Scandix australis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	+	+	+	1	+	+	+	+	+	.	.	II
Erysimum comatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	1	1	1	1	1	1	1	1	II
Thesium divaricatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	+	.	.	.	.	.	.	.	1	1	1	1	1	2	+	+	.	.	.	.	II
Saturejo-Thymion																																																			
Koeleria splendens	.	.	.	.	1	.	.	+	2	2	1	2	1	+	+	1	+	1	1	+	1	1	1	1	1	1	2	2	2	2	2	+	+	1	+	1	1	1	2	2	1	1	1	2	2	1	1	2	+	+	V
Medicago rigidula	.	.	.	.	.	1	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	2	2	+	+	+	+	.	.	.	.	+	+	+	+	+	+	.	.	.	.	.	+	+	1	.	.	.	.	.	III
Ziziphora capitata	1	+	+	+	+	1	+	1	1	+	+	.	1	+	.	.	.	1	+	+	.	.	.	.	1	+	1	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Coronilla scorpioides	+	.	.	.	.	+	+	1	.	+	1	.	+	.	.	.	+	.	.	.	.	.	+	1	1	1	1	+	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	II
Minuartia hamata	1	.	.	+	+	.	1	+	1	1	1	.	.	.	.	.	.	.	.	.	+	+	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	II
Tragopogon balcanicus	.	.	.	.	.	+	+	.	+	+	+	+	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	+	.	+	+	II
Tremastelma palestinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	+	.	.	.	+	1	1	2	1	1	1	1	+	+	.	.	II
Fumana procumbens	.	.	.	.	.	+	2	2	+	2	2	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hippocrepis ciliata	.	+	.	.	.	.	.	.	.	.	.	1	+	1	2	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Allium flavum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Minuartia glomerata subsp. *macedonica*		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I

Table 1. (continuation)

Astragalo-Potentilletalia																																																			
Bromus squarrosus	1	1	+	+	+	1	1	1	1	+	+	+	+	.	.	.	.	.	.	.	1	1	1	1	1	1	1	+	+	+	+	1	1	1	1	1	1	1	1	1	+	1	1	1	+	+	+	+	+	+	V
Petrorhagia saxifraga	1	1	+	.	1	+	+	+	1	+	+	1	1	+	1	+	1	1	+	+	1	1	+	+	1	1	+	1	1	+	+	1	1	+	1	+	1	1	.	.	.	1	.	.	.	.	.	.	.	.	IV
Hypericum rumeliacum	.	.	.	.	.	1	2	2	2	+	1	+	+	+	+	+	.	1	1	+	+	1	1	+	+	+	.	.	.	.	+	+	1	1	+	.	.	+	1	+	+	1	1	1	1	1	+	1	1	1	IV
Xeranthemum annuum	1	+	.	.	.	+	+	+	+	.	.	+	+	+	1	+	+	+	+	+	1	+	+	+	+	+	1	.	.	.	.	+	1	1	1	1	1	+	.	+	+	+	.	.	.	.	.	+	+	+	IV
Psilurus incurvus	1	2	2	2	2	1	1	1	+	+	+	+	1	+	.	.	.	1	1	+	.	.	.	+	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Melica ciliata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	1	+	+	+	+	+	+	+	+	+	+	II
Potentilla laciniosa	+	.	.	.	.	+	1	+	+	1	+	+	+	.	.	.	.	.	.	.	+	.	1	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	II
Erysimum diffusum	.	.	.	.	.	.	+	.	.	.	+	.	+	.	.	.	+	.	+	.	+	.	+	+	+	+	+	.	.	.	+	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Astragalus onobrychis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	2	2	2	1	+	+	1	.	.	.	.	.	.	1	1	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	II
Asperula aristata subsp. *scabra*	.	.	.	.	.	.	1	1	+	+	+	+	1	+	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Festuca callieri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	1	+	+	.	1	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Centaurea grisebachii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Crepis foetida subsp. *rhoeadifolia*	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Festuco-Brometea																																																			
Crupina vulgaris	1	+	+	.	1	1	1	1	1	+	+	1	1	+	1	+	+	1	1	+	1	+	+	1	+	+	1	.	.	.	.	1	1	+	+	1	1	1	+	+	1	1	1	1	1	1	+	1	+	+	V
Teucrium chamaedrys	+	+	.	+	1	+	+	1	+	1	+	1	+	1	.	.	.	.	.	+	.	.	1	+	1	+	1	+	.	.	.	+	+	+	+	+	.	.	1	+	+	+	.	.	.	.	.	.	.	.	III
Anthyllis vulneraria subsp. *polyphylla*	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	.	+	.	1	1	1	1	1	+	+	1	1	+	1	2	+	1	2	2	2	3	3	3	4	3	III
Leontodon biscutellifolius	.	.	.	.	.	1	1	2	2	+	1	+	+	1	.	.	.	+	+	+	1	2	1	1	+	+	+	1	+	+	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	+	1	III
Convolvulus cantabrica	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	.	+	+	.	+	+	+	+	+	+	+	+	IV
Muscari racemosum	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	+	.	1	+	.	.	+	1	1	+	+	+	+	2	+	+	.	+	+	+	+	+	+	+	+	+	+	+	+	III
Eryngium campestre	.	.	+	+	.	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Helianthemum nummularium	1	1	1	1	1	+	1	1	+	1	1	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	2	+	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Pilosella piloselloides subsp. bauhinii	1	2	1	1	1	.	1	2	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Linum tenuifolium	.	.	.	.	.	+	1	3	+	+	+	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	1	+	+	II
Festuca valesiaca	+	.	.	+	+	+	1	+	2	+	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Eryngium amethistinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	.	+	+	+	1	+	+	II
Prunella laciniata	+	+	1	1	+	+	1	1	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Onosma heterophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	.	+	+	+	+	II
Phleum montanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	+	1	+	+	.	.	.	.	+	.	.	.	1	+	+	.	.	II
Scabiosa triniifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	+	.	+	+	.	.	.	.	.	.	.	+	+	+	+	.	+	II
Stipa pennata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	II
Stipa pulcherrima subsp. epilosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	+	2	1	1	1	.	.	.	.	.	.	.	.	I
Linum austriacum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	1	1	+	1	1	I

Table 1. (continuation)

Dorycnium pentaphyllum subsp. herbaceum	2	.	1	1	1	.	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Medicago falcata	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Jurinea mollis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	+	+	1	1	I
Noccaea praecox	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	+	+	+	+	I
Petrorhagia illyrica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	+	+	+	+	I
Artemisia alba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	2	1	+	.	+	.	.	.	.	.	I
Securigera varia	+	.	1	.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Salvia sclarea	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trigonella gladiata	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Achillea setacea	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Medicago lupulina	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Allium sphaerocephalon subsp. *arvense*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Cytisus procumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Ononis pusilla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Leopoldia comosa	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium incarnatum subsp. *molinerii*	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Anthyllis vulneraria subsp. *bulgarica*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Arabis sagittata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Iris pumila subsp. attica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Herniaria incana	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Poa angustifolia	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Inula oculus-christi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Thymus longicaulis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Polygala vulgaris	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Stipa capillata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Genista januensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Carex halleriana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Silene otites	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Anacamptis pyramidalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Minuartia verna subsp. *collina*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	I
Trinia glauca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
other species																																																			
Medicago minima	2	2	1	1	1	1	1	+	1	1	+	2	1	1	1	+	1	1	2	1	2	1	1	2	1	2	1	1	1	1	1	2	1	1	1	1	1	+	2	2	2	2	1	+	+	+	+	+	+	+	V
Poa bulbosa	1	1	1	1	+	+	1	1	2	1	1	1	1	1	1	1	+	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+	+	+	.	.	.	.	+	+	+	+	+	+	+	+	V
Teucrium capitatum	.	.	+	.	+	3	2	2	2	1	1	2	1	1	1	1	1	2	1	1	+	1	+	1	+	+	1	1	.	+	+	1	+	1	1	1	1	1	1	1	1	1	+	+	1	1	+	+	1	1	V

Table 1. (continuation)

Valerianella coronata	1	.	.	.	.	1	+	+	+	+	+	.	+	+	+	+	.	1	1	1	1	1	1	1	1	+	1	.	+	1	+	+	.	+	+	+	.	+	1	1	1	1	1	1	+	1	+	+	+	+	V
Aegilops neglecta	+	1	1	1	1	+	+	+	+	+	+	+	+	+	+	+	1	+	1	+	+	+	+	+	+	+	+	.	.	.	.	+	+	+	+	+	+	+	1	1	1	1	+	.	.	.	.	.	.	.	IV
Helianthemum salicifolium	.	.	.	.	.	+	+	.	.	.	.	1	+	1	1	1	1	1	1	2	1	1	1	1	1	1	+	.	+	+	.	2	2	1	1	1	1	1	1	1	1	+	1	1	1	1	+	1	+	+	IV
Sedum urvillei	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	.	1	+	1	1	+	+	1	1	2	1	+	+	+	+	+	.	+	+	+	+	1	1	1	1	1	1	1	+	+	+	1	+	+	IV
Arenaria leptoclados	1	+	.	+	.	2	1	1	1	1	1	1	+	1	+	+	.	1	2	1	1	1	1	1	1	1	+	+	+	+	1	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	IV
Trifolium campestre	1	2	1	2	+	+	+	.	.	.	+	1	1	1	+	+	1	+	+	+	.	+	.	+	+	+	+	2	2	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	+	IV
Onobrychis alba subsp. *laconica*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	1	+	.	1	1	+	+	+	2	1	+	+	1	+	+	1	1	1	1	1	+	+	1	+	1	1	1	III
Bombycilaena erecta	1	.	1	.	1	1	2	2	1	1	1	1	1	1	1	+	+	1	2	1	1	1	1	2	1	1	1	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Sanguisorba minor subsp. *muricata*	+	+	+	.	+	+	1	1	.	+	1	.	+	+	+	+	.	.	.	.	1	+	1	1	1	+	+	.	.	.	.	1	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	III
Crepis pulchra	.	.	.	.	.	1	+	.	1	+	+	1	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	+	+	+	+	1	1	+	+	+	+	+	+	.	.	.	.	III
Euphorbia myrsinites	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	+	+	1	1	+	1	1	+	+	+	+	.	.	+	+	.	.	.	+	+	.	+	+	+	+	+	+	.	+	.	.	.	.	.	III
Euphorbia falcata	+	.	.	.	.	1	1	1	1	+	.	+	+	.	+	+	+	1	1	+	.	.	.	.	1	+	1	.	.	.	.	1	1	1	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	III
Centaurea salonitana	.	+	.	.	+	.	+	.	+	.	.	+	.	+	+	.	+	+	.	+	1	1	+	+	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	+	+	+	.	+	+	+	+	.	.	.	III
Crucianella angustifolia	+	.	+	.	.	1	1	1	+	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	+	1	1	+	1	1	1	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	III
Lathyrus cicera	+	+	+	+	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	.	.	II
Linum strictum subsp. *corymbulosum*	.	.	.	.	1	.	.	.	.	.	.	.	+	.	+	+	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	1	1	1	1	1	+	+	+	+	+	II
Nigella damascena	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	.	.	.	.	.	.	+	.	.	.	.	+	+	+	.	.	+	+	.	+	+	+	+	+	+	+	+	+	.	.	II
Petrorhagia prolifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	+	+	1	1	1	+	+	1	1	1	1	1	2	1	1	1	1	+	+	II
Linaria simplex	.	.	.	.	.	1	+	+	+	.	+	.	.	.	.	.	.	1	+	+	+	+	.	+	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	.	.	II
Orlaya daucorlaya	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	+	+	1	+	1	+	+	+	.	+	.	.	II
Satureja montana subsp. *pisidica*	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	3	1	.	.	.	.	.	.	.	1	1	1	2	1	1	1	+	+	+	+	1	II
Silene conica	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	+	1	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Plantago lanceolata	.	.	+	.	+	+	+	+	+	+	+	1	+	+	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Galium oreophilum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	+	+	+	+	1	1	+	1	+	1	1	1	II
Orlaya daucoides	+	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	.	+	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Ajuga chamaepitys subsp. *chia*	.	.	.	.	.	.	.	.	1	+	+	.	.	.	+	.	+	1	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	+	1	II
Althaea hirsuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	1	1	1	1	+	+	.	.	II
Clypeola jonthlaspi	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	+	+	+	.	.	II
Arenaria serpyllifolia	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	+	1	1	1	1	+	+	+	II
Iberis sempervirens	.	.	.	.	.	.	.	.	.	.	1	.	+	+	.	.	1	.	.	+	.	.	.	.	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	1	1	+	.	.	.	.	.	.	.	+	II
Pterocephalus papposus	.	.	.	.	.	+	1	.	1	+	+	.	.	.	1	1	1	1	+	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Galium verticillatum	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Dactylis glomerata	+	.	.	1	.	.	.	.	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	1	.	.	.	.	.	.	.	.	.	+	.	.	II
Trifolium cherleri	.	3	1	1	1	.	.	.	.	.	.	1	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Cynosurus echinatus	.	1	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I

Table 1. (continuation)

Medicago monspeliaca	.	.	.	.	+	.	.	.	.	+	.	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Asyneuma limonifolium	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	I
Geranium columbinum	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	+	+	.	+	+	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Crepis sancta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	1	+	+	+	+	1	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Haplophyllum coronatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	1	1	1	1	+	.	.	I
Lotus tenuis	+	.	1	+	1	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium angustifolium	.	1	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Micromeria juliana	.	.	.	.	.	.	.	.	.	.	.	1	1	2	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Picris pauciflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	I
Silene graeca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	+	+	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Lens nigricans	.	.	.	.	.	+	1	+	+	+	1	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Scabiosa webbiana	.	.	.	.	.	.	+	+	+	1	1	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Myosotis arvensis	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Potentilla pedata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	I
Thymus perinicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	+	+	1	2	I
Pilosella officinarum	.	.	+	+	.	.	.	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Sedum acre	.	.	.	.	.	+	+	.	+	+	+	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Haplophyllum patavinum	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Orlaya grandiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Thymus sibthorpii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium scabrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Veronica arvensis	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Medicago orbicularis	+	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Catapodium rigidum	+	.	.	.	.	1	+	+	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Erodium cicutarium	.	.	.	.	.	+	+	.	.	.	.	.	.	+	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Thymelaea passerina	.	.	.	.	.	+	.	+	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Bromopsis cappadocica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	1	+	+	I
Linum nodiflorum	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Anisantha tectorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Himantoglossum caprinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Silene squamigera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	2	1	+	.	.	.	.	.	I
Arabis allionii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	I
Juniperus communis	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hypochaeris cretensis	.	+	.	.	.	2	1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Potentilla detommasii	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I

Table 1. (continuation)

Velezia rigida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Asphodeline lutea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Cerastium decalvans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Festuca hercegovinica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	I
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Ajuga genevensis	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Carduus candicans	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Verbascum sinuatum	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Silene vulgaris subsp. *vulgaris*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Euphorbia taurinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Juniperus excelsa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hypericum perforatum subsp. *veronense*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Centaurea tomorosii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	I
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Vicia sativa subsp. *nigra*	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trifolium striatum	.	2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Rostraria cristata	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Silene bupleuroides subsp. *staticifolia*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Table 1. (continuation)

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Vicia onobrychioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Verbascum longifolium subsp. *pannosum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	I
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Achillea holosericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	I
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Capsella bursa-pastoris	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Centaurea solstitialis	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Avena barbata	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Sedum album	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Aurinia saxatilis subsp. *orientalis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Lathyrus saxatilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Micromeria cristata subsp. *kosanini*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Myosotis incrassata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Cynoglossum officinale	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Clinopodium vulgare subsp. *vulgare*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
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Helictotrichon convolutum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
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CONCLUSION

This paper represents an oveview of the distribution and syntaxonomic position of the dry grasslands that develop on carbonate geological substrate on the territory of the Republic of Macedonia. They are covered by the alliances *Saturejo-Thymion* Micevski [2], which is an additional information of the occurrence of this type of vegetation on the territory of the Republic of Macedonia. Furthermore, with numerical analyses it has also been shown that dry grasslands from Mountain Galičica significantly differ from the rest of the communities representing *Saturejo-Thymion*. The fact that species *Sideritis montana* subsp. *remota*, and *Trifolium dalmaticum* were significantly represented in the reaserched stands led us to distinguish a new association *Siderito montanae-Trifolietum dalmaticae* ass. nova which was confirmed with additional ecological analyses. Within this association the subassociation *erodietosum guicciardii* subass. nova, was also a separate one that floristically, physiognomically and structurally differed from the typical form of the association.

This study complements the picture of dry grasslands in the Republic of Macedonia, but there are still areas that are not sufficietly researched.

APPENDIX

Descriptions of the reléves in the Table 1. Running number, original reléve number, locality, latitude, longitude, sampling date, area, altitude (m), aspect, inclination (%), cover.

1, 7, above Mal Osoj, 40.943518, 20.791347, 13.06.2009, 100, 924, W, 3, 80; **2**, 8, above Mal Osoj, 40.94358, 20.786834, 13.06.2009, 100, 863, /, 0, 100; **3**, 10, above Mal Osoj, 40.943194, 20.786489, 13.06.2009, 100, 854, S, 2, 95; **4**, 11, Mal Osoj, 40.94245, 20.784913, 13.06.2009, 80, 846, /, 0, 90; **5**, 9, Mal Osoj, 40.943481, 20.786471, 13.06.2009, 80, 860, SE, 2, 95; **6**, 36, above v. Elšani, 41.015555, 20.822328, 17.06.2009, 100, 1010, NW, 10, 90; **7**, 37, above v. Elšani, 41.015622, 20.82229, 17.06.2009, 100, 1005, W, 10, 95; **8**, 38, above v. Elšani, 41.015933, 20.822255, 17.06.2009, 100, 1005, W, 10, 75; **9**, 39, above v. Elšani, 41.015258, 20.822473, 17.06.2009, 100, 1012, E, 3, 80; **10**, 40, above v.Elšani, 41.01475, 20.822452, 17.06.2009, 100, 1017, E, 5, 80; **11**, 41, above v.Elšani, 41.014616, 20.821935, 17.06.2009, 100, 1016, E, 5, 80; **12**, 12, above v. Tpejca, 40.961058, 20.785142, 14.06.2009, 100, 770, SW, 10, 90; **13**, 13, above v. Tpejca, 40.960888, 20.785106, 14.06.2009, 75,770, W, 5, 85; **14**, above v. Tpejca, 40.961046, 20.785218, 14.06.2009, 100,768, W, 10, 75; **15**, 15, above v. Tpejca, 40.988548, 20.800466, 14.06.2009, 100,741, E, 3, 85; **16**, 16, above v. Tpejca, 40.988604, 20.80054, 14.06.2009, 80,735, E, 5, 75; **17**, 17, above v. Tpejca, 40.988692, 20.799871, 14.06.2009, 70,728, SW, 30, 80; **18**, 42, the road to Vršec,41.102696, 20.819711, 18.06.2009, 100,803, W, 10, 90; **19**, 43, the road to Vršec, 41.102616, 20.81987, 18.06.2009, 100,805, W, 10, 85; **20**, 44, the road to Vršec, 41.102462, 20.820022, 18.06.2009, 100,808, W, 10, 80; **21**, 45, above v. Velestovo, 41.092053, 20.834874, 19.06.2009, 100,1220, W, 10, 90; **22**, 46, above v. Velestovo, 41.091977, 20.834999, 19.06.2009, 100,1222, W, 2, 90; **23**, 47, above v. Velestovo, 41.092087, 20.83529, 19.06.2009, 100,1232, W, 5, 85; **24**, 48, above v. Velestovo, 41.095369, 20.835676, 19.06.2009, 100,1193, W, 5, 85; **25**, 49, above v. Velestovo, 41.095184, 20.833828, 19.06.2009, 100,1112, W, 15, 90; **26**, 50, above v. Velestovo, 41.092037, 20.830171, 19.06.2009, 100,1082, W, 15, 95; **27**, 51, above v. Velestovo, 41.090417, 20.819471, 19.06.2009, 100,932, SW, 15, 95; **28**, 32, Glajšo-Pogled, 40.994076, 20.816384, 16.06.2009, 80,1055, W, 5, 80; **29**, 33, Glajšo-Pogled, 40.99416, 20.816393, 16.06.2009, 80,1057, SW, 3, 80; **30**, 34, Glajšo-Pogled, 40.994138, 20.816552, 16.06.2009, 90,1056, SW, 2, 85; **31**, 35, Glajšo-Pogled, 40.994205, 20.8165, 16.06.2009, 90, 1056, SW, 2, 90; **32**, 281, Margarina above Oteševo, 41.0106, 20.92367, 26.06.2010, 100,1027, S, 2, 100; **33**, 282, Margarina above Oteševo, 41.011036, 20.923481, 26.06.2010, 100,1034, SW, 2, 100; **34**, 283, Margarina above Oteševo, 41.011318, 20.923387, 26.06.2010, 100,1041, SW, 2, 100; **35**, 284, Margarina above Oteševo, 41.012154, 20.922591, 26.06.2010, 100,1043, /, 0, 100; **36**, 285, Margarina above Oteševo, 41.012575, 20.923359, 26.06.2010, 100,1047, SW, 2, 100; **37**, 286, Margarina above Oteševo, 41.012872, 20.923333, 26.06.2010, 100, 1043, SW, 2, 100; **38**, 287, Margarina above Oteševo, 41.01318, 20.921496, 26.06.2010, 100, 1047, W, 2, 100; **39**, 58, over the bend M, Prespa side, 40.976222, 20.883362, 24.06.2009, 100,1238, SE, 20, 80; **40**, 59, over the bend M, Prespa side, 40.976149, 20.88247, 24.06.2009, 100,1241, SE, 20, 80; **41**, 60, over the bend M, Prespa side, 40.976239, 20.882323, 24.06.2009, 100,1251, SE, 25, 90; **42**, 61, over the bend M, Prespa side, 40.976292, 20.881983, 24.06.2009, 100,1252, SE, 25, 95; **43**, 79, over the bend M, Prespa side, 40.976618, 20.883337, 28.06.2009, 100,1255, SE, 20, 95; **44**, 80, over the bend M, Prespa side, 40.976688, 20.883196, 28.06.2009, 100, 1269, SE, 20, 90; **45**, 81, over the bend M, Prespa side, 40.97714, 20.882492, 28.06.2009, 100,1296, SE, 25, 90; **46**, 82, over the bend M, Prespa side, 40.977308, 20.88189, 28.06.2009, 100, 1336, SE, 25, 95; **47**, 83, over the bend M, Prespa side, 40.977954, 20.880192, 28.06.2009, 100, 1383, SE, 25, 95; **48**, 84, over the bend M, Prespa side, 40.979023, 20.87924, 28.06.2009, 100, 1416, S, 25, 90; **49**, 85, over the bend M, Prespa side, 40.979653, 20.879324, 28.06.2009, 100, 1468, S, 15, 90; **50**, 86, over the bend M, Prespa side, 40.981345, 20.879862, 28.06.2009, 100, 1507, W, 15, 90;

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БРДСКИ ПАСИШТА НА НАЦИОНАЛНИОТ ПАРК ГАЛИЧИЦА (ЈЗ МАКЕДОНИЈА)

Рената Ќуштеревска

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Во трудот се презентирани брдските пасишта (*Festuco-Brometea*) во Националниот парк „Галичица“. Истражувањата на кои се темели овој труд беа спроведени во периодот од 2009–2010 на повеќе локалитети, на карбонатна подлога, од охридската и преспанската страна. Регистрираната заедница од овој тип е подредена кон редот *Astragalo-Potentilletalia* Мицевски [1] и сојузот *Saturejo-Thymion* Мицевски [2]. Од флористичкиот состав и деталните фитоценолошки анализи на истражуваната вегетација беше заклучено дека класата *Festuco-Brometea* е претставена со асоцијацијата *Siderito montanae-Trifolietum dalmaticae* ass. nova subass. *erodietosum guicciardii* subass. nova.

Клучни зборови: вегетација; брдски пасишта; Галичица

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Original scientific paper

SPECIES OF THE DIATOM GENUS *CRATICULA* GRUNOW (BACILLARIOPHYCEAE) FROM MACEDONIA

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The species of the genus *Craticula* are widely distributed in Europe, mostly occurring in brackish, saline to heavily polluted waters. Some of the species are considered as being most tolerant to pollution. Recently, detailed observations of this genus in Macedonia have been performed. During this study, 15 taxa have been recorded. One of the species (*Craticula simplex*) was observed with three different morphotypes, which can be distinguished by the valve size and shape. *Craticula cuspidata* and *C. ambigua* were the most frequently recorded species in various habitats, while species *C. halophila*, *C. germainii* and *C. fumantii* were observed only on a single locality. The highest diversity of *Craticula* was observed in temporary ponds on halomorphic soils and mineral springs in Eastern Macedonia.

Key words: *Craticula*; diatoms, diversity, Macedonia

INTRODUCTION

The genus *Craticula* Grunow was described based on the species *C. perrotettii* Grunow [1, p. 20, Fig. 1: 21] and was forgotten for a long time until Mann & Stickle [2] re-established the genus and provided a more detailed description based on ultrastructural and sexual characteristics. Most of the members of this genus were previously included in *Navicula* Bory section Orthostichae (Cleve [3], Hustedt [4]). One of the prominent features of this genus is the presence of "craticula" – inner valves produced during resting spore formation. Such inner valves might be produced as a result of elevated salt concentrations or desiccation (Schmid [5, 6]). The inner valves were referred as "*heribaudii*" valves and they differ by several ultrastructural features from the normal valves. However, "*heribaudii*" valves are so far observed only in few members of the genus *Craticula*.

The genus is characterized by cells with two plastids with lenticular pyrenoids that are usually associated with a cytoplasmic bridge holding the nucleus (Cox [7]). The raphe is filiform and can be located externally on thickened conopeum or on valve face (Morales & Le [8]). Internally the raphe branches are positioned on elevated sternum. The striae are composed of a single row of round or apically elongated areolae. Internally the areolae are covered by hymen. In some species areolae are separated by strongly thickened frets that appear as longitudinal ribs. In most of the species, striae are parallel to weakly radiate in the mid-valve, becoming slightly convergent toward the valve apices.

The genus is widely distributed in various habitats, from acidic oligotrophic waters to alkaline, (hyper)saline, (hyper)eutrophic and heavily polluted waters. Some of the members of the genus are considered as one of the most tolerant species to organic pollution (Lange-Bertalot [9, 10]). High diversity of the genus was noticed in alkaline, slightly saline and warm (even temporary) water habitats (Lange-Bertalot [10], Lange-Bertalot *et al.* [11]). *Craticula* was observed frequently in the Tropics (Morales *et al.* 12, Rumrich *et al*. [13]), but also on Antarctica (Van de Vijver *et al.* [14]; Sabbe *et al.* [15]).

The first records of the genus *Craticula* in Macedonia originated from Schröder [16] and Hustedt [17] for lakes Dojran and Ohrid with two recorded species: *C. ambigua* (Ehrenberg) D. G. Mann and *C. cuspidata* (Kützing) D. G. Mann. Additionally, Hustedt described *Navicula demissa* [17, p. 928, Fig. 40: 12–15], which was later synonymyzed by Krammer & Lange-Bertalot [19] with *N. subminuscula* Manguin [18, p. 139, Fig. 2: 39] ≡ *C. subminuscula* (Manguin) C.E. Wetzel & Ector. Later, two more species *C. perrotettii* (Grunow) D.G. Mann and *C. accomoda* (Hustedt) D.G. Mann were recorded in Lake Dojran (Stojanov [20]) and the River Vardar (Krstic *et al.* [21]). Recently, a detailed observation of the diatom flora of Macedonia has been initiated and several genera, including *Amphora* Ehrenberg (Levkov [22]), *Eunotia* Ehrenberg (Pavlov & Levkov [23]), *Hippodonta* Lange-Bertalot, Metzeltin & Witkowski (Pavlov *et al.* [24]), *Diploneis* Ehrenberg (Jovanovska *et al.* [25]), *Luticola* D.G. Mann (Levkov *et al.* [26]), *Odontidium* Kützing (Jüttner *et al.* [27]), *Mastogloia* Thwaites (Pavlov *et al.* [28]) and *Gomphonema* Ehrenberg (Levkov *et al.* [29]) were observed in more details. This resulted in many new records of the species distribution and additional descriptions of new taxa. Here, we provide a revision of the *Craticula* species, as a part of an ongoing comprehensive research on the diatom flora of Macedonia.

EXPERIMENTAL SECTION

More than 6.000 samples observed in this study have been collected during various field campaigns, starting from 1995 until present. Most of the samples were collected within the period June–August. Samples from the various habitats include: sediments at various depths (0.5–50 m) from Ohrid, Prespa and Dojran lakes, sediments, stones and macrophytes from rivers, small springs, streams and rivulets, high altitude glacial and non-glacial lakes, ponds and pools of various size, peat bogs, fens and mires. The altitudinal range at the different sampling sites varies between ca. 200–2500 m a.s.l. The samples with higher abundance of *Craticula* species are listed in Table 1. Diatom samples were cleaned by acid digestion using K_2MnO_4/HCl, and permanent slides were mounted in Naphrax®. Photomicrographs were taken with a Nikon E-80i, a digital Nikon Coolpix 600. For scanning electron microscope (SEM) analyses, cleaned material was dried onto aluminum stubs and coated with gold/palladium using a sputter coater. SEM micrographs were produced with a Cambridge Instrument S4 Steroscan electron microscope operated at 5 kV. Slides are deposited in the Macedonian National Diatom Collection (MKNDC), Institute of Biology, Skopje, Macedonia (holotype), and the Friedrich Hustedt Centre for Diatom Research (BRM) in Bremerhaven, Germany (isotype).

Table 1. List of observed samples with the highest abundance and diversity of *Craticula* species

Acc. No.	Locality	Sample
001133	Lake Ohrid, the Bay of St. Naum	sediment 9 m depth
002212	Lake Dojran, Alex Beach	plankton
003084	Šara Mountain, Lake Karanikoličko	macrophytes
004798	Lake Dojran, Alex Beach	sediment
005603	Mining Lake Usje	macrophytes
006795	River Bregalnica, before the village of Mačevo	epiphytes on reed
006806	River Bregalnica, before the mouth of river Kočanska	yellow filaments
006837	River Kočanska, before the mouth in R. Bregalnica	brown filaments
006967	Reservoir Ratevsko (Berovsko)	sediment
008234	River Vodenišnica, near Monospitovo	rock scrape
008835	Sveti Nikole, near the village of Adzimatovo, pond	sediment
008836	Sveti Nikole, near the village of Adzimatovo, channel	sediment
008838	Gladno Pole, near Štip, spring,	mud
008858	Mineral spring near the village of Gabrovo, Delčevo	*Chara* sp.
008868	Slan Dol, temporary pond	mud
008872	Slan Dol, temporary pond	macrophytes
008873	Slan Dol, temporary pond	mud
PS001035	Thermo-mineral spring Negorska Banja	rock scrape

RESULTS AND DISCUSSION

During the observations of the genus *Craticula* in Macedonia, 13 species in total have been recorded. One of the species, *C. simplex* (Krasske) Levkov comb. nov. was present with three morphotypes which differ with respect to the valve outline and size. However, we still consider these populations as a part of the morphological variation of a single species. Few valves with similar numerical features as *C. acidoclinata* Lange-Bertalot & Metzeltin were observed in glacial Lake Karanikoličko on Šara Mountain, but they differ from the type population with respect to the shape of the valve apices.

Craticula perrotettii Grunow
(Figs 1: 1–3; 2: 1–3)

Valve morphology, LM (Figs 1: 1–3): Valves are lanceolate to broadly-lanceolate with shortly protracted and rounded apices. Valve length varies from 220–244 μm, and valve width 44–48 μm. Axial area is narrow, linear, widened near the central area. Central area is variable in size and shape, lanceolate to slightly constricted in the middle. Raphe is straight, filiform, positioned on well developed sternum. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are clearly visible with LM, parallel throughout, 11–12 in 10 μm. Areolae are visible with LM, 16–18 in 10 μm. Areolae are separated by the longitudinal frets.

Valve morphology, SEM (Figs 2: 1–3): Raphe branches are located on strongly thickened conopeum with equal width throughout. Central pores are dilated and slightly unilaterally deflected. Transapical striae are uniseriate composed by areola with variable size and shape. Areolae near the axial and central area have small round apertures, while the rest are apically elongated with slit-like external openings. Longitudinal frets are well developed and forming grooves in which areola are located.

Comment: The conopeum and longitudinal frets present in the specimen from Lake Dojran are narrower and not strongly pronounced as in the specimen depicted in Lange-Bertalot [10, Figs 81: 1–4].

Similar species: In general, *C. perrotettii* has a unique set of characters (valve size, shape and presence of strongly thickened longitudinal frets) that clearly separates it from other *Craticula* species. *Craticula pampeana* (Frenguelli) Lange-Bertalot has similar valve size, but different valve shape, lanceolate with broadly rounded apices (Frenguelli [30]). *Craticula cuspidata* has similar valve shape and longitudinal frets, however it can be clearly differentiated by its smaller valves (lenght 82–122 μm, width 21.0–27.5 μm).

Distribution in Macedonia: This species was observed only in Lake Dojran. According to Lange-Bertalot [10, p. 117] this species is rare in Europe and it was observed only in Southern Italy.

Ecology: *Craticula perrotettii* occurs in eutrophic to hypereutrophic habitats on organic sediment. This is a tropical/subtropical species preferring habitats with higher temperature [10].

Craticula cuspidata (Kützing) D.G.Mann
(Figs 3: 1–5; 4: 1–5; 5: 1–5)

Basionym: *Frustulia cuspidata* Kützing [31, p. 549, Fig. 14: 26]

Nomenclatural synonym: *Navicula cuspidata* (Kützing) Kützing [32, p. 94]

Valve morphology, LM (Figs 3: 1–5; 4: 1–5): Valves are broadly lanceolate to rhombic-lanceolate, gradually tapering towards apices. Valve apices in larger specimens are shortly protracted and subcapitate to almost acutely rounded in smaller specimens. Valve length varies from 82–122 μm, valve width 21.0–27.5 μm. Axial area is very narrow, linear. Central area is absent to narrow lanceolate, slightly wider than axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are clearly visible with LM, parallel throughout, 11–14 in 10 μm. Areolae are visible with LM, 26–30 in 10 μm.

Valve morphology, SEM (Figs 5: 1–5): The valve surface is ornamented with narrow and slightly thickened longitudinal frets (Fig. 5: 4). Raphe is located on a narrow, strongly thickened sternum (Fig. 5: 1). External proximal raphe endings are short, expanded into central pores and slightly unilaterally deflected (Fig. 5: 4). Distally, raphe endings are long, hooked and continuing onto the mantle (Fig. 5: 2). Striae are uniseriate composed of narrow, apically elongated slit-like areolae, except near the central area where areolae have round foramina (Fig. 5: 4). Internally, central nodule is slightly raised (Fig. 5: 5). Raphe branches are straight, located on inwardly elevated sternum. Raphe proximally terminates with short, unilaterally weakly deflected endings, while distally with well developed helictoglossa. Areolae are occluded by hymenes, located inside each areola (Fig. 5: 5).

Similar species: *Craticula acidoclinata* Lange-Bertalot & Metzeltin [33, figs 26: 1–3] and

C. sardiniana Bahls [34, figs 96–101] are similar to *C. cuspidata*. However, both species have lanceolate valves with broadly rounded apices, opposite to rhombic-lanceolate with shortly protracted or acutely rounded apices in *C. cuspidata*.

Distribution in Macedonia: *Craticula cuspidata* is frequently recorded taxon in the diatom flora of Macedonia. During this study it was recorded in: lakes: Ohrid, Prespa, Dojran; rivers: Vardar, Lepenec, Bregalnica, Zrnovka, Golema Reka, Anska; reservoirs: Kalimanci and Mladost, stream Jastrebnik on Mt. Osogovo, unnamed streams on mountains Kozuf and Šara, peat-bogs on Karadzica, Šara and Pelister mountains.

Ecology: This species was observed in wide spectrum of habitats: oligotrophic to eutrophic and hyper eutrophic lakes, oligotrophic to mesotrophic rivers, slightly polluted to highly polluted rivers. It occurs on fine inorganic or organic sediments.

Craticula aff. *acidoclinata* Lange-Bertalot & Metzeltin (Figs 6: 1–7)

Valve morphology, LM: Valves are broadly lanceolate gradually tapering towards apices. Valve apices are shortly protracted and rostrate. Valve length varies from 64–91 μm, valve width from 17.0–21.0 μm. Axial area is very narrow, linear. Central area is absent to narrow lanceolate, slightly wider than axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are clearly visible with LM, parallel throughout, 16–19 in 10 μm. Areolae are hardly visible with LM, c. 30 in 10 μm. Heribaudii stages are frequently observed.

Comment: *Craticula* aff. *acidoclinata* resembles *C. cuspidata*, *C. acidoclinata* and *C. nonambigua* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. In general, *C.* aff. *acidoclinata* shares the morphological features of *C. cuspidata* and might represent a smaller form of *C. cuspidata*. However, most of the records of *C. cuspidata* in the available literature show larger cells with width 24–35 μm and lower striae density (11–15 in 10 μm) in contrast to *C.* aff. *acidoclinata*. Also *C. cuspidata* is usually observed in the eutrophic lotic and lentic waters, while the observed taxon in this study (*C.* aff. *acidoclinata*) was recorded in an oligotrophic, slightly acidic glacial lake. From aspect of the ecology, this species is similar to *C. acidoclinata*. Also, similarities in the morphology can be observed with the specimen depicted in Lange-Bertalot [10, Fig. 87: 2] from the type population. However, other illustrated specimens [op.cit., figs 87: 1, 3–5] have completely different valve apices (not protracted and broadly rounded). Similar concept of *C. acidoclinata* (apices are never or only slightly protracted) is presented by Bahls [34, p. 23]. There is difference too in the valve size (17.0–21.0 μm. vs 24–35 μm in *C. acidoclinata*) and stria density (16–19 in 10 μm vs 11–15 in 10 μm in *C. acidoclinata*). *Craticula* aff. *acidoclinata* differs from *C. nonambigua* by shape of the valve apices, having weakly protracted apices, opposite to long protracted, rostrate to subcapitate apices in *C. nonambigua*. Additionally, both populations observed in this study have different ecology, cold oligotrophic and slightly acidic (*C.* aff. *acidoclinata*) *vs* dystrophic, alkaline with high mineral content (*C. nonambigua*).

Distribution in Macedonia: This taxon was observed only in glacial Lake Karanikoličko on Šara Mountain.

Ecology: The locality where this taxon was observed represents an oligotrophic lake, circumneutral to slightly acidic, with low mineral content.

Craticula sardiniana Bahls (Figs 7: 1–3)

Valve morphology, LM: Valves are lanceolate gradually tapering towards apices. Apices weakly protracted and rounded. Valve length varies from 76–93 μm and valve width from 18.5–19.5 μm. Axial area is very narrow, linear. Central area is absent to slightly concave. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are parallel in the mid-valve, becoming slightly convergent towards the apices, 13–17 in 10 μm. Areolae are hardly visible with LM, 28–32 in 10 μm.

Comment: According to Lange-Bertalot & Metzeltin [33, p. 42] *C. acidoclinata* occurs in oligo-distrophic habitats, while *C. sardiniana* prefers alkaline waters with higher electrolyte content. *Craticula sardiniana* in Macedonia was observed in a small pond on halomorphic soils near Sveti Nikole, characterized by slightly alkaline pH (8.3) and high conductivity (1300 $\mu S \cdot cm^{-1}$).

The differences between *C. sardiniana* from the type population of Bahls [34, figs 96–101], and the population from Macedonia might be noticed in the shape of valve apices. In *C. sardiniana* from the type population, apices are bluntly rounded and not protracted, while the population from the halomorphic soils is characterized by weakly protracted and narrower apices. However, the valve shape of the population from Macedonia is similar to the taxon depicted by Lange-Bertalot [10, Figs 88: 1–5] named as *Craticula silviae* Lange-Bertalot nov. spec. prov. observed in alkaline ephemeral ponds from Sardinia. The conspecificity of these two taxa is questionable. Further studies are necessary to check the identity of *C. silviae* and its relation with *C. sardiniana*.

Similar species: The most similar species to *C. sardiniana* is *C acidoclinata* Lange-Bertalot & Metzeltin (Lange-Bertalot & Metzeltin 33, Figs 26: [1–3]). In general morphological and numeral features of *C. sardiniana* and *C. acidoclinata* are overlapping: length 68–113 μm *vs* 60–130 μm; width 15.6–19.5 μm *vs* 16.0–24.0 μm; stria density 14 in 10 μm *vs* 13–15.5 in 10 μm. The main difference between these two species is the habitat preference Bahl (2013, p. 23).

Distribution in Macedonia: *Craticula sardiniana* was observed only from a small, temporary pond on halomorphic soils, Ovche Pole, near the town Sveti Nikole.

Ecology: *Craticula sardiniana* prefers alkaline, dystrophic waters with high electrolyte content (high conductivity) such as temporary ponds and alkaline ferns.

Craticula ambigua (Ehrenberg) D.G.Mann
(Figs 8: 1–12; 9: 1–5)

Basionym: *Navicula ambigua* Ehrenberg [35, p. 417, Fig. 2/2: 9]

Nomenclatural synonym: *Navicula cuspidata* var. *ambigua* (Ehrenberg) Cleve [36, p. 110]

Valve morphology, LM (Figs 8: 1–12): Valves are broadly elliptic, elliptic-lanceolate to lanceolate to with abruptly protracted and subcapitate apices. Valve margins are with "shoulders" near the valve apices. Valve length varies from 47–77 μm, valve width 14.5–20.0 μm. Axial area is very narrow, linear. Central area is absent to slightly wider than axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae slightly radiate in the midvalve, becoming slightly convergent towards the apices, 14–17 in 10 μm. Areolae are visible with LM, 26–32 in 10 μm.

Valve morphology, SEM (Figs. 9: 1–5): The valve surface is slightly uneven, ornamented with weakly developed longitudinal frets (Figs. 9: 1–4). Raphe is located on a narrow, strongly thickened sternum, slightly expanded in the central area (Fig. 9: 3). External proximal raphe endings are short, expanded into central pores and slightly unilaterally deflected (Fig. 9: 3). Distally, raphe endings are long, strongly hooked and continuing onto the mantle (Fig. 9: 4). Striae are uniseriate composed of narrow, apically elongated slit-like areolae, except near the central area where areolae have round foramina (Fig. 9: 3). Internally, central nodule is slightly raised (Fig. 9: 5). Raphe branches are straight, located on inwardly strongly elevated sternum. Raphe proximally terminates with short, simple endings, while distally with well developed helictoglossa. Areolae are covered by hymenes located inside each areola (Fig. 9: 5).

Similar species: *Craticula nonambigua* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, and *C. lange-bertalotii* E. Reichardt [37, figs 14–20] are similar to *Craticula ambigua*. In general numerical features of *C. ambigua* sensu lato and *C. nonambigua* are overlapping: length 42–77 μm *vs* 49–66 μm; width 14.5–20.0 μm *vs* 12.5–18.0 μm; stria density 14–17/10 μm *vs* 14–18/10 μm; areola density c. 30 in 10 μm *vs* 30 in 10 μm. Also significant differences in the valve shape cannot be noticed, except the presence of "shoulders" in *C. ambigua*. However, in some smaller specimens of *C. nonambigua* (Figs 11: 6–10) indistinct "shoulders" might be noticed too. According to Lange-Bertalot [10], both species can be differentiated by the size and valve outline. In general, both species can be differentiated only by the valve outline (broadly elliptic in *C. ambigua vs* rhombic-lanceolate in *C. nonambigua*) *Craticula lange-bertalotii* has wider valves 21–25 μm with slightly undulated margins and lower areola density 24–26 in 10 μm.

Distribution in Macedonia: Lakes: Ohrid, Dojran; rivers: Vardar, Bregalnica, Zrnovka, Zletovska, Svetinikolska, Shamachka, Boshava, Buturica; wetland Studenčiško, mining lake of Usje. The record of *C. ambigua* from Šara Mountain (Levkov *et al.* [38]) belongs to *C. fumantii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Some older records of *C. ambigua* (Stojanov [39–41]) might belong to other species.

Ecology: This species was observed in various habitats starting from deep oligotrophic Lake Ohrid, mesotrophic Lake Prespa, the eutrophic River Bregalnica and Lake Dojran. It usually occurs in epipelic diatom assemblages on organic or fine inorganic sediments.

Craticula nonambigua Lange-Bertalot, Cavacini, Tagliaventi & Alfinito (Figs 10: 1–8; 11: 1–10)

Valve morphology, LM: Valves are rhombic-lanceolate to elliptic-lanceolate with abruptly protracted and sub-capitate apices. Valve margin is gradually narrowing towards the apices in the larger and medium-sized specimens, while in smaller specimens (Figs 11: 6–10) "shoulders" might be present. Valve length varies from 49–66 µm, valve width 12.5–18.0 µm. Axial area is very narrow, linear. Central area is absent to slightly wider than axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae radiate in the mid-valve, becoming slightly convergent towards the apices, 14–18 in 10 µm. Areolae are hardly visible with LM, 30–35 in 10 µm.

Similar species: *Craticula ambigua*, *C. lange-bertalotii* and *C. fumantii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito (Lange-Bertalot *et al*. [11, Figs 8: 1–8; 9: 1–10]). *Craticula nonambigua* and *C. ambigua* can be hardly differentiated by the valve size. The main difference is that the valve margins in *C. ambigua* have "shoulders" near the apices. *Craticula lange-bertalotii* has wider valves (width = 21–25 µm) with slightly undulated margins. *Craticula fumantii* has narrower, lanceolate valves (not rhombic-lanceolate or elliptic-lanceolate as in *C. nonambigua*).

Distribution in Macedonia: During this study, *C. nonambigua* was observed only in a small, temporary pond on halomorphic soils, Ovče Pole, near the town of town of Sveti Nikole. However, some other records of *C. ambigua* in Macedonia might belong to this species or to *C. fumantii*.

Ecology: Not precisely known. During this study, *C. nonambigua* was observed in an alkaline dystrophic pond and channel on halomorphic soils with high electrolyte content (high conductivity).

Craticula fumantii Lange-Bertalot, Cavacini, Tagliaventi & Alfinito

(Figs 7: 4–8; 12: 1–11; 14: 1–3)

Valve morphology, LM (Figs 7: 4–8; 12: 1–11): Valves are strictly lanceolate, with abruptly protracted and sub-capitate apices. Valve length varies from 49–66 µm, valve width 11.5–13.5 µm. Axial area is very narrow, linear. Central area is absent to slightly wider than axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae radiate in the mid-valve, becoming slightly convergent towards the apices, 16–20 in 10 µm. Areolae are hardly visible with LM, 30–35 in 10 µm.

Valve morphology, SEM (Figs 14: 1–3): The valve surface is flat, without developed longitudinal frets (Figs 14: 1, 2). Raphe is located on a moderately wide, strongly thickened sternum, slightly expanded in the central area (Fig. 14: 2). External proximal raphe endings are short, expanded into central pores and slightly unilaterally deflected (Fig. 14: 2). Distally, raphe endings are long, hooked and continuing onto the mantle (Fig. 14: 3). Striae are strongly radiate, uniseriate, composed mainly of round areolae. Areolae near the raphe sternum, and especially around the central area have larger, slightly elongated to ovate foramina (Fig. 14: 2). Internally, central nodule is slightly raised. Raphe branches are straight located on inwardly strongly elevated sternum. Raphe proximally terminates with short, simple endings, while distally with well developed helictoglossa. Areolae are covered by hymenes, located inside each areola (figure not shown).

Similar species: *Craticula ambigua, C. nonambigua* and *C. johnstoniae* Bahls [34, Figs 90–95]. *Craticula ambigua* and *C. nonambigua* appear very similar to *C. fumantii*. Although Lange-Bertalot et al. [11, p. 34] stated that there is a difference in the striae density between *C. ambigua* and *C. fumantii*, in this study that cannot be confirmed. Differentiation between these three species can be made in combination of valve shape and size. *Craticula ambigua* and *C. nonambigua* are wider (14.5–20.0 µm and 12.5–18.0 µm respectively) with elliptic-lanceolate to rhombic-lanceolate valve outline. *Craticula johnstoniae* has similar valve outline as *C. fumantii*, but the valves are larger (length 68–113 µm, width 15.6–19.5 µm).

Distribution in Macedonia: *Craticula fumantii* has been observed on two localities in Macedonia: Lake Karanikoličko on Šara Mountain and the River Buturica, Mariovo.

Ecology: Not precisely known. In Macedonia it was observed in an oligotrophic lake and river, slightly acidic to circumneutral, with low mineral content.

Craticula germainii Lange-Bertalot, Cavacini, Tagliaventi & Alfinito (Figs 13: 1–17; 14: 4, 5)

Valve morphology, LM (Figs 13: 1–17): Valves are linear-lanceolate to elliptic-lanceolate, with sub-capitate to rostrate and broadly rounded apices. Valve length varies from 32–43 µm, valve width 9.0–11.5 µm. Axial area is very narrow, linear. Central area is well defined, lanceolate. Striae around central area more distantly spaced. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are radiate to strongly radiate, becoming convergent near the apices, 14–20 in 10 μm. Areolae are not visible with LM.

Valve morphology, SEM (Figs 14: 4, 5): The species is rare in the sample and SEM observations of the valve exterior were not possible and only valve interior was observed. Internally, central nodule is distinct, elliptical and slightly raised (Fig. 14: 5). Raphe branches are straight located on inwardly strongly elevated sternum (Fig. 14: 4). Raphe proximally terminates with short, slightly deflected endings, while distally with well developed helictoglossa (Fig. 14: 4). Striae are strongly radiate, uniseriate, composed mainly of round areolae. Areolae probably are covered by hymenes, but due to the cleaning process, hymens are corroded. Areolae have slightly transapically elongated internal foramina (Fig. 14: 4).

Comment: The population of *C. germainii* from Macedonia is characterized by smaller valves compared to the type population (length 42–58 μm, width 11.5–13.5 μm). Additionally, difference in the striae orientation between this and the type population can be noticed. The striae in the type population are more or less equally spaced, are parallel to slightly radiate throughout the valve, while the observed valves in this study have more distantly spaced striae in the mid-valve and distinctly radiate striae. No SEM images are available for *C. germainii*, so ultrastructural features cannot be compared. In this moment we consider this population as conspecific with *C. germainii*, but further studies might suggest their separation into two taxa.

Similar species: *Craticula germainii* has unique set of characters (valve shape, striae orientation) that make its identification simple and cannot be confused with other species. *Craticula simplex* (Krasske) Levkov comb. nov. and *C. accomodiformis* Lange-Bertalot have comparable valve size, but they significantly differ in valve shape.

Distribution in Macedonia: *Craticula germainii* was observed only in a small, temporary pond on halomorphic soils, Ovče Pole, near the town of Sveti Nikole.

Ecology: *Craticula germainii* prefers alkaline dystrophic waters with high electrolyte content (high conductivity) such as temporary ponds and alkaline ferns.

Craticula minusculoides (Hustedt) Lange-Bertalot (Figs 13: 18, 19; 20: 1)

Valve morphology, LM (Figs 13: 18, 19): Valves are elliptic to elliptic-lanceolate with narrowly rounded and not protracted apices. Valve length varies from 14–15 μm, valve width 4.5–5.0 μm. Axial area is very narrow, linear. Central area is absent or weakly expressed. Raphe is straight, filiform. Proximal raphe endings are slightly expanded into central pores, while distal endings are curved and terminating on the valve face near the valve apex. Transapical striae parallel throughout the valve, 25–28 in 10 μm. Areolae are not visible with LM, c. 50 in 10 μm.

Valve morphology, SEM (Fig. 20: 1): The valve surface is flat, without developed longitudinal frets. Well developed sternum is absent. Raphe branches are straight and proximally terminate with expanded central pores. Distally, raphe endings are long, curved and not continuing on the valve mantle. Striae are parallel throughout the whole valve, uniseriate, composed of slightly elongated areolae.

Similar species: *Craticula minusculoides* can be confused with *C. molestiformis* (Hustedt) Mayama (Figs 18: 31–58) and *C. subminuscula* (Manguin) C.E.Wetzel & Ector (Figs 21: 31–69). These three species can be clearly separated with SEM. In *C. minusculoides* the areolae are not occluded with hymens externally as in the other two species (compare with Figs 20: 2–5 and Figs 23: 1–4). The distal raphe endings in *C. molestiformis* are long, strongly hooked and continuing onto the valve mantle (Figs 20: 2–5). In *C. subminuscula* the distal raphe endings are short, strongly deflected and not passing on the valve mantle (Figs 23: 1–4), while in *C. minusculoides* they are curved and terminating on the valve face. The areolae in *C. subminuscula* and *C. molestiformis* have round foramina, while in *C. minusculoides* the areolae have transapically elliptical foramina.

Distribution in Macedonia: *Craticula minusculoides* was observed only in a small, temporary pond on halomorphic soils, Ovče Pole, near the town of Sveti Nikole. It is extremely rare in the sample.

Ecology: Not precisely known. According to Lange-Bertalot [10, p. 115] it occurs in electrolyte rich, eutrophic, α-β mesosaprobic waters. The locality where it was observed is characterized by slightly alkaline water (pH = 8.3) with high conductivity (1300 $\mu S \cdot cm^{-1}$).

Craticula accomodiformis Lange-Bertalot (Figs 15: 1–20)

Valve morphology, LM: Valves are elliptic-lanceolate to elliptic with shortly rostrate apices. Valve length varies from 32–50 μm, valve width 10.5–13.0 μm. Axial area is very narrow, linear. Central area is small, lanceolate. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are parallel in the mid-valve, becoming convergent near the apices, 19–21 in 10 μm. Areolae are hardly visible with LM, c. 35 in 10 μm.

Similar species: *Craticula accomodiformis* can be confused with *C. accomoda* (Hustedt) D.G. Mann and *C. halophila* (Grunow) D.G. Mann. *Craticula accomoda* can be easily differentiated by its smaller valves (length 18–22 μm, width 6.0–7.5 μm), while *C. halophila* has different valve shape (rhombic to rhombic-lanceolate)

Comment: The population of *C. accomodiformis* observed in this study is characterized by larger valves than type population (length 24–37 μm, width 8–11.5 μm).

Distribution in Macedonia: *Craticula accomodiformis* was observed only on two localities, Negorska Banja and Banjsko.

Ecology: Both localities where *C. accomodiformis* was observed are thermo-mineral springs with high electrolyte content. The type population originates from Syria (Lange-Bertalot [9, Figs 69: 6–8, 10]), and was infrequently observed in Europe, mainly in the regions with a Mediterranean climate (Lange-Bertalot [10]).

***Craticula halophila* (Grunow) D.G.Mann**
(Figs 16: 1–18)

Basionym: *Navicula cuspidata* var. *halophila* Grunow in Van Heurck [42, p. 100, Suppl. pl. B, Fig. 30]

Nomenclatural synonym: *Navicula halophila* (Grunow) Cleve [36, p. 109]

Valve morphology, LM: Valves are rhombic to rhombic-lanceolate with acute to slightly protracted apices. Valve length varies from 27–54 μm, valve width 9.0–12.0 μm. Axial area is very narrow, linear. Central area is absent with same width as axial areal. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are parallel to slightly radiate in the mid-valve becoming strongly convergent towards the apices, 17–19 in 10 μm. Areolae are hardly visible with LM, c. 35 in 10 μm.

Similar species: *Craticula halophila* can be hardly confused with other species, since it has characteristic valve shape that makes its identification simple. *Craticula accomodiformis* Lange-Bertalot has similar size, but it has elliptic-lanceolate valves with shortly rostrate apices.

Distribution in Macedonia: So far, *C. halophila* was observed only in temporary ponds on Slan Dol. It was reported from Lake Dojran, but this data was not confirmed during this study.

Ecology: Halophilic species, occurring in salt springs and ponds with high content of salts.

***Craticula simplex* (Krasske) Levkov comb. nov.**
(Figs 17: 1–38; 18: 1–20; 19: 1–6)

Basionym: *Navicula simplex* Krasske [43], *Abhandlungen und Bericht LVI des Vereins für Naturkunde zu Cassel, 84-89 Vereinsjahr 1919–1925*, p. 51, Fig. 2: 33.

Valve morphology, LM (Figs 17: 1–38; 18: 1–20): Valves are lanceolate, linear-lanceolate to rhombic-lanceolate with shortly protracted, rostrate to subcapitate apices. Valve length varies from 19–37 μm, valve width 5.5–8.5 μm. Axial area is narrow, linear. Central area is absent or weakly developed, slightly wider than the axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and are slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are parallel to slightly radiate in the mid-valve becoming convergent towards the apices, 17–19 in 10 μm. Areolae are not visible with LM.

Valve morphology, SEM (Figs 19: 1–6): The valve surface is flat without longitudinal frets (Figs 19: 1, 2, 4). The axial area is moderately wide. Raphe branches are straight. External proximal raphe endings are short, expanded into small central pores and unilaterally deflected (Fig. 19: 4). Distally, raphe endings are long, strongly hooked and continuing onto the mantle (Fig. 19: 5). Striae are uniseriate composed of large, apically elongated like areolae, except near the central area where areolae have elliptical foramina (Fig. 19: 4). Internally, central nodule is slightly raised (Fig. 19: 5). Raphe branches are straight located on inwardly slightly elevated raphe sternum. Raphe proximally terminates with short, slightly deflected endings, while distally with weakly developed helictoglossa. Areolae are covered by hymenes, located inside each areola (Fig. 19: 4).

Comment: The observed species has similar characteristics as *Navicula simplex* Krasske [43, Fig. 2: 33]. In the past, this taxon was recognized as a separate and distinct species by Hustedt [44, p. 296, fig. 500], and there are several records in the older literature. More recently, Hustedt's concept of *N. simplex* was presented by Krammer & Lange-Bertalot [19, Fig. 44: 6]. However, later Lange-Bertalot [10, p. 110] considered this species as a part of the life cycle of *N. buderi* Hustedt [45, p. 279, figs 11–15] ≡ *C. buderi* (Hustedt) Lange-Bertalot (in Rumrich *et al.* [13, p. 101]). The type material of *N. buderi* was observed with LM and SEM by Ector & Wetzel (pers. comm.) and both species considerably differ with respect to the valve shape and size.

During this study three different morphotypes of *C. simplex* were observed. The first morphotype (Figs 17: 1–18; 18: 11–21), is characterized by larger (26–37 μm long, 7.0–8.5 μm wide) and lanceolate valves with subcapitate apices. This morphotype is the most commonly observed during this study. The second morphotype (Figs 17: 19–38) has smaller (23–27 μm long, 5.5–6.0 μm) lanceolate valves with rostrate apices. This population was observed as epiphyte in temporary ponds on Slan Dol. The third morphotype (Figs 18: 1–10) is characterized by smaller (19–26 μm long, 6.0–7.0 μm wide) linear-lanceolate valves with shortly rostrate apices. This morphotype was observed in sediments from saline temporary ponds. However, all habitats are characterized with same ecology: higher temperature (around 30 ^{0}C) and high mineral content (conductivity 1200–2000 μS•cm^{-1}). Although clear difference in the valve morphology between these three populations can be noticed, we still consider them as conspecific, being a part of the morphological variability of a single species.

Similar species: *Craticula simplex* is similar to *C. guaykuruorum* C.E.Wetzel, E.Morales & Ector (in Morales *et al.* [12, Figs 15–23, 31–37]), *C. elkab* (O. Müller ex O. Müller) Lange-Bertalot, Kusber & Cocquyt (Kusber & Cocquyt [46]), *C. riparia* (Hustedt) Lange-Bertalot and *C. antarctica* Van de Vijver & Sabbe (in Van de Vijver *et al*. [14, figs 19–36]). *Craticula simplex* can be differentiated from *C. guaykuruorum* by the shape of valve apices (narrow and weakly protracted), stria density (21–23 in 10 μm) and orientation (parallel in *C. guaykuruorum*) as well as by the absence of longitudinal frets. *Craticula elkab* has comparable valve size and shape with morphotype 3 (Figs 18: 1–10), but it differs with the shape of the valve apices (narrowly rounded to weakly protracted especially in larger specimens) and striae density (22–26 in 10 μm). *Craticula riparia* var. *riparia* is characterized by larger valves (35–50 μm long, 8.0–10.5 μm wide) with 15–18 striae in 10 μm which are parallel through. *Craticula riparia* var. *mollenhaueri* Lange-Bertalot [9, figs 70: 10–13) has comparable valve size as *C. simplex*, but can be differentiated by the presence of strongly silicified raphe sternum and striae orientation (parallel in *C. riparia* var. *mollenhaueri*). Probably the most similar species to *C. simplex* is *C. antarctica*. The latter species is characterized by lanceolate valves with (sub) capitate apices, 23.5–36.0 μm long and 6.2–8.0 μm wide with 17–22 striae in 10 μm which are radiate in the middle, becoming convergent towards apices. Slight difference between these two species can be noticed in the valve shape (rhombic lanceolate *vs*. elliptic lanceolate in *C. antarctica*) and valve apices (rostrate vs. capitate *C. antarctica*). Difference can be noticed also in ecology: *Craticula antarctica* was observed in a cold lake on Antarctica, while *C. simplex* was observed in thermo-mineral springs and warm temporary ponds on halomorphic soils.

Distribution in Macedonia: *Craticula simplex* was observed on several localities in Macedonia: halomorphic soils in Sveti Nikole and Gladno Pole, the thermo-mineral springs near the villages Gabrovo, Stamer and Katlanovo, temporary ponds in Slan Dol and mining Lake Usje.

Ecology: Halophilic and alkaliphilic species, present in mineral springs, temporary ponds on halomorphic soils, mining lakes.

***Craticula accomoda* (Hustedt) D.G.Mann**
(Figs 18: 21–30; 21: 1–30; 22: 1–6)

Basionym: *Navicula accommoda* Hustedt [47, p. 446, Figs 39: 17, 18]

Valve morphology, LM (Figs 18: 21–30; 21: 1–30): Valves are elliptic-lanceolate to elliptic with shortly rostrate apices. Valve length varies from 18–22 μm, valve width 6.0–7.5 μm. Axial area is very narrow, linear. Central area is absent or weakly expressed with almost the same width as axial area. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores and slightly deflected, while distal endings are hooked and reaching the valve mantle at the apex. Transapical striae are parallel to slightly radiate in the mid-valve becoming convergent towards the apices, 22–28 in 10 μm. Areolae are not visible with LM.

Valve morphology, SEM (Figs 22: 1–6): The valve surface is flat, without developed longitudinal frets (Figs 22: 1–4). Axial area is very narrow. Raphe is linear, located on the valve surface (Figs 22: 1–4). External proximal raphe endings are short, straight and slightly expanded into central small pores (Fig. 22: 4). Distally, raphe endings are long, strongly hooked and terminating on the valve face (Figs 22: 1–3). Striae are uniseriate composed of narrow, apically elongated slit-like areolae. Areolae around central area have transapically elongated foramina (Fig. 22: 4). Internally, central nodule is distinctly raised (Figs 22: 5, 6). Raphe branches are straight located on inwardly strongly elevated sternum (Fig. 22: 6). Raphe proximally terminates with short slightly deflected endings, while distally with slightly developed helictoglossa. Areolae are covered by hymenes, located inside each areola (Figs 22: 5, 6).

Similar species: *Craticula accomoda* can be hardly confused with other species. *Craticula accomodiformis* is larger (32–50 μm long, 10.5–13.0 μm wide), while *C. molestiformis* (Hustedt) Mayama is smaller (9.5–22 μm long and 3–5 μm wide) with weakly protracted apices. *Craticula simplex* MT3 has comparable valve size, but it can be easily differentiated by the stria density and orientation.

Distribution in Macedonia: During this study *C. accomoda* was observed in the rivers Vardar, Bregalnica, Strumica, Zrnovka, Kočanska, Svetinikolska, Vodenišnica, reservoir Kalimanci, halomorphic soils near Sveti Nikole and Gladno Pole, temporary ponds in Slan Dol and mining Lake Usje.

Ecology: Eutraphentic species, it was observed in the most polluted sites in rivers. In the River Vodenišnica (a heavy polluted river with communal and industrial waste waters) is one of the dominant species, together with *C. subminuscula* (Manguin) Wetzel & Ector.

Craticula molestiformis (Hustedt) Mayama
(Figs 18: 31–58; 20: 2–6)

Basionym: *Navicula molestiformis* Hustedt [48, p. 86, fig. 5: 9]

Valve morphology, LM (Figs 18: 31–58): Valves are elliptic to elliptic-lanceolate with narrowly rounded apices. Valve length varies from 9–16 μm, valve width 3.5–5.0 μm. Axial area is very narrow, linear. Central area is absent or weakly expressed. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores, while distal endings are long, strongly hooked and continuing on the valve mantle. Transapical striae are parallel in the middle becoming slightly radiate towards the apices, 26–32 in 10 μm. Areolae are not visible with LM, c. 50 in 10 μm.

Valve morphology, SEM (Figs 20: 2–6): The valve surface is flat, without developed longitudinal frets (Figs 20: 2–5). Axial area is very narrow. Raphe is linear located on the valve surface (Figs 20: 2–5). External proximal raphe endings are short, straight and slightly expanded into small central pores (Figs 20: 2–5). Distally, raphe endings are long, strongly hooked and continuing onto valve mantle (Figs 20: 2, 4, 5). Striae are uniseriate composed of small elliptical areolae with same size. Externally, areolae are covered with hymens. Internally, central nodule is slightly inwardly elevated (Fig. 20: 6). Raphe branches are straight located on inwardly weakly elevated sternum (Fig. 20: 6). Raphe proximally terminates with short and distinctly deflected endings, while distally with slightly developed helictoglossa. Areolae covered by hymenes, located inside each areola towards the outer valve surface (Fig. 20: 6).

Similar species: *Craticula molestiformis* can be confused with *C. subminuscula*. Both species have similar valve size and valve shape, but can be differentiated by the stria density (26–32/10 μm *vs* 22–26/10 μm). Additional differences can be observed in the raphe morphology. The distal raphe endings in *C. molestiformis* are long, strongly hooked and continuing onto the valve mantle (Figs 20: 2–5). In *C. subminuscula* the distal raphe endings are short, deflected and not passing on the valve mantle (Figs 23: 1–4). *Craticula submolesta* (Hustedt) Lange-Bertalot and *C. molesta* (Krasske) Lange-Bertalot & Willmann have shortly rostrate apices.

Distribution in Macedonia: *Craticula molestiformis* was observed only in the reservoir Ratevsko. It is possible to have broader distribution in Macedonia, but very likely it is overlooked or misidentified with other small-celled species.

Ecology: According to Lange-Bertalot [10] *C. molestiformis* prefers electrolyte rich, often heavily polluted waters. However, during this study it was observed in the oligo- to mesotrophic reservoir and Lake Vevčansko on Mountain Jablanica.

Craticula subminuscula (Manguin) C.E.Wetzel & Ector (Figs 21: 31–69; 23: 1–6)

Basionym: *Navicula subminuscula* Manguin [18, p. 139, Fig. 2: 39]

Nomenclatural synonym: *Eolimna subminuscula* (Manguin) Moser, Lange-Bertalot & Metzeltin [49, p. 154]

Valve morphology, LM (Figs 21: 31–69): Valves are elliptic to narrowly to broadly rounded apices. Valve length varies from 8–14 μm, valve width 3.5–5.5 μm. Axial area is very narrow, linear. Central area is absent or weakly expressed. Raphe is straight, filiform. Proximal raphe endings are expanded into central pores, while distal endings are short, deflected and not passing on the valve mantle. Transapical striae are radiate to strongly radiate throughout the valve, 22–24 in 10 μm. Areolae are not visible with LM.

Valve morphology, SEM (Figs 23: 1–6): The valve surface is flat, without developed longitudinal frets (Figs 23: 1–4). Axial area is very narrow. Raphe is linear located on the valve surface (Figs 23: 1, 4) or on slightly elevated sternum (Figs 23: 2, 3). External proximal raphe endings are short, weakly deflected and expanded into small central small pores (Figs 23: 1–4). Distally, raphe endings are short and unilaterally deflected and not continuing onto valve mantle (Figs 23: 1–4). Striae are uniseriate composed of small round areolae. Areolae near the valve face/mantle junction have larger external foramina (Figs 23: 2, 3). Externally, areolae are covered with slightly recessed hymens. Internally, central nodule is slightly inwardly elevated (Figs 23: 5, 6). Raphe branches are straight located on inwardly weakly elevated sternum (Figs 23: 5, 6). Raphe proximally terminates with short and slightly deflected endings, while distally with slightly developed helictoglossa. Areolae are covered by hymenes, located inside each areola towards the outer valve surface (Figs 23: 5, 6).

Comment: *Craticula subminuscula* was formerly transferred to the genus *Eolimna* Lange-Bertalot & W.Schiller [in Schiller & Lange-Bertalot 50] by Moser et al. [49]. More recently it was transferred to the genus *Craticula* by Wetzel *et al.* [51, p. 229], based on previously published morphological and molecular data. However, *C. subminuscula* and C. *molestiformis* have slightly different ultrastructural features than other *Craticula* species. The areola are externally occluded (Figs 20: 2–5 and Figs 23: 1–4) opposite to other *Craticula* species where the areolae are internally occluded. The shapes of the foramina in *C. subminuscula* and C. *molestiformis* are round opposite to slit-like areola in other *Craticula* species. Their allocation in the genus *Craticula* should be examined more in detail in the future.

Similar species: As mentioned above, *C. subminuscula* can be confused with *C. molestiformis*, but both species can be easily differentiated by the raphe morphology, stria orientation and density.

Distribution in Macedonia: The rivers: Vodenišnica, Strumica, Bregalnica and Vardar. Probably it has wider distribution in polluted rivers, but very likely it is neglected or confused with other small-celled species. Hustedt [17] recorded this species from Lake Ohrid under *N. demissa*. However, during the recent observations of the flora of Lake Ohrid (Levkov *et al.* [52]) and this study, *N. demissa* (or *C. subminuscula*) was not recorded.

Ecology: *Craticula subminuscula* is one of the most tolerant species to organic pollution. During this study, this species was observed with high abundance in two of the most polluted rivers: Vodenišnica and Bregalnica.

CONCLUSIONS

The Republic of Macedonia is characterized by presence of various water habitats which host highly diverse diatom flora. Recently more attention was paid to the so called "extreme habitats". Those habitats include thermo-mineral springs, temporarily wet rocks, hypersaline lakes, wet halomorphic soils, ice layers and caves. Such habitats are unfavourable for most of the algae, but on the other hand, they are inhabited by specialized organisms which are adapted to numerous fluctuating and extremely adverse physico-chemical conditions. During this study the highest diversity of *Craticula* was observed exactly in such extreme habitats. A large number of species were observed on the halomorphic soils near Gladno Pole and Slan Dol. However, these regions are most intensively utilized for agriculture and farming which have a significant impact on their surface area and degradation. Moreover, the scenarios for climate change of the region of Gladno Pole suggest decrease of precipitation and increase of air temperature. Such alterations will have an influence on environment and the functioning of habitats. Therefore the distribution of the remarkable diatom species inhabiting these habitats is under threat.

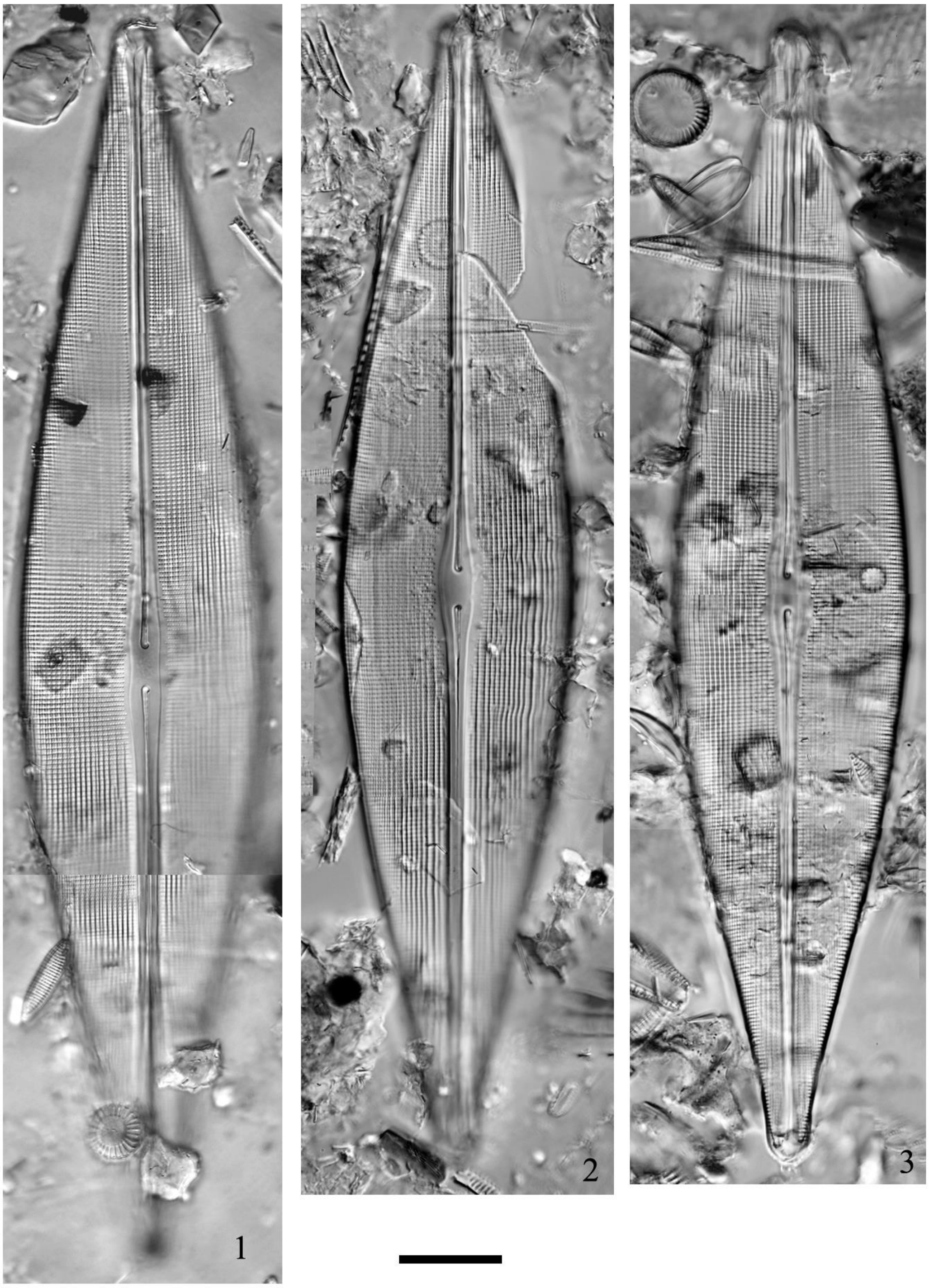

Figure 1: 1–3. Light micrographs (LM) of *Craticula perrotettii* Grunow. Lake Dojran, Alex Beach, plankton (Slide MKNDC 002212). Scale bar = 20 μm.

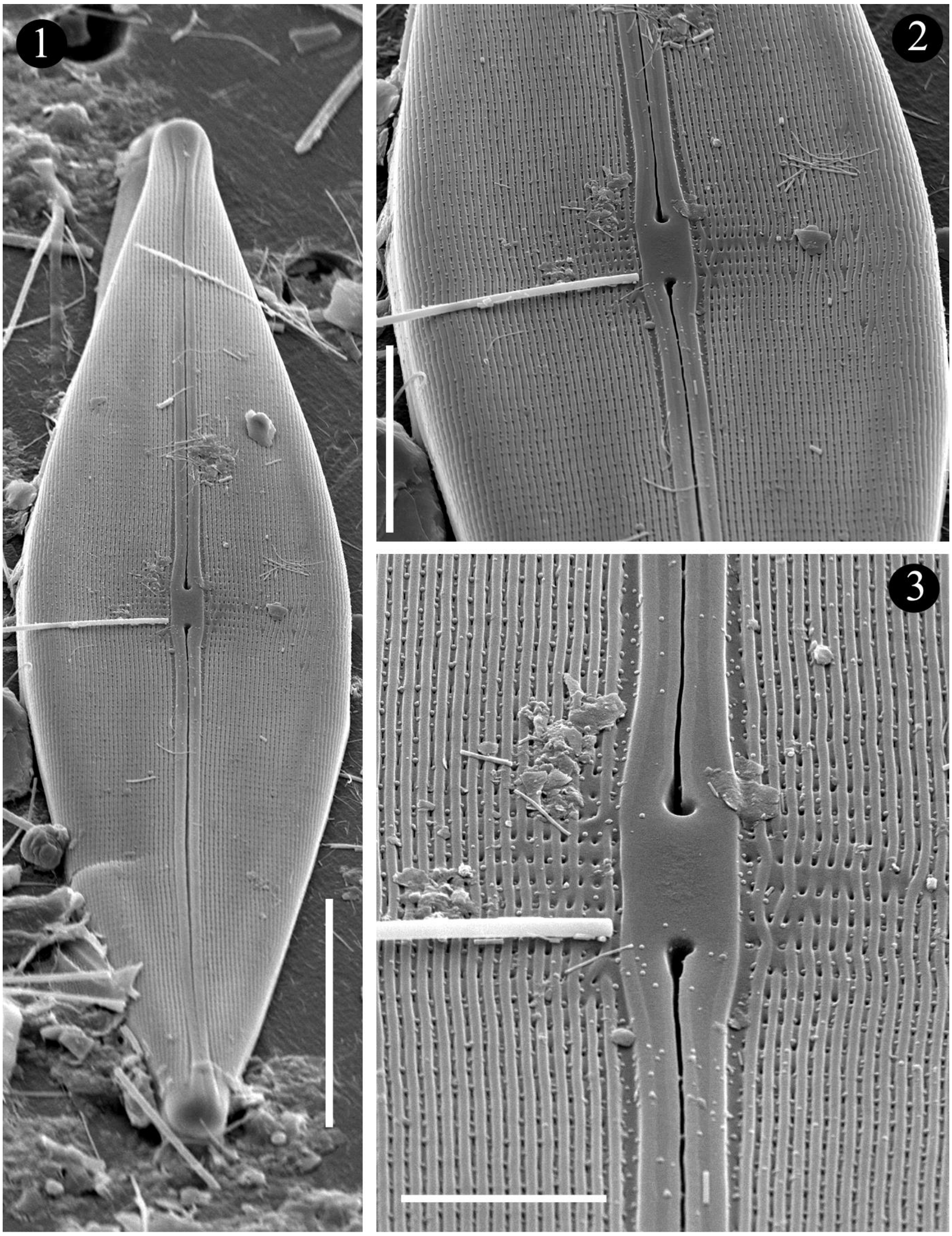

Figure 2: 1–3. Scanning electron micrographs of *Craticula perrotettii*. **1**. External view of the whole valve. **2, 3**. Detailed view of the mid-valve. Areolae are separated by strongly thickened frets (longitudinal ribs). Areolae in the mid-valve have round foramina, while distally have slit-like openings. Scale bar = 20 µm (**1**), 10 µm (**2**), 5 µm (**3**).

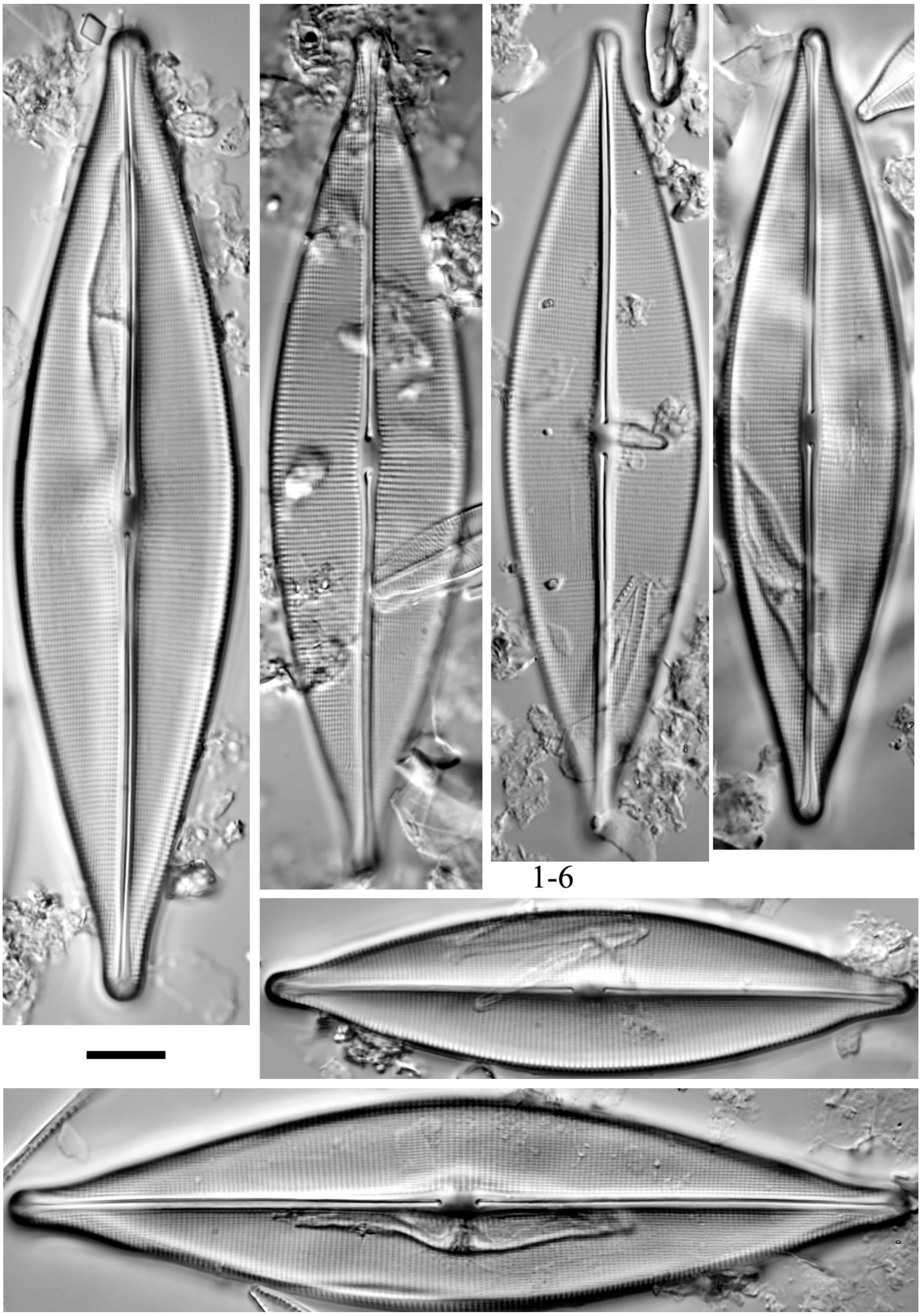

Figure 3: 1–6. LM micrographs of *Craticula cuspidata* (Kützing) D. G. Mann. The River Bregalnica, before the mouth of the River Kočanska, yellow filaments (Slide MKNDC 006806). Scale bar = 10 µm.

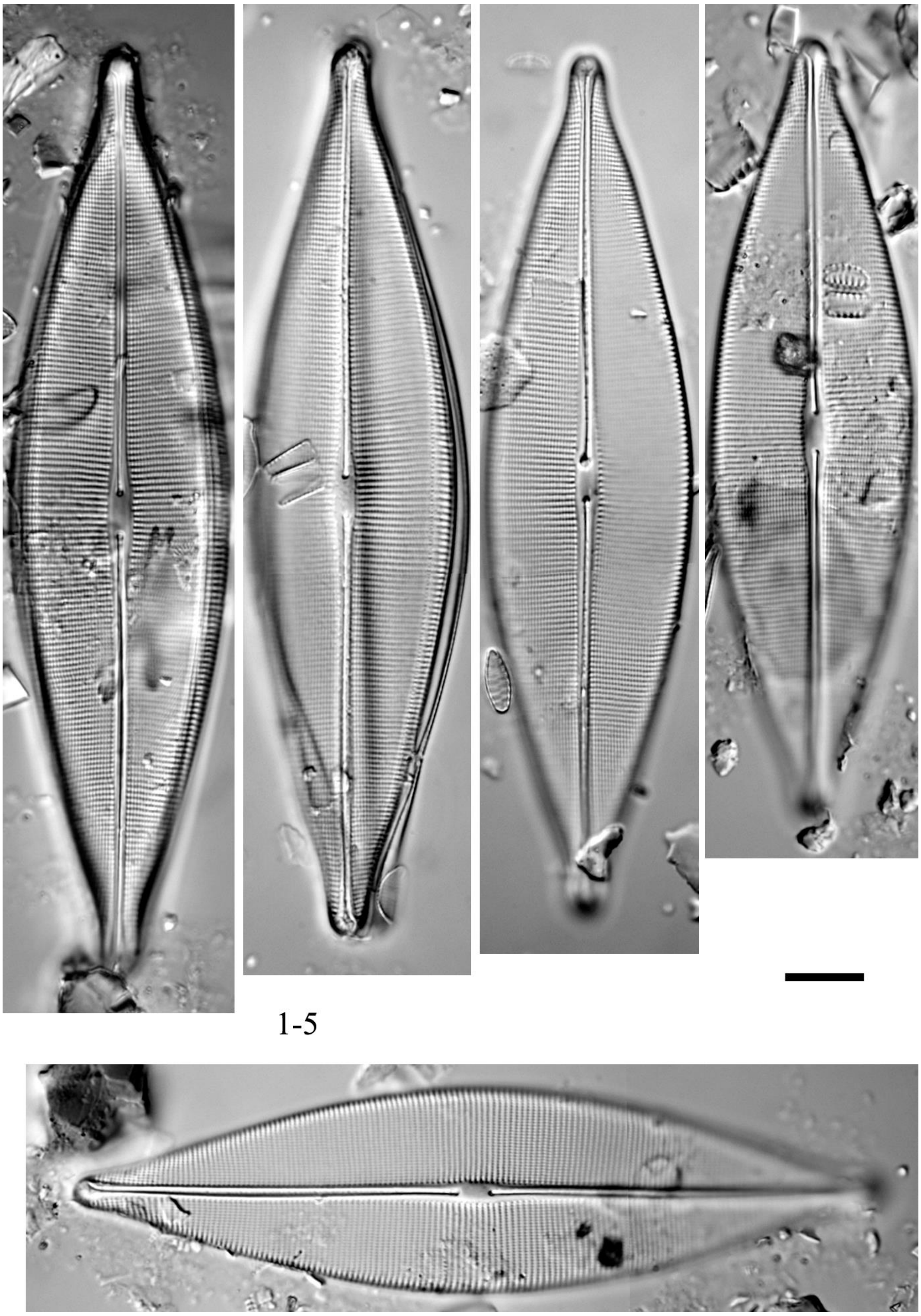

Figure 4: 1–5. LM micrographs of *Craticula cuspidata* (Kützing) D.G.Mann. Lake Ohrid, Bay of St. Naum, sediment 9 m depth (Slide MKNDC 001133). Scale bar = 10 µm.

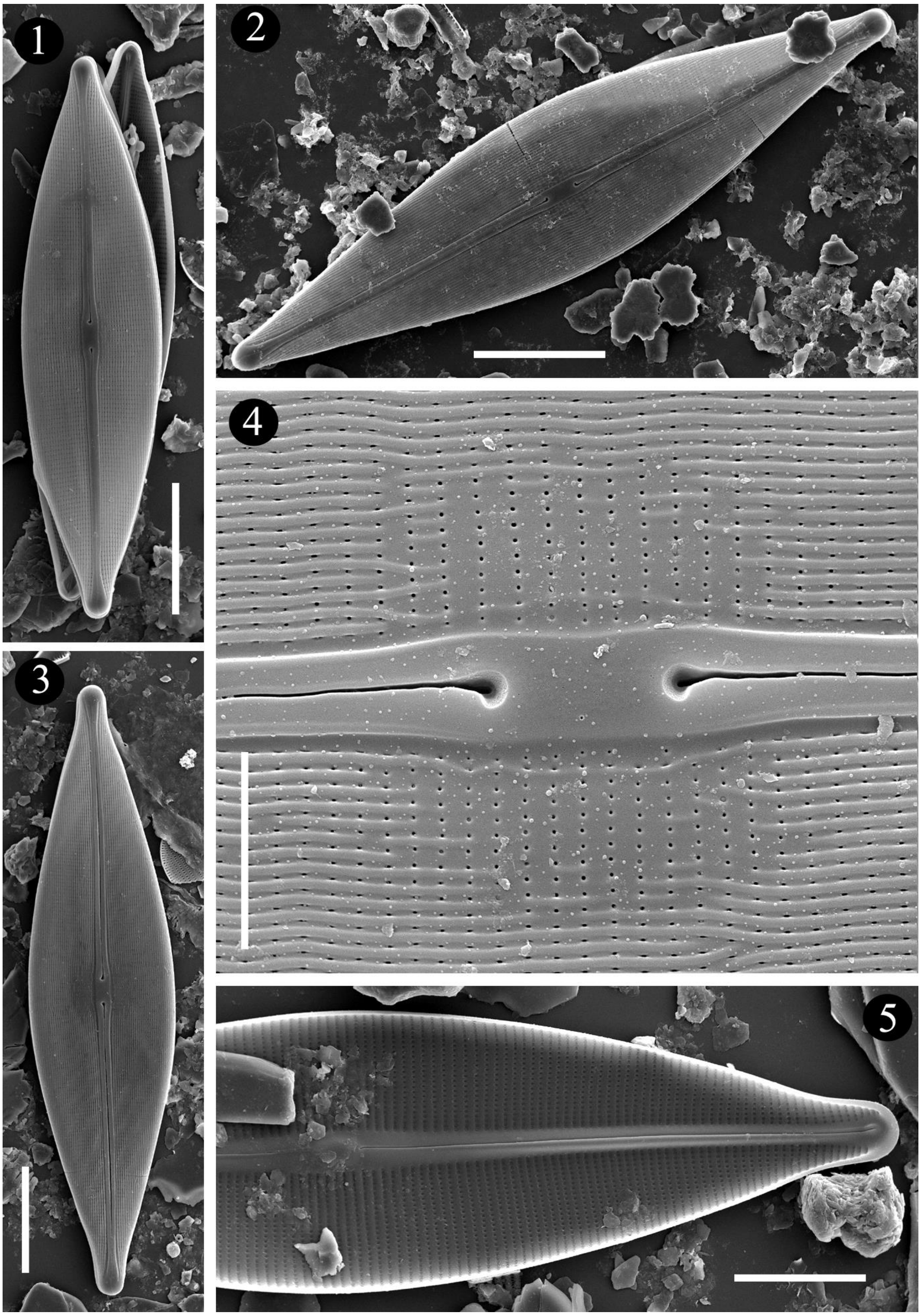

Figure 5: 1–**5**. Scanning electron micrographs of *Craticula cuspidata*. **1**–**3**. External view of the whole valve. **4**. Detailed view of the mid-valve. Areolae are separated by thickened frets (longitudinal ribs). Areolae in the mid-valve have round foramina, while distally have slit-like openings. **5.** Internal view. Areolae are occluded by hymen. Scale bar = 20 µm (**1–3**), 5 µm (**4**), 10 µm (**5**).

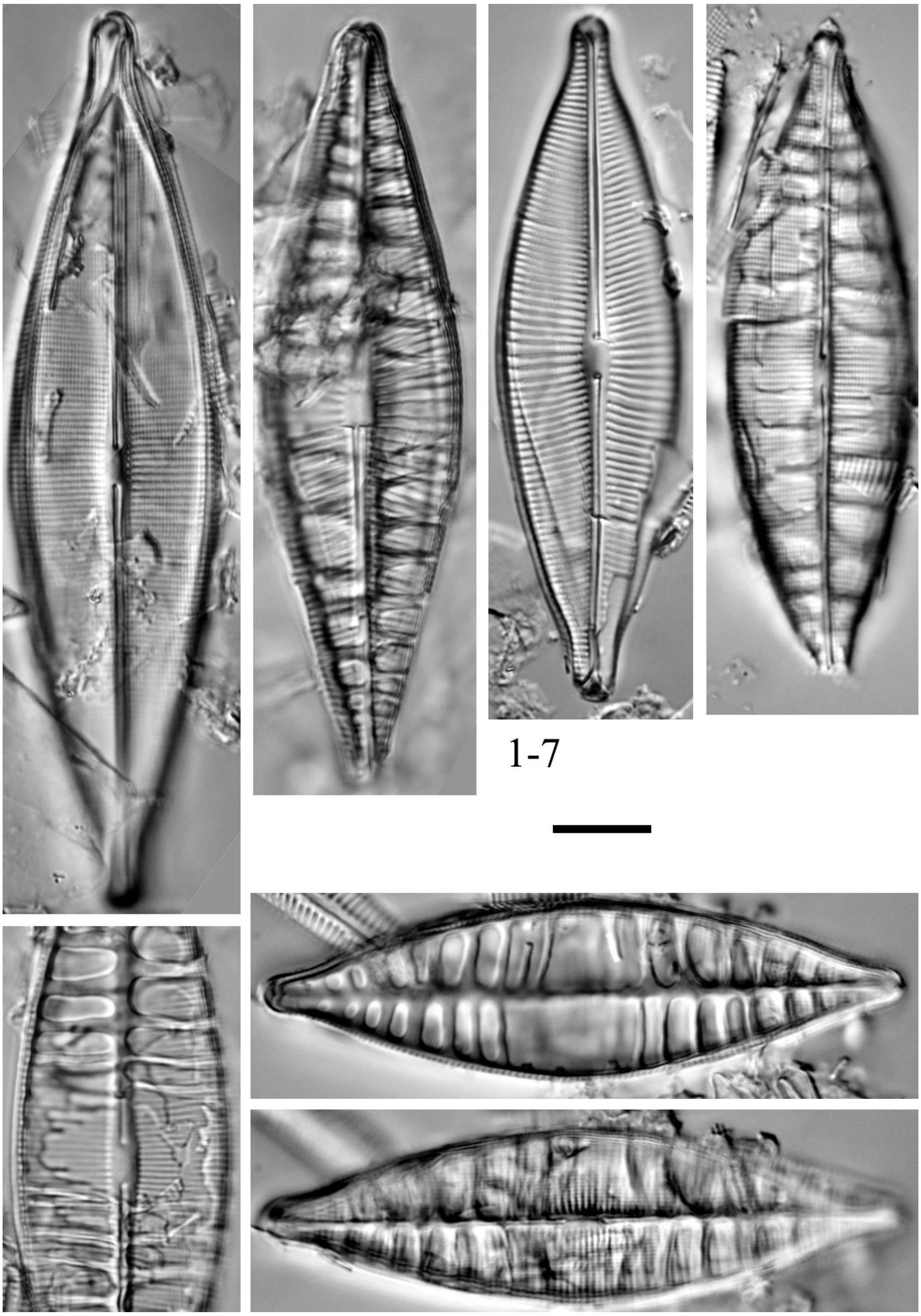

Figure 6: 1–7. LM micrographs of *Craticula* aff. *acidoclinata* Lange-Bertalot & Metzeltin. Šara Mountain, Lake Karanikoličko, macrophytes (Slide MKNDC 003084). Scale bar = 10 μm.

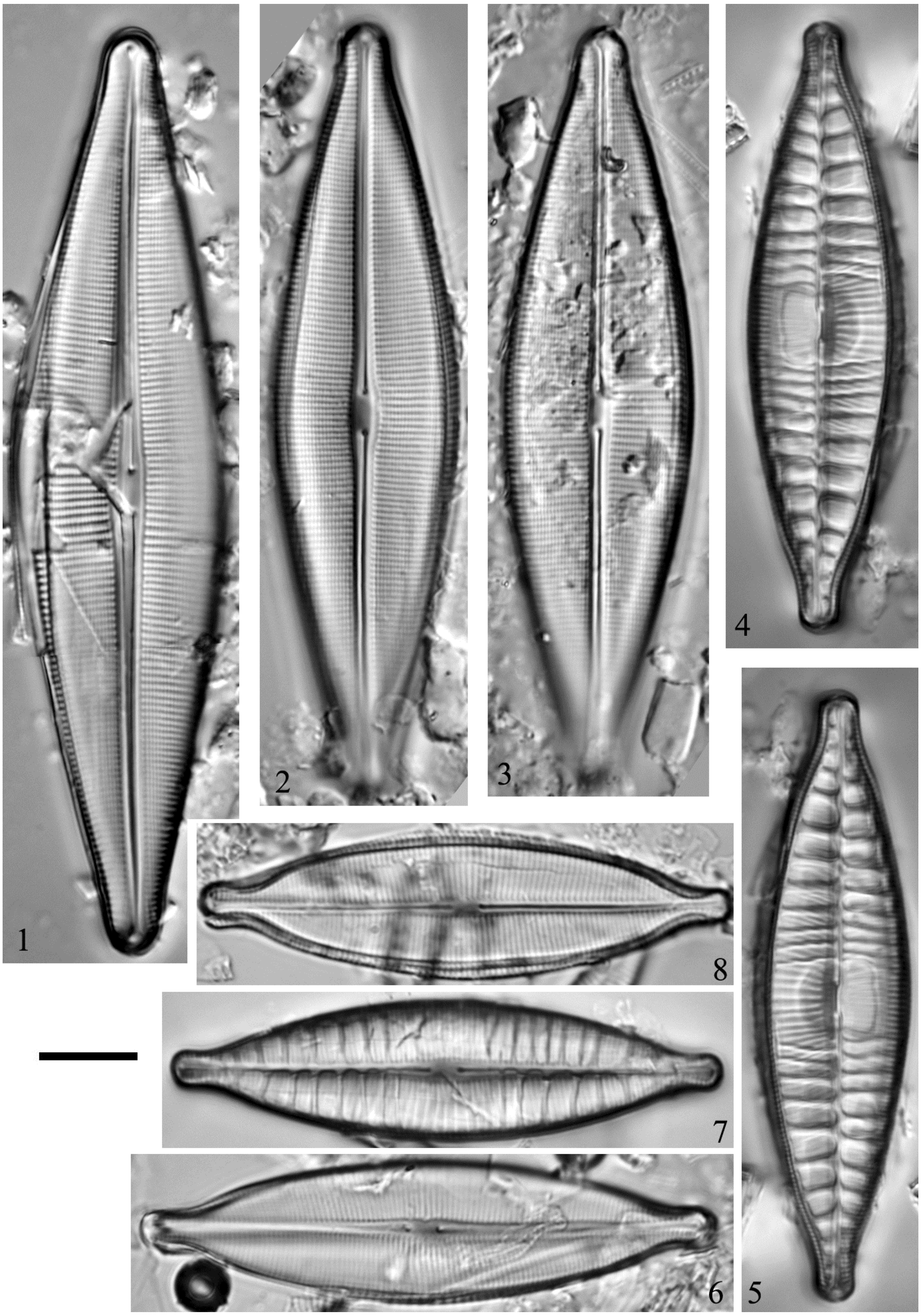

Figure 7: 1–**3**. LM micrographs of *Craticula sardiniana* Bahls. Sveti Nikole, the village of Adzimatovo, pond, sediment (Slide MKNDC 008835). **4–8**. LM micrographs of *Craticula fumantii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Lake Karanikoličko, Šara Mountain, macrophytes (Slide MKNDC 003084). Scale bar = 10 µm.

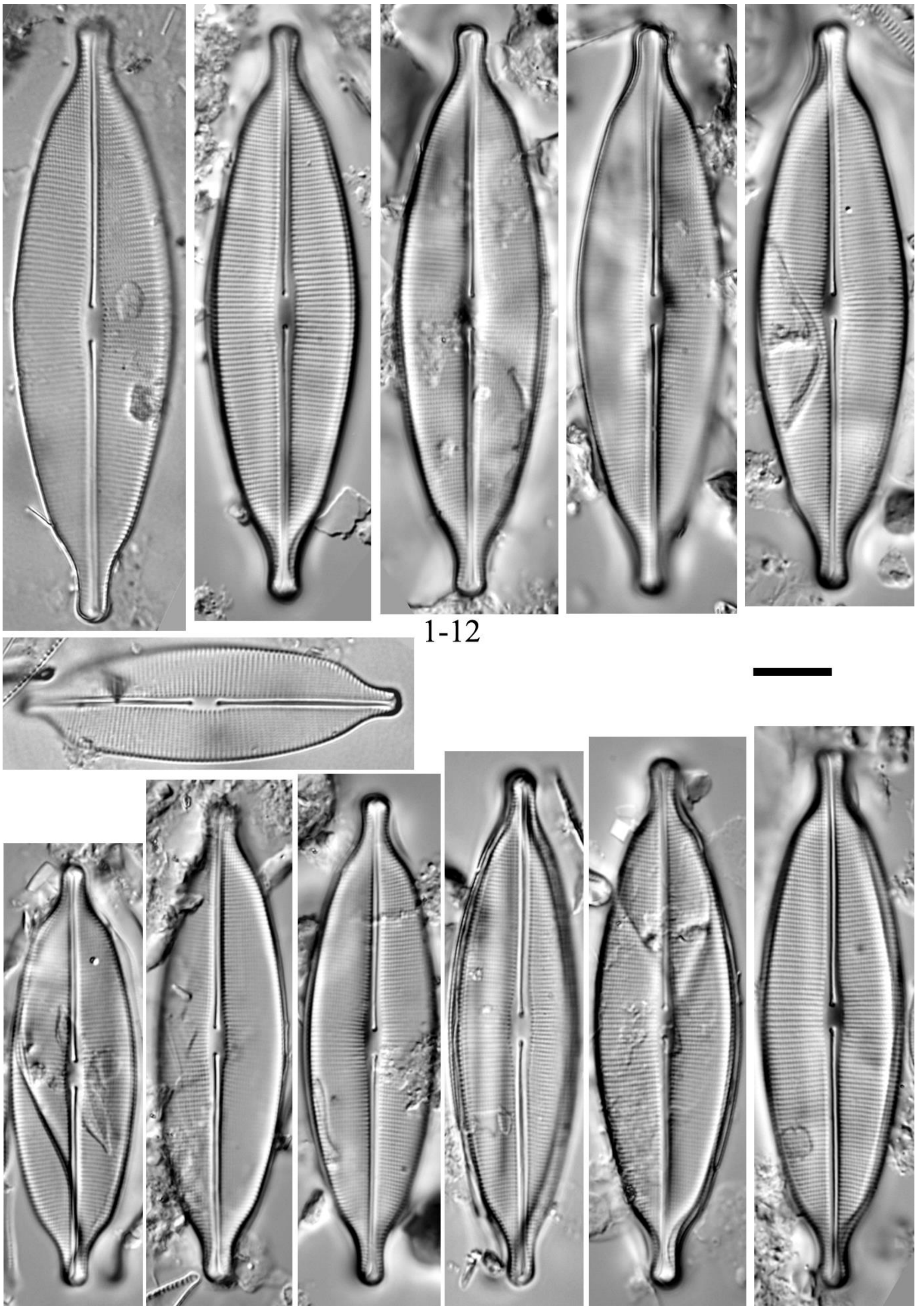

Figure 8: 1–12. LM micrographs of *Craticula ambigua* (Ehrenberg) D.G. Mann. The River Bregalnica, before the mouth of the River Kočanska, yellow filaments (Slide MKNDC 006806). Scale bar = 10 µm.

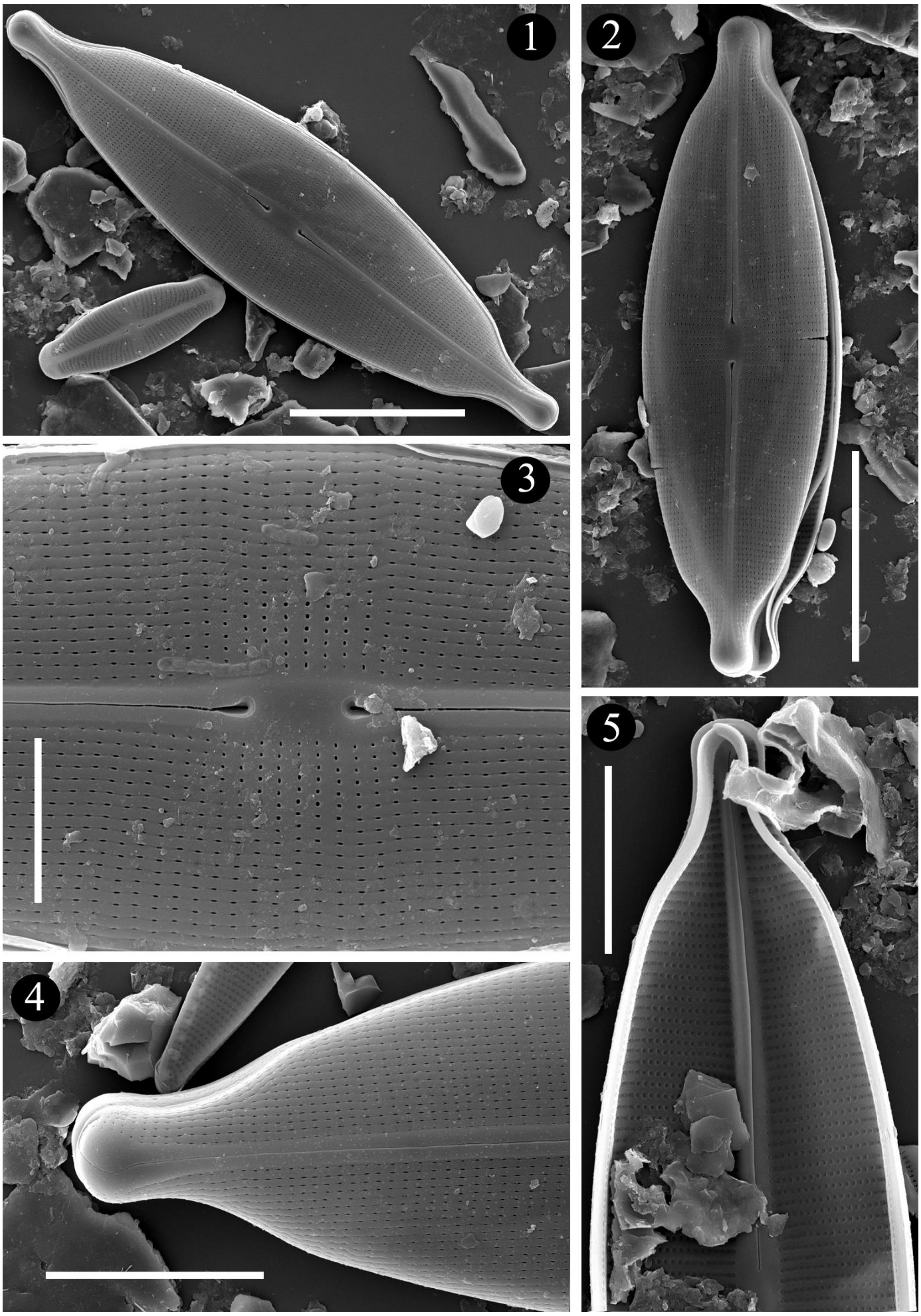

Figure 9: 1–5. Scanning electron micrographs of *Craticula ambigua*. **1, 2**. External view of the whole valve. **3**. Detailed view of the mid-valve. Areolae in the mid-valve have round foramina, while distally have slit-like openings. **4**. Detailed view of the valve apex showing the "shoulder" and capitate apex. **5**. Internal view. Areolae are occluded by hymen. Scale bar = 20 μm (**1, 2**), 5 μm (**3**), 10 μm (**4, 5**).

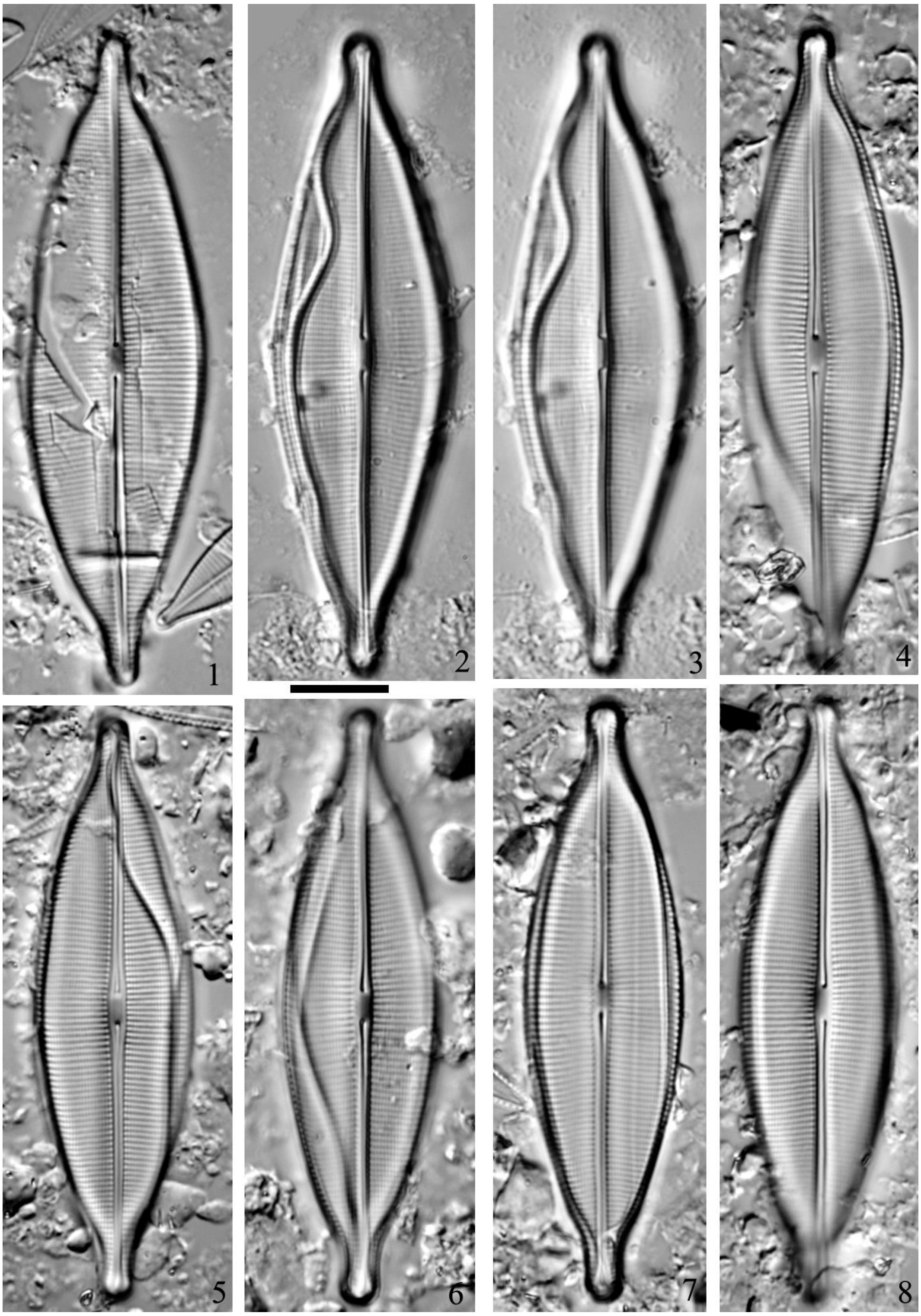

Figure 10: 1–8. LM micrographs of *Craticula nonambigua* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Sveti Nikole, near the village of Adzimatovo, pond, mud (Slides MKNDC 008835 and 008836). Scale bar = 10 µm.

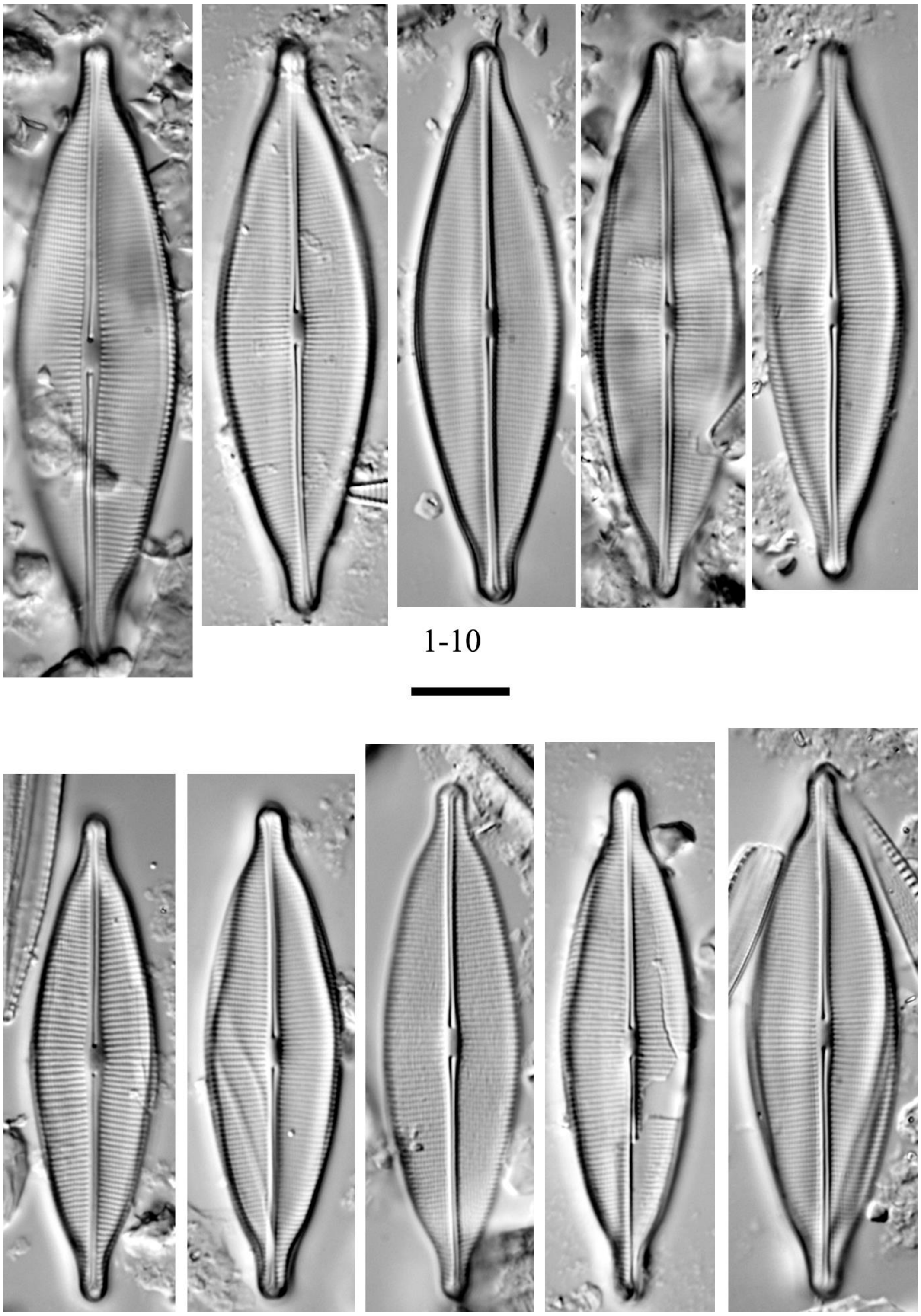

Figure 11: 1–10. LM micrographs of *Craticula nonambigua* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Sveti Nikole, near the village of Adzimatovo, pond, mud (Slides MKNDC 008835 and 008836). Scale bar = 10 µm.

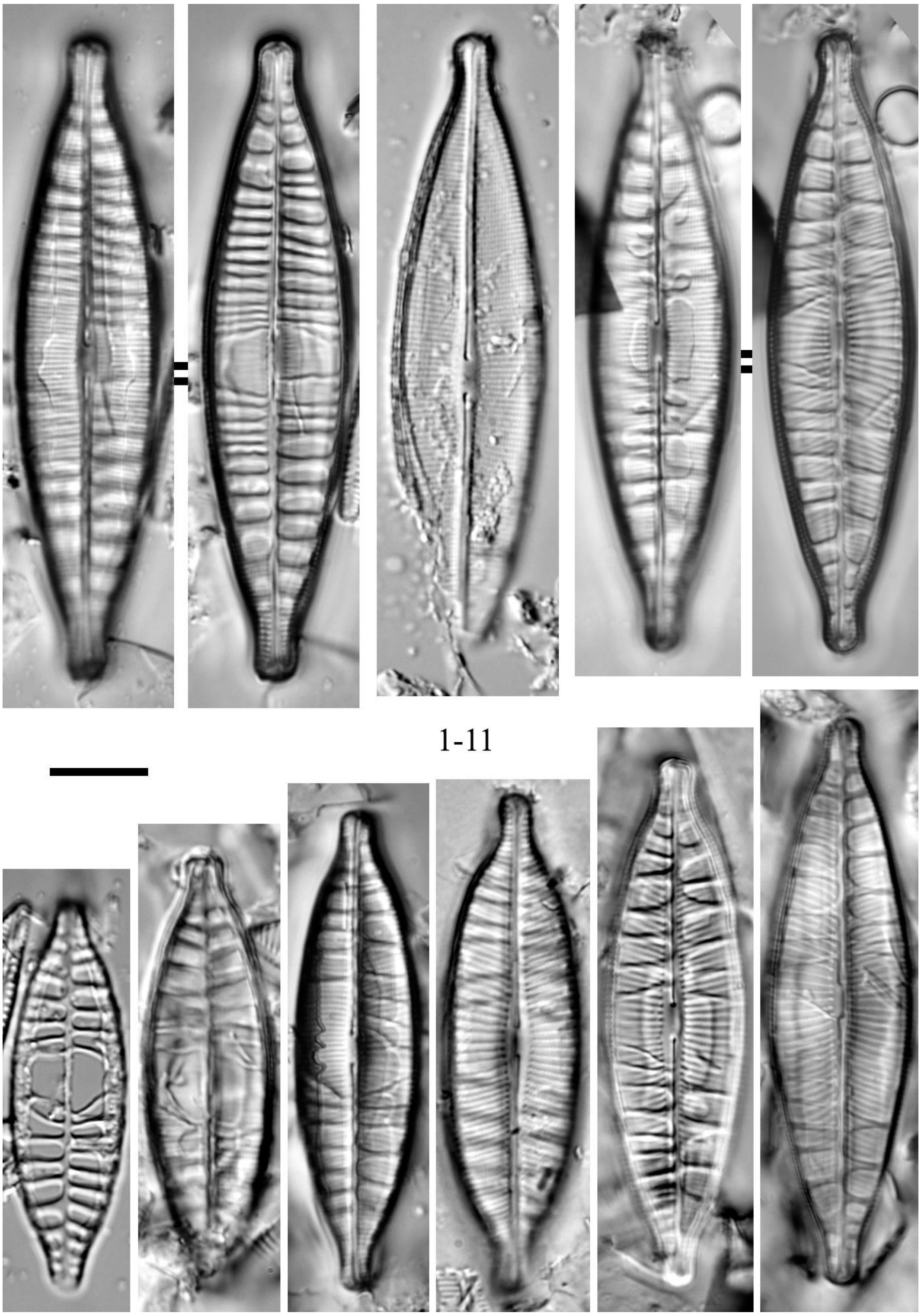

Figure 12: 1–11. LM micrographs of *Craticula fumantii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Lake Karanikoličko, Šara Mountain, macrophytes (Slide MKNDC 003084). Scale bar = 10 μm.

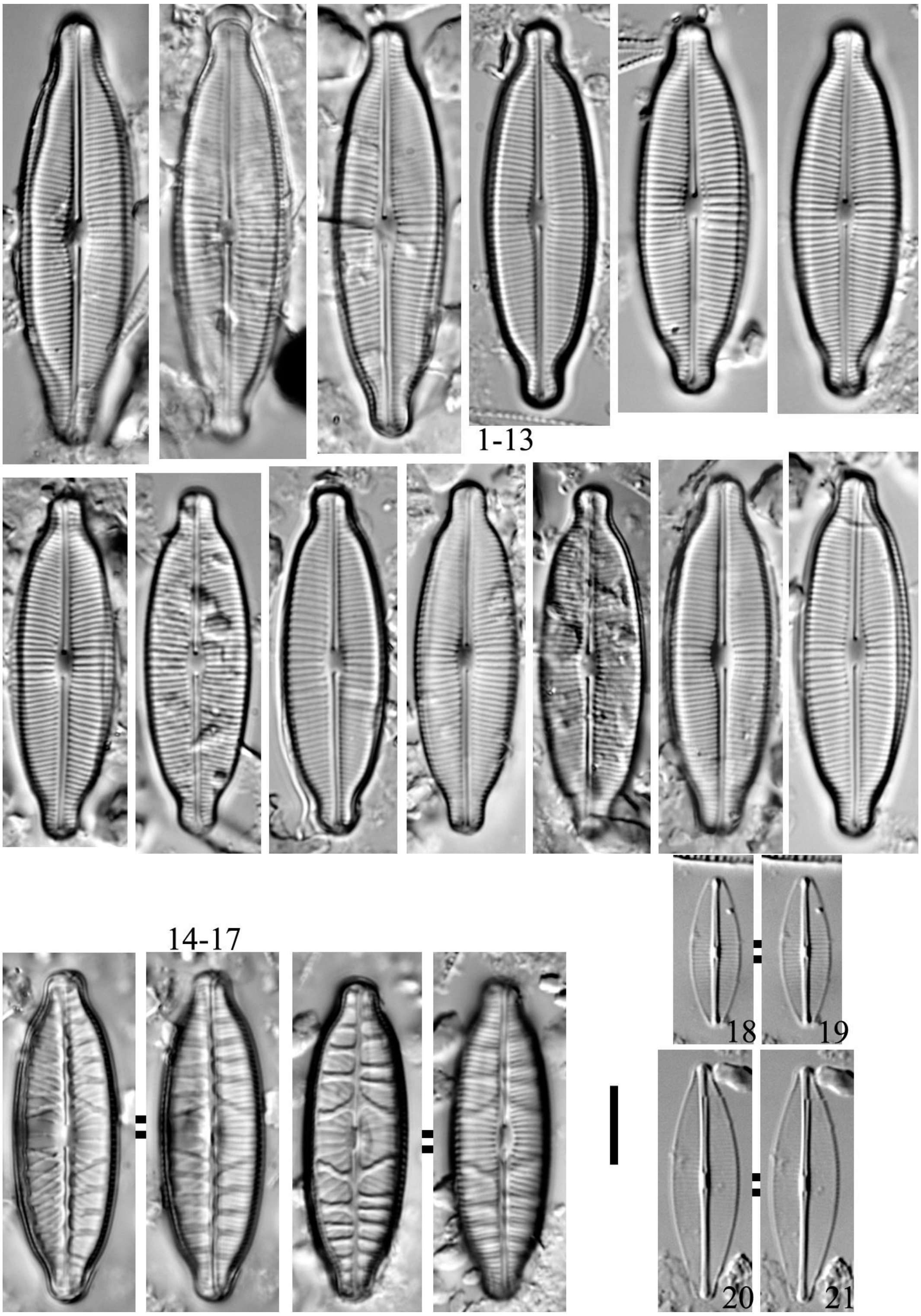

Figure 13: 1–17. LM micrographs of *Craticula germainii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito. Sveti Nikole, near the village of Adzimatovo, pond, mud (Slide MKNDC 008835). **18, 19**. LM micrographs of *Craticula minusculoides* (Hustedt) Lange-Bertalot. Gladno Pole, near Shtip, spring, mud (Slide MKNDC 008838). **20, 21**. LM micrographs of *Craticula* aff. *molestiformis* (Hustedt) D.G.Mann. The River Bregalnica, before the village of Mačevo, epiphytes on reed (Slide MKNDC 006795). Scale bar = 10 μm.

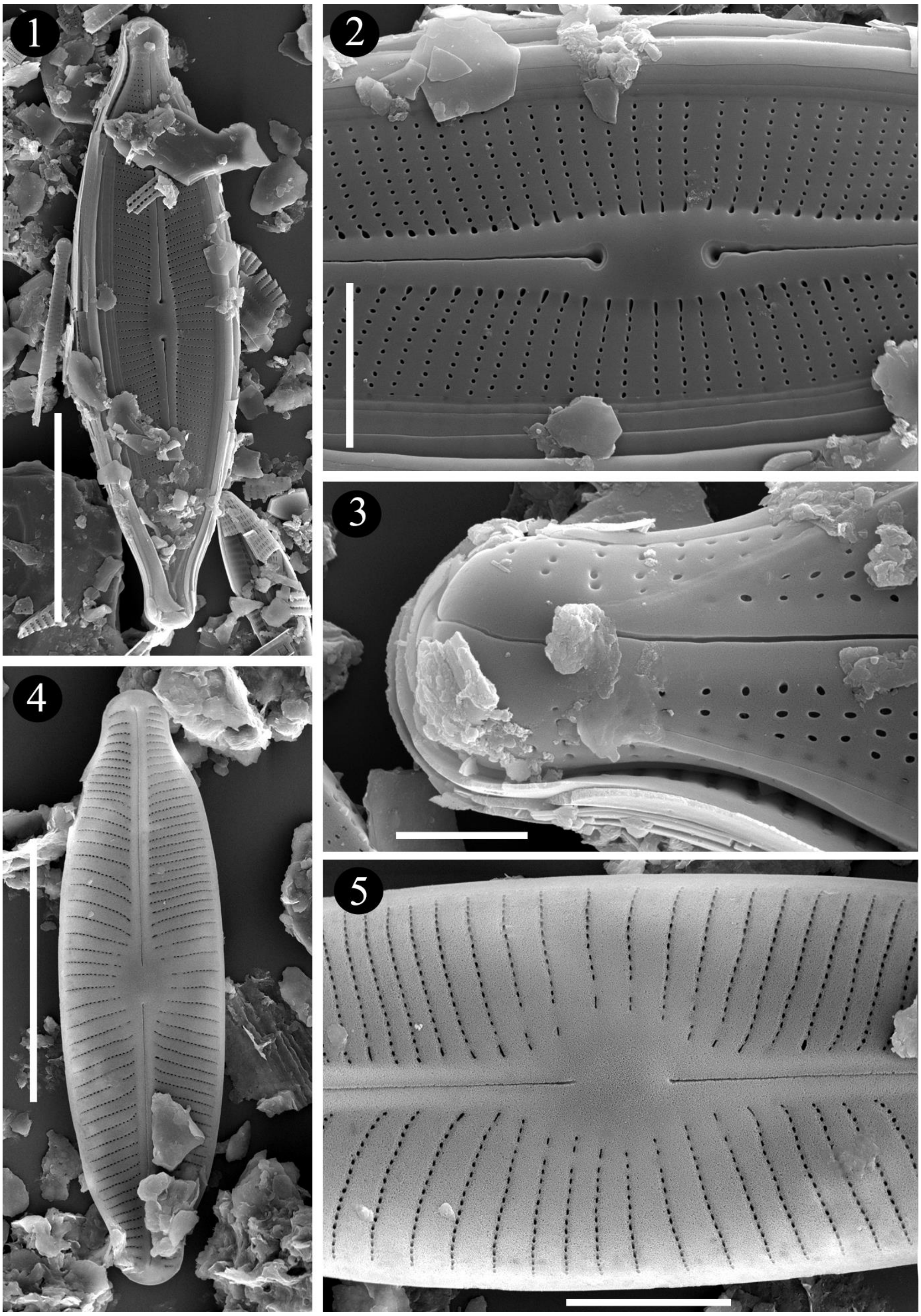

Figure 14: 1–3. Scanning electron micrographs of *Craticula fumantii.* **1**. External view of the whole valve. **2**. Detailed view of the mid-valve. The central area is strongly thickened. Proximally raphe branches terminate with large central pores. **3**. Detailed view of the valve apex. The raphe fissure is long, curved and continuing on the valve mantle. **4, 5**. Scanning electron micrographs of *Craticula germainii.* **4**. Internal view of the whole valve. **5**. Detailed view of the mid-valve. Central area is distinct and bordered with more distantly spaced striae. Scale bar = 20 μm (**1, 4**), 5 μm (**2, 5**), 2 μm (**3**).

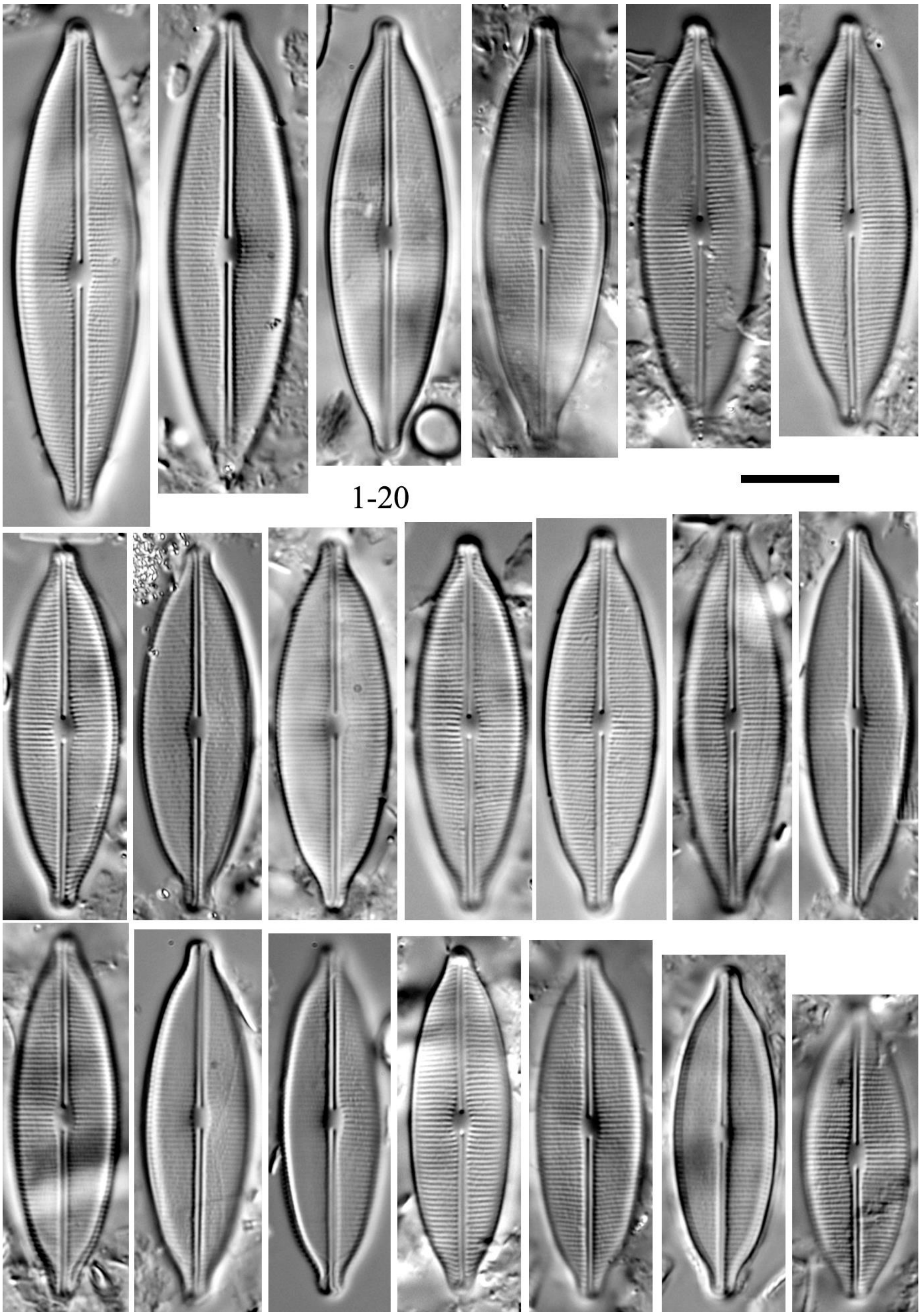

Figure 15: 1–20. LM micrographs of *Craticula accomodiformis* Lange-Bertalot.
Thermo-mineral spring Negorska Banja, rock scrape (Slide MKNDC PS001035). Scale bar = 10 µm.

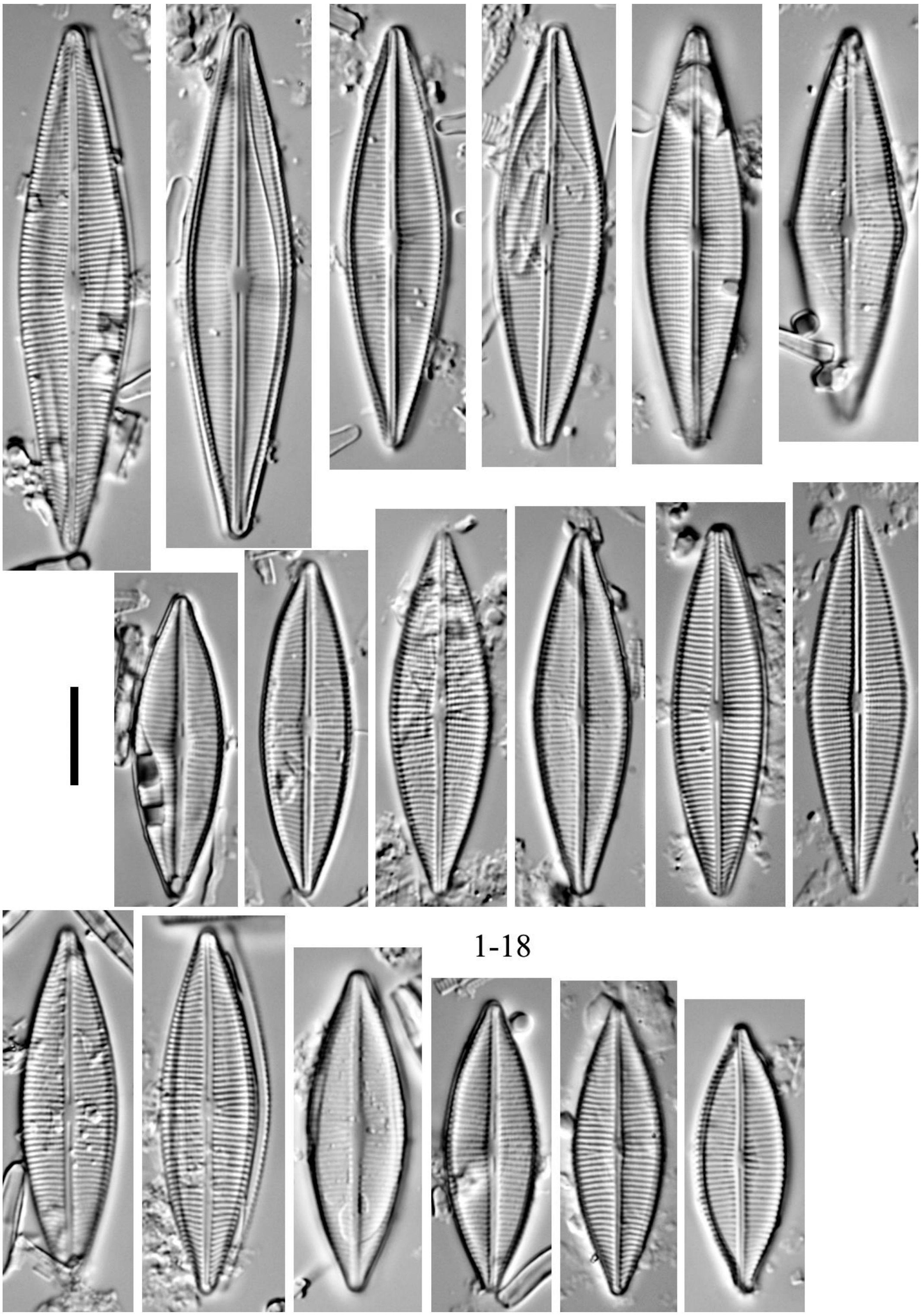

Figure 16: 1–18. LM micrographs of *Craticula halophila* (Grunow) D.G.Mann. Slan Dol, temporary pond, mud (Slide MKNDC 008873). Scale bar = 10 µm.

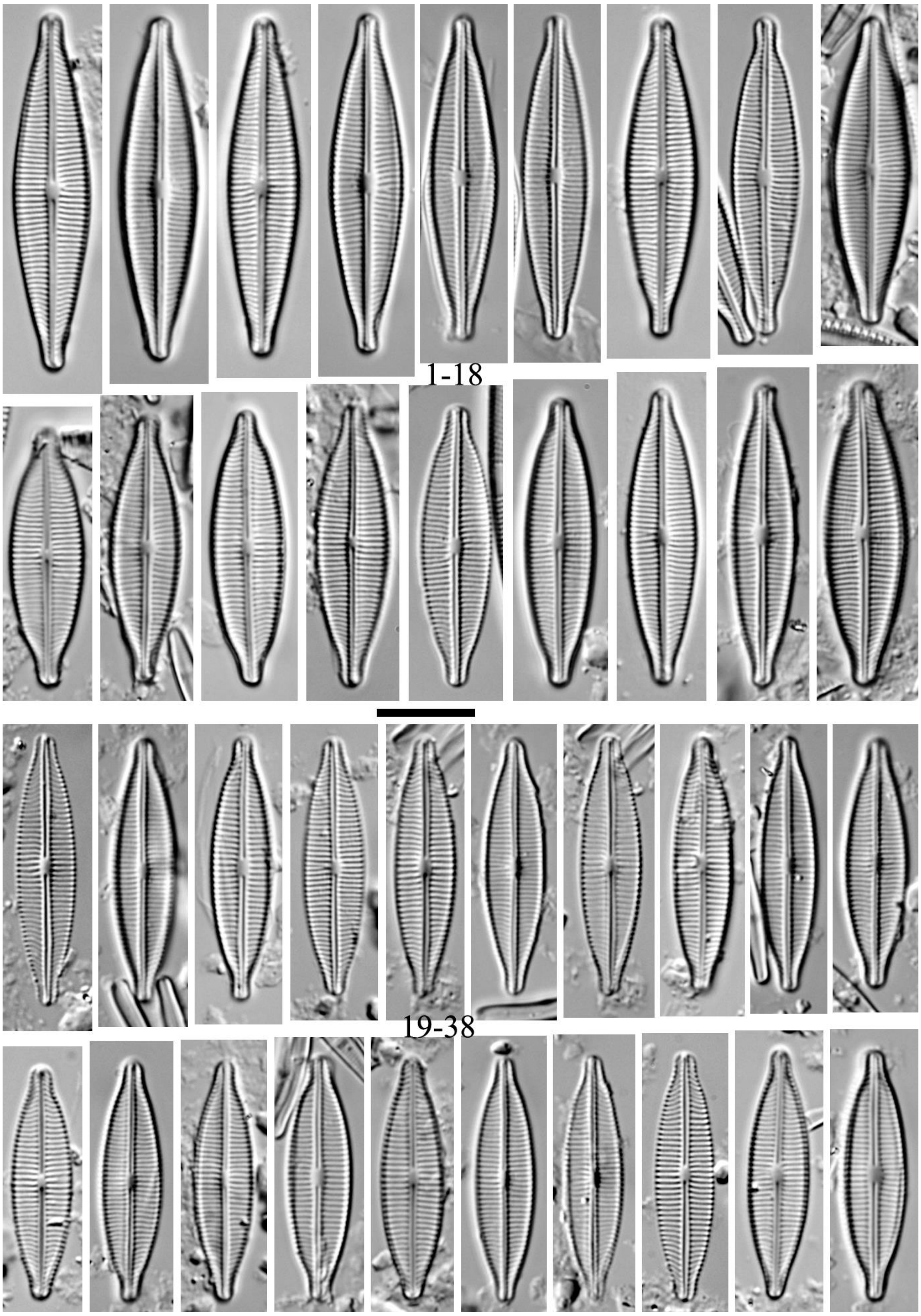

Figure 17: 1–18. LM micrographs of *Craticula simplex* (Krasske) Levkov comb. nov. MT 1. Mineral spring near the village of Gabrovo, Delchevo, *Chara* sp. (Slide MKNDC 008858). **19–38.** LM micrographs of *Craticula simplex* Krasske) Levkov comb. nov. MT 2. Slan Dol, pond, macrophytes (Slide MKNDC 008872). Scale bar = 10 µm.

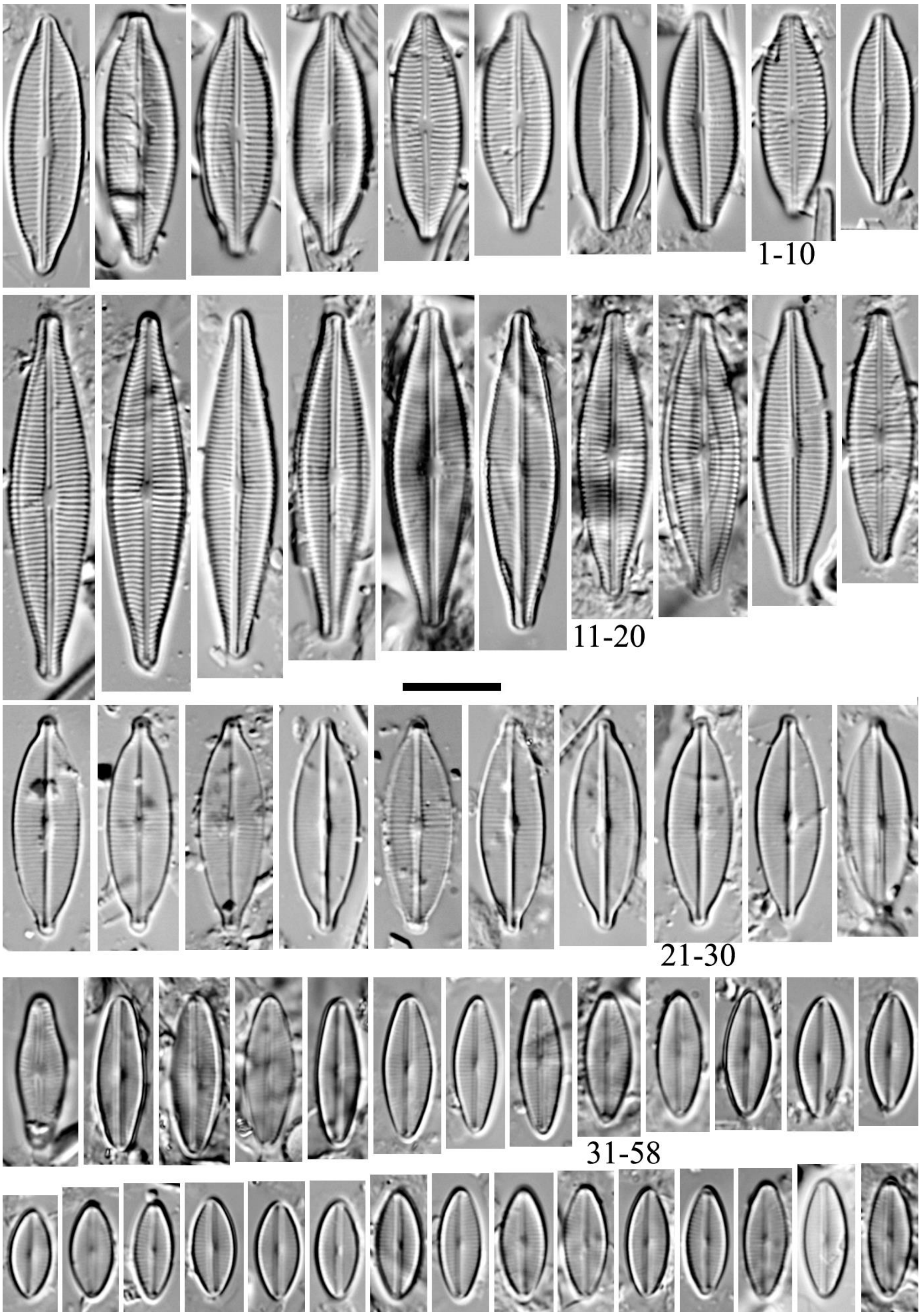

Figure 18: 1–10. LM micrographs of *Craticula simplex* (Krasske) Levkov comb. nov. MT 3. Slan Dol, pond, mud (Slide MKNDC 008873). **11–20**. LM micrographs of *Craticula simplex* (Krasske) Levkov comb. nov. MT 1. Slan Dol, pond, macrophytes (Slide MKNDC 008872). **21–30**. LM micrographs of *Craticula accomoda* (Hustedt) D.G.Mann. Mining Lake Usje, macrophytes (Slide MKNDC 005603). **31–58**. LM micrographs of *Craticula molestiformis* (Hustedt) Lange-Bertalot. Reservoir Ratevsko, sediment (Slide MKNDC 006967). Scale bar = 10 µm.

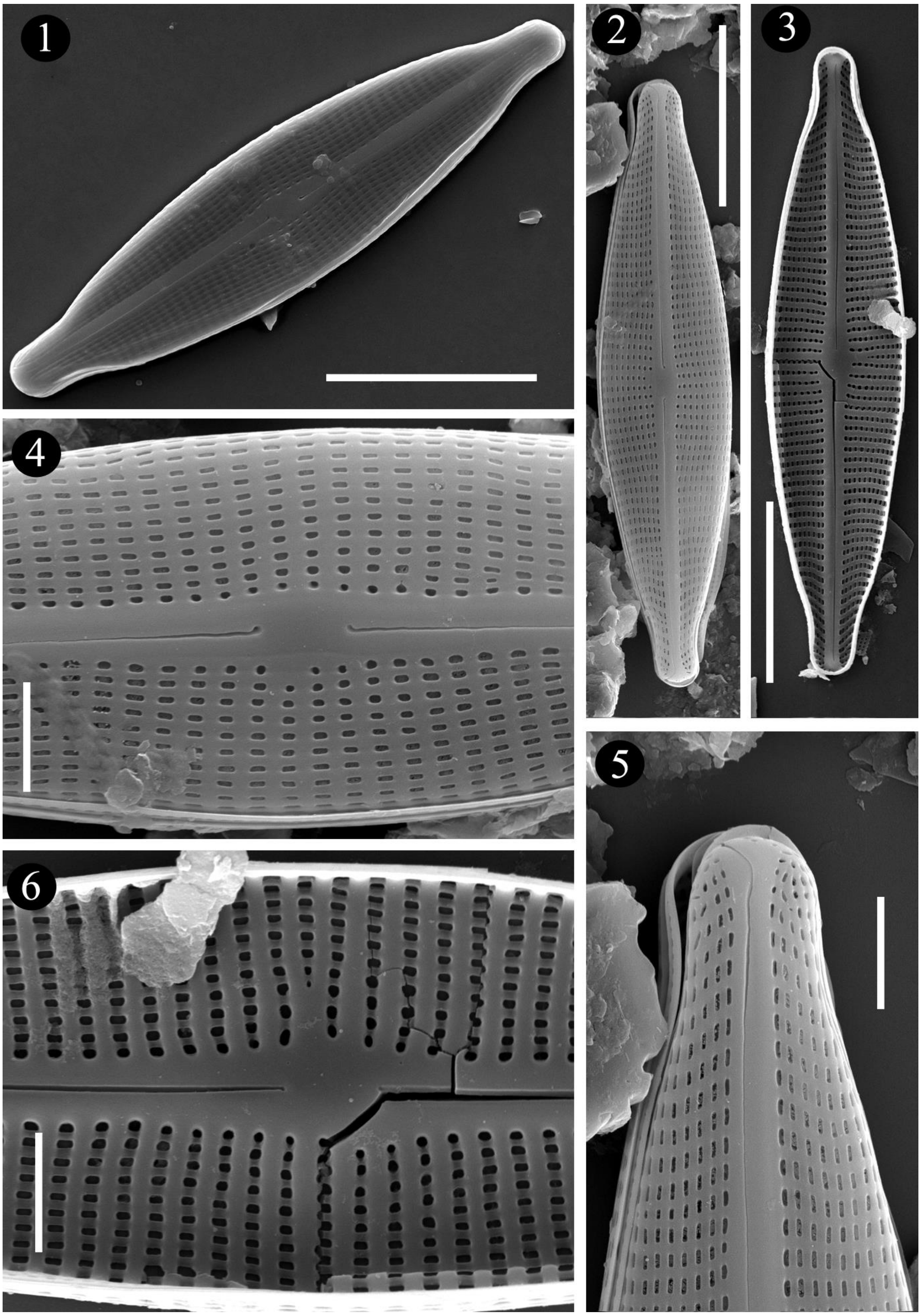

Figure 19: 1–**6.** Scanning electron micrographs of *Craticula simplex.* **1, 2**. External view of the whole valve. **3**. Internal view of the whole valve. Raphe located on strongly thickened sternum. **4**. Detailed view of the mid-valve. Areolae in the mid-valve have round foramina near the central area, while distally are longitudinally elongated foramina. Proximal raphe endings slightly unilaterally deflected. **5**. Detailed view of the valve apex. Distal raphe fissures long, hooked and continuing on the valve mantle. **6**. Internal view of the mid-valve. Proximal raphe endings not expanded.
Scale bar = 10 μm (**1**–**3**), 2 μm (**4**–**6**).

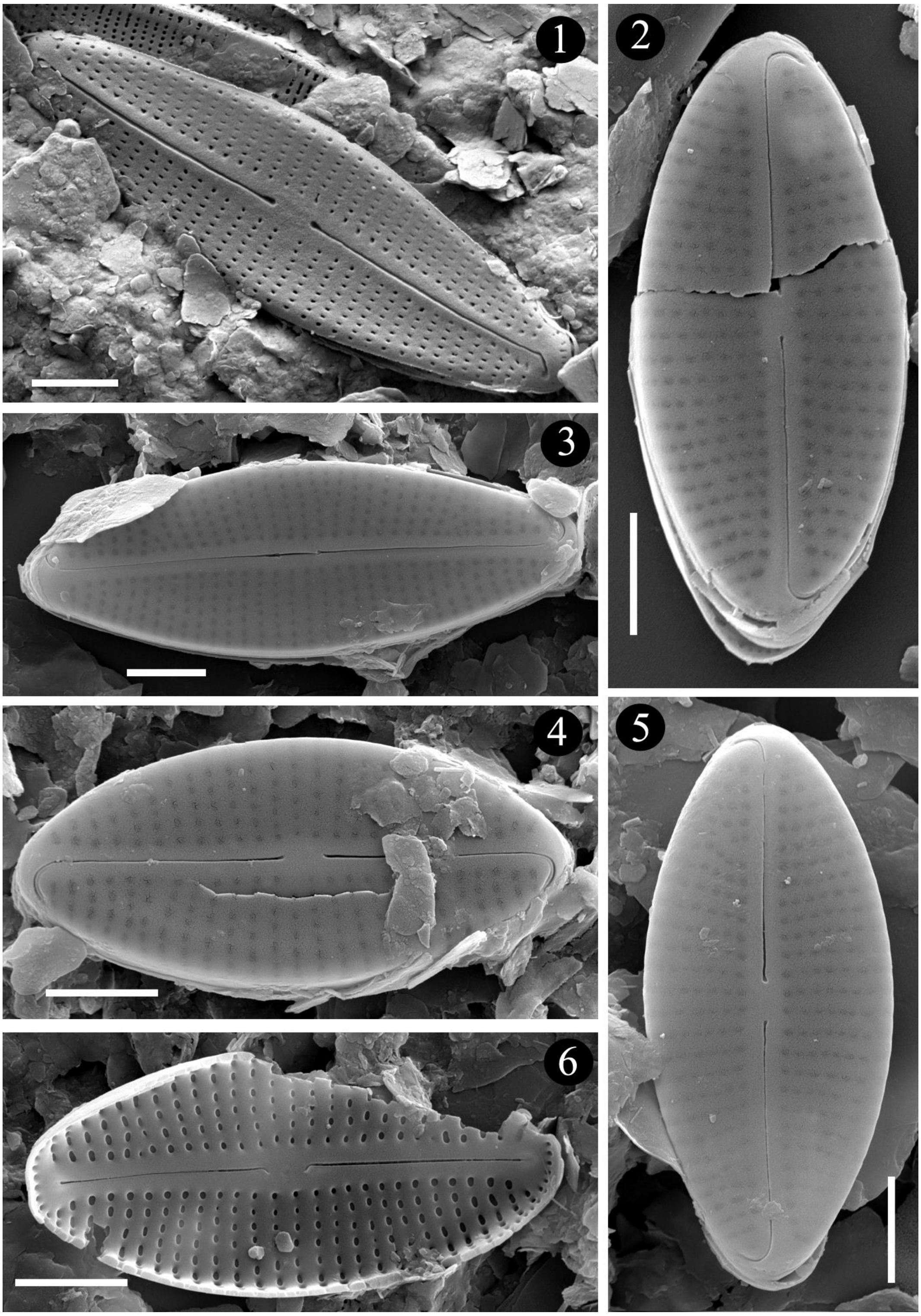

Figure 20: 1. Scanning electron micrograph of *Craticula minusculoides*. Distally raphe fissures deflected and not continuing on the valve mantle, proximally terminate with small central pores. Areolae around central area and near the raphe with round openings, the rest with small longitudinally orientated openings. **2–6**. Scanning electron micrographs of *Craticula molestiformis*. **2–5**. External view of the whole valve. Distally raphe fissures long, hooked and continuing on the valve mantle. Externally, areolae occluded with a fine hymen. **6**. Internal valve view. Raphe branches located on the valve surface, without elevated sternum. Areolae occluded with hymen located towards the outer valve surface. Proximal raphe endings unilaterally deflected. Scale bar = 2 µm (**1–6**).

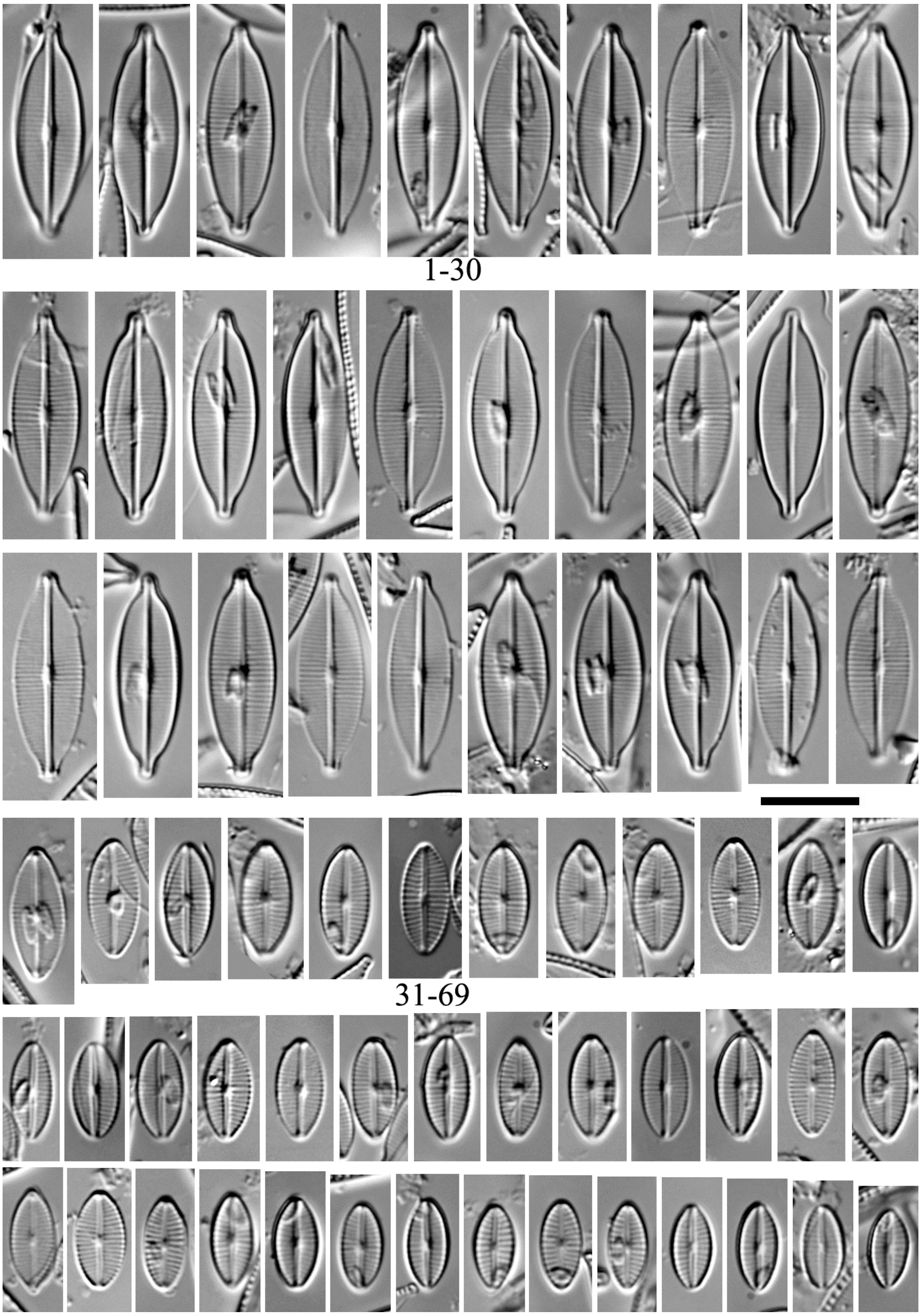

Figure 21: 1–30. LM micrographs of *Craticula accomoda* (Hustedt) D.G.Mann. The River Vodenišnica, near Monospitovo, rock scrape (Slide MKNDC 008234). **31–69.** LM micrographs of *Craticula subminuscula* (Manguin) C. E. Wetzel & Ector. The River Vodenišnica, near Monospitovo, rock scrape (Slide MKNDC 008234). Scale bar = 10 μm.

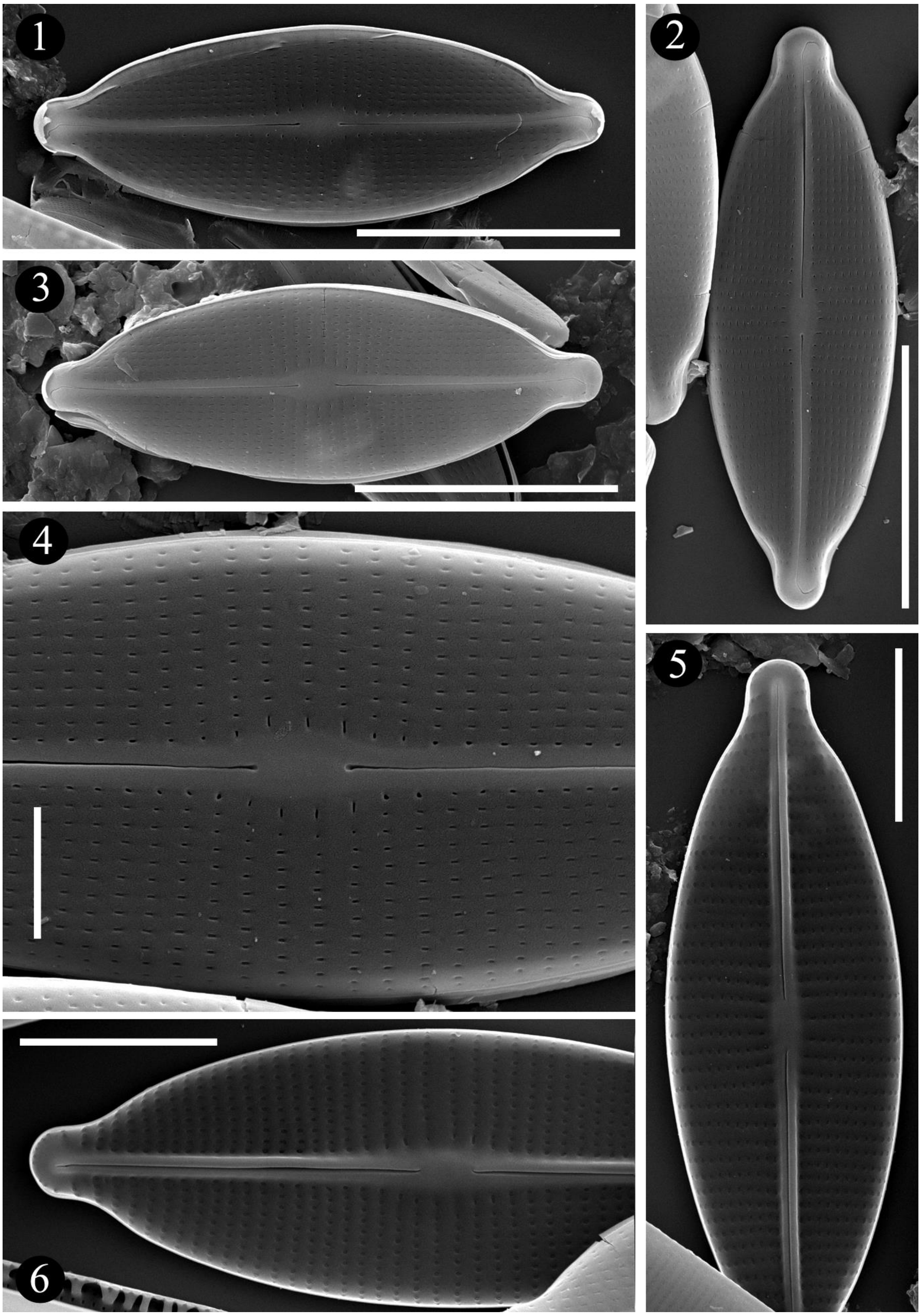

Figure 22: 1–**6**. Scanning electron micrographs of *Craticula accomoda*. **1**–**3**. External view of the whole valve. **4**. Detailed view of the mid-valve. Areolae around central area with transversally elongated slit-like opening, the rest with longitudinally orientated openings. **5, 6**. Internal view. Areolae are occluded by hymen. Raphe located on elevated sternum. Scale bar = 10 µm (**1**–**3**), 2 µm (**4**), 5 µm (**5, 6**).

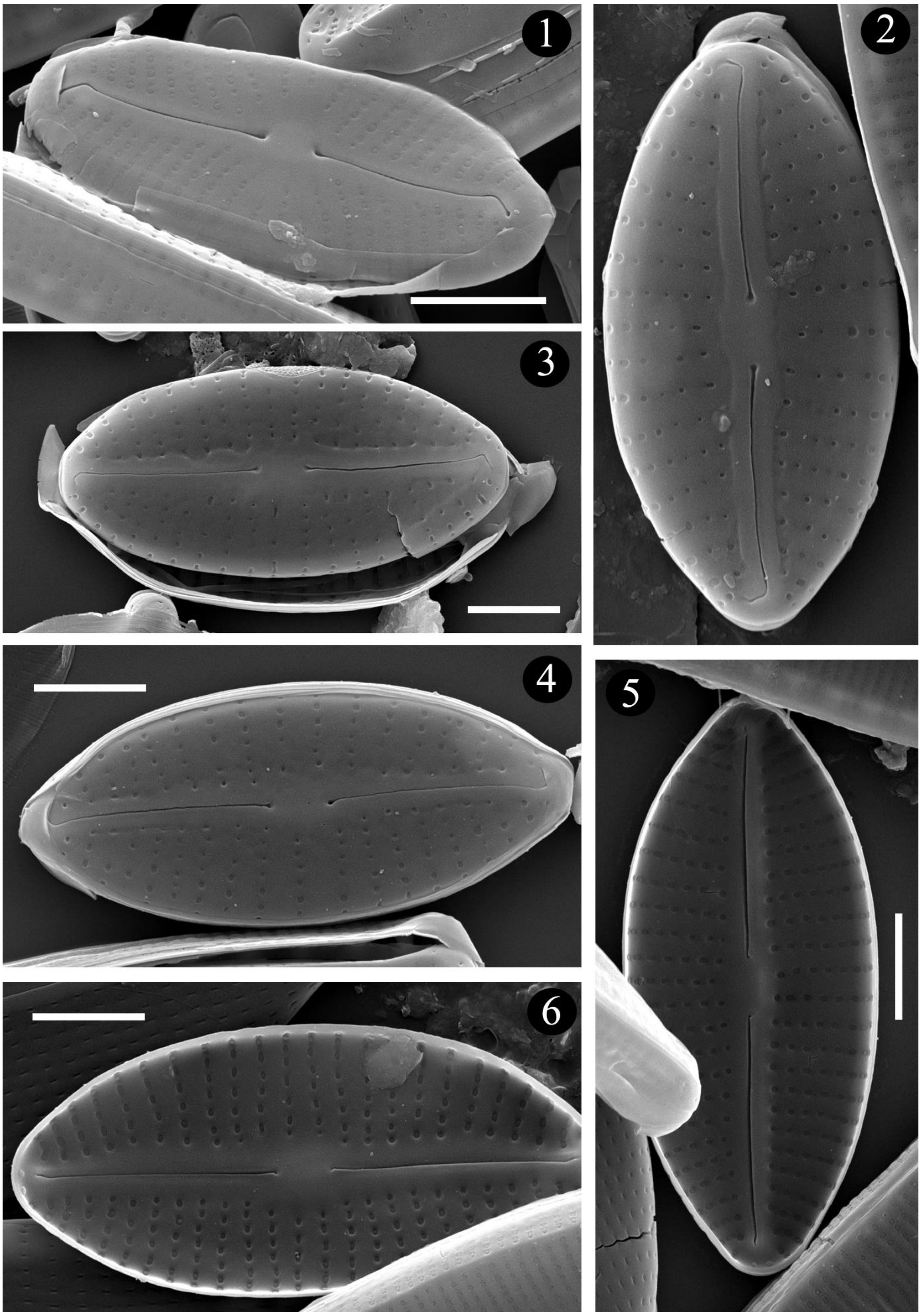

Figure 23: 1–**6**. Scanning electron micrographs of *Craticula subminuscula*. **1**–**4**. External view of the whole valve. Distally raphe fissures strongly deflected, not continuing on the valve mantle. Proximally raphe fissures terminate with small central pores, slightly deflected on the same side. Areolae with small, round foramina. **5, 6**. Internal view. Areolae are occluded by hymen. Raphe branches located on the valve surface, without elevated sternum. Scale bar = 2 µm (**1–6**).

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ВИДОВИ ОД РОДОТ *CRATICULA* GRUNOW (BACILLARIOPHYCEAE) ВО МАКЕДОНИЈА

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Видовите од родот *Craticula* се широко распространети во Европа и главно се сретнуваат во бракични, солени до силно загадени води. Некои од видовите се сметаат и за едни од најтолерантните кон загадување. Во поново време се спроведени детални истражувања на видовите од родот *Craticula*. Во рамките на оваа студија се регистрирани вкупно 15 вида. Кај еден од видовите (*Craticula simplex*) е утврдено постоење на три различни морфотипови, кои можат да се разликуваат според големината и формата на валвата. *Craticula cuspidata* и *C. ambigua* се видови кои беа најчесто забележани и тоа на различни станишта, додека видовите *C. halophila*, *C. germainii* и *C. fumantii* беа регистрирани само на едно станиште. Највисока видова разновидност на *Craticula* беше забележана во непостојани бари на халоморфни почви и минерални извори во Источна Македонија.

Клучни зборови: *Craticula*; дијатомеи; диверзитет; Македонија

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NEW DATA ON MACROMYCETE SPECIES (BASIDIOMYCOTA) IN MACEDONIA

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A study of mycodiversity in Macedonia is underway. The interest in macrofungi studies in Macedonia has been growing in the past 20 years. According to the research conducted up to now, approximately 2,500 macromycetes species have been recorded in the country. A half of this number is a result of the field and taxonomic work in the Mycological Laboratory in the last decade. This work represents a contribution to the Macedonian mycobiota with some rare fungi species.

Key words: new data; Basidiomycota; Macedonia

INTRODUCTION

The Republic of Macedonia is mycologically well investigated. Recently, mycological studies with special emphasis on systematical researches in various groups, such as: *Amanita*, *Peniophora*, *Phellinus,* bolets, morels, Pyrenomycetes, hypogeous fungi, has been conducted by the following authors (Karadelev *et al.* [1–5], Lambevska *et al.* [6], Karadelev & Rusevska [7], Kajevska *et al.* [8], Chavdarova *et al.* [9]). In addition, phylogenetic analyses and assessment of antioxidant activities for certain fungi species have been provided (Martín *et al.* [10], Rusevska *et al.* [11, 12], Nikolovska-Nedelkoska *et al*. [13]). The large data amount enabled us to update the preliminary Red List of fungi (Karadelev & Rusevska [14]). On the basis of the research done so far, 2,500 macromycetes species have been recorded in the Republic of Macedonia. The majority of the species (1,300) belong to the class Basidiomycetes, and 200 species to the class Ascomycetes.

EXPERIMENTAL SECTION

The data sources used are as follows: exsiccatae and notes from our own studies, the Macedonian Collection of Fungi (MCF), the database (MAK FUNGI), as well as specimens from other collectors.

The determination of the species was performed during the field research and in the Mycological Laboratory of the Institute of Biology at the Faculty of Natural Science in Skopje, microscopically, by using reagents (Melzers reagent, KOH, Cotton blue, Congo Red, sulphovanillin etc.). Certain species were identified while still in a fresh condition, and the others were to undergo further laboratory analyses. Part of the samples was preserved and deposited in MCF, while all indispensable data about the species were stored in the MACFUNGI database. The identification of the species was carried out using Jülich [15], Allesio [16], Breitenbach & Kranzlin [17, 18], Hansen & Knudsen [19], Fernández [20], Krieglsteiner [21, 22], Horak [23], Galli [24] and Knudsen & Vesterholt [25]. The species names follow Index Fungorum (Kirk, 2016) and MycoBank (Stalpers & Cock, 2016). The species are reported in alphabetical order. All important data pertaining to geographical distribution, altitude, forest association, and data source are provided under each species. The species distribution map was generated in ArcGIS 10.1 based on Digital Elevation Model (ASTERGDEM) (http://asterweb.jpl.nasa.gov/gdem.asp, 09. 2012).

RESULTS AND DISCUSSION

A list of 15 taxa with important data (localities, associations and/or substrates) and distribution maps is presented.

1. *Amanita crocea* var. *subnudipes* Romagn.

Skopska Crna Gora: Brodec vill. (vicinity), *Quercus* forest, soil, 1400 m a.s.l., 16.06.2016.

Papradishte vill. (vicinity), footpath to Solunska Glava, oak forest, soil, 900 m a.s.l., 19.06.2016.

2. *Amanita verna* var. *decipiens* Trimbach

Skopska Crna Gora: Brodec vill. (vicinity), *Fagus* forest, soil, 1400 m a.s.l., 16.06.2016.

3. *Arrhenia griseopallida* (Desm.) Watling (syn. *Omphalina griseopallida* (Desm.) Quél.)

Ljubanci vill., along r. Ljubanska Reka, *Quercus* forest with *Populus* and *Salix*, 900 m a.s.l., 11.03.2016.

4. *Lachnella alboviolascens* (Alb. & Schwein.) Fr.

Markova Reka, yard, *Clematis vitalba* (fallen branch), 21.02.2016.

5. *Leucocoprinus birnbaumii* (Corda) Singer (Figure 3)

Skopje: Botanical Garden, pot, soil, 250 m a.s.l., 28.06.2010.

6. *Leucopaxillus lepistoides* (Maire) Singer

Kumanovo (vicinity): Studena Bara vill., hill pasture, soil, 17.10.2008;

Skopska Crna Gora Mt.: Ljubanci vill., meadow, soil, 800 m a.s.l., 26.04.2010; Pobozhje vill. (vicinity), soil, 27.05.2010 meadow;

Pijanec: Delchevo, soil, 15.08.2014

7. *Marasmius buxi* Quél.

Taorska Klisura and Badar: between the monasteries of St. Bogorodica and St. Ilija, azonal vegetation (*Buxus*, *Phillyrea*, *Qurcus*, *Carpinus*), *Buxus* (fallen leaves), 03.05.2012.

8. *Neolentinus schaefferi* (Weinm.) Redhead & Ginns (*Lentinus cyathiformis* (Schaeff.) Bres.)

Skopsko Pole: Saraj, park, *Populus*, 06.04.2016, 09.05.2016.

9. *Phaeogalera dissimulans* (Berk. & Broome) Holec (syn. *Pholiota oedipus* (Cooke) P. D. Orton)

Vodno, deciduous forest (? *Tilia* sp.), leaves litter, 24.02.2016.

10. *Pholiota highlandensis* (Peck) Quadr. & Lunghini (*Ph. carbonaria* (Fr.) Singer non A. H. Sm.)

Jasen reserve: Selishte, Plocha, Pinetum (burned) with *Acer*, 1180 m a.s.l., 14.10.2010;

Taorska Klisura and Badar: Kozhle vill. (below), azonal vegetation, sandy soil, 05.04.2016.

11. *Pholiota populnea* (Pers.) Kuyper & Tjall.-Beuk.

Skopska Crna Gora Mt.: Banjani vill., at roadsides, *Populus* (trunk), 800 m a.s.l., 25.09.2005; Ljubanci vill., above the monastery of St. Nikola, deciduous forest with chestnut plantings, *Castanea sativa*? (fallen trunk), 800–900 m a.s.l., 07.10.2007, *Populus*, (fallen trunk), 18.10.2009.

Kumanovo (vicinity): by the r. Pchinja, *Pinus* plantings, unknown substrate, 29.10.2007;

Vodno: between Sredno Vodno and the peak, mixed forest, deciduous tree.

12. *Resupinatus trichotis* (Pers.) Singer

Kozhuf Mt.: Umida, deciduous tree, rotten wood, 800 m a.s.l., 29.04.2002;

Osogovski Planini Mt.: Sasa vill. (vicinity), Quercettum frainetto-cerris, *Quercus frainetto* (fallen branch), 685 m a.s.l., 09.04.2008;

Dobra Voda Mt.: Quercettum frainetto-cerris, *Salix* sp. (fallen branches), 850-900 m a.s.l., 21.01.2009;

Skopje: Flower market, park, unknown tree (fallen branch), 250 m a.s.l., 09.11.2009.

13. *Rubroboletus rubrosanguineus* (Cheype) Kuan Zhao et Zhu L. Yang (Fig. 4)

German, *Fagus* forest, soil, 1400 m a.s.l., 02.07.2016.

14. *Xerocomus ichnusanus* Alessio

Kumanovo (vicinity): Vojnik vill., *Salix* and *Populus* forest, soil, 311 m a.s.l., 17.04.2011;

Galičica Mt.: Leskoec vill. (above), Quercetum frainetto-cerris, soil, 1150 m a.s.l., 13.10.2011.

15. *Xerocomus persicolor* H. Engel (Fig. 5)

Skopska Crna Gora: Brodec vill. (vicinity), *Quercus* and *Fagus* forest, soil, 1400 m a.s.l., 16.06.2016.

A total of 15 species, belonging to Basidiomycota, are part of this work, representing new data for Macedonian mycobiota. One third of the species (5) are lignicolous, all found as saprobes (*Lachnella alboviolascens*, *Marasmius buxi*, *Neolentinus schaefferi*, *Pholiota populnea* and *Resupinatus trichotis*), while the other 10 are terricolous.

The following eight species: *Amanita verna* var. *decipiens, Arrhenia griseopallida, Lachnella alboviolascens, Leucocoprinus birnbaumii, Marasmius buxi, Neolentinus schaefferi, Phaeogalera dissimulans* and *Rubroboletus rubrosanguineus* are were found only on single localities, while the other on two or four localities (Figures 1 and 2).

Some of the species are more or less specific to the substrate. *Marasmius buxi* grows on fallen leaves of *Buxus sempervirens*. This fungus was collected from one locality, although its host is not so rare in the country. According to the host distribution we expected to find *M. buxi* on more localities. *Pholiota populnea* occurs on dead or living poplar wood and more rarely also on other hardwoods. It was found on four localities and according to the data available up to now it is a rare species.

Three very rare boletoid species should be pointed out. *Xerocomus ichnusanus* is a rare thermophilic species distributed in the southern part of Europe, connected mainly to oak forests, but also with other deciduous trees. Our collections originate from oak forest and azonal vegetation with willows and poplars.

Rubroboletus rubrosanguineus is a very rare species, found in the beech forest, on German Mountain. *Xerocomus persicolor* forms mycorrhiza with oak and beech. It was found only on one locality, in mixed oak and beech forest.

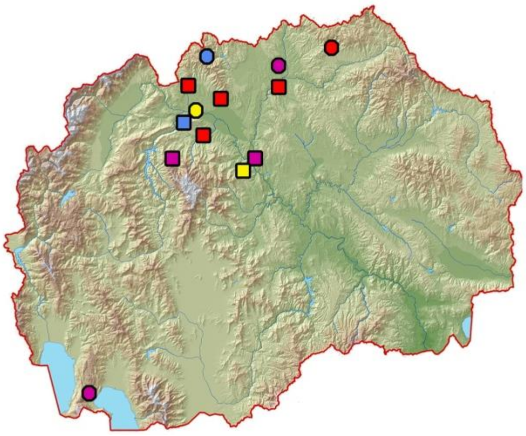

Figure 1. Distribution map of the species: *Leucocoprinus birnbaumii* (○), *Marasmius buxi* (□), *Neolentinus schaefferi* (□),*Pholiota highlandensis* (□), *Ph. populnea* (□), *Rubroboletus rubrosanguineus* (○), *Xerocomus ichnusanus* (○), *X. persicolor* (○).

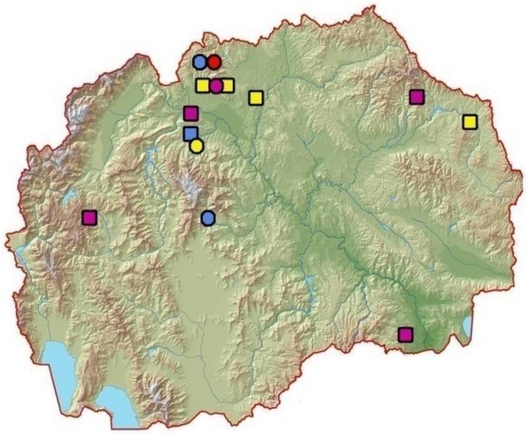

Figure 2. Distribution map of the species: *A. crocea* var. *subnudipes* (○), *A. verna* var. *decipiens* (○), *Arrhenia griseopallida* (○), *Lachnella alboviolascens* (○), *Leucopaxillus lepistoides* (□), *Phaeogalera dissimulans* (□), and *Resupinatus trichotis* (□).

Figure 3. *Leucocoprinus birnbaumii*, basidiocarps (photo: Mitko Karadelev)

Figure 4. *Rubroboletus rubrosanguineus*, basidiocarp (photo: Tome Jovanovski)

Figure 5. *Xerocomus persicolor*, basidiocarp (photo: Tome Jovanovski)

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НОВИ ПОДАТОЦИ ЗА МАКРОМИЦЕТИТЕ (BASIDIOMYCOTA) ВО МАКЕДОНИЈА

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Истражувањата на микодиверзитетот во Македонија се во тек. Во последните дваесетина години се посветува особено внимание на диверзитетот на макромицетите во Македонија. Според податоците од досегашните истражувања за Македонија се познати околу 2500 видови макромицети. Приближно половина од нив се резултат на интензивните теренски и лабораториски истражувања во однос на нивната таксономија во последната декада. Овој труд претставува прилог кон микодиверзитетот на Македонија, во кој се претставени некои ретки видови габи.

Клучни зборови: нови податоци; Basidiomycota; Македонија

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Original scientific paper

THE CATALOGUE OF FRESHWATER DECAPODA (DECAPODA: POTAMONIDAE, ASTACIDAE, ATYIDAE) FROM THE REPUBLIC OF MACEDONIA IN THE COLLECTION OF MACEDONIAN MUSEUM OF NATURAL HISTORY

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The catalogue summarizes the data found in the collection of freshwater decapods of the Macedonian Museum of Natural History in Skopje, Republic of Macedonia. In the present work we have also critically reviewed the historical data on the occurrence and distribution of representatives of decapods present in the country. The populations of decapods have never been intensively studied in Macedonia, and thus, this catalogue may serve as a valuable source of data for nature conservation and protection of crustaceans and their habitats.

Key words: catalogue; Decapoda; Macedonian Museum of Natural History; Macedonia

INTRODUCTION

Freshwater decapods are a highly diverse group of crustaceans currently known from all biogeographical regions (except Antarctica and India for crayfishes). Among an estimated number of 3.000 described freshwater decapod crustaceans, about 640 species can be considered as crayfish species (Astacidea) [1, 2]. A total of 655 freshwater shrimps (Caridea) and 1.300 freshwater crabs (Brachyura) are presently known [3, 4]. The key processes driving decapod crustaceans diversification are likely to be habitat heterogeneity, high diversity of ecological niches in freshwater ecosystems and frequent genetic isolation between populations [1, 3, 4]. Relatively low fecundity and poor dispersal abilities, probably, contributed to the evolution of rich assemblage of freshwater decapods [2].

There are scarce published data about the decapod fauna (Crustacea: Decapoda) from the Republic of Macedonia. The oldest data are from the 1920's, when Balss [5] registered three species for the country. On the basis of morphological criteria Karaman S. [6] gave a description of two crayfish subspecies, *Astacus astacus balcanicus* S. Karaman, 1929 (under synonymic name *Potamobius fluviatilis balcanicus* S. Karaman, 1929) and *Austropotamobius torrentium macedonicus* S. Karaman, 1929 (under synonymic name *Potamobius torrentium macedonicus* S. Karaman, 1929) in his review of freshwater decapods (Astacidea: Astacidae) in former Yugoslavia. According to Karaman S., *A. t. macedonicus* represents a national (Macedonian) endemic crayfish restricted to the River Vardar drainage. Few decades later, the most widely accepted taxonomic studies by Karaman M. [7, 8] recognized three subspecies of crayfish *Astacus astacus* (Linnaeus, 1758), confirming the presence of subspecies *A. a. Balcanicus* in the Western Balkans, in the drainage system of the River Vardar in the Republic of Macedonia and Greece, as well as in Ohrid Lake. It must be emphasized that the taxonomic status and distribution of *A. a. balcanicus* and *A. t. macedonicus* has been discussed by many researchers (e.g. [9–11]) and still has not been fully resolved. Herein, we accept taxonomic studies by Karaman M. [7, 8, 12].

Concerning the freshwater crabs (Brachyura: Potamonidae), a more detailed research on taxonomy and distribution in Macedonia was conducted during the 1960's by Preitzmann [13] and Bott [14]. The first information about shrimps (Caridea: Atyidae) on the territory of the country was published by Karaman M. [15]. He described new subspecies named *Atyaephyra desmaresti stankoi* Karaman, 1972 (synonym of *Atyaephyra stankoi* Karaman, 1972) from material collected from Dojran Lake (Macedonia). Furthermore, Karaman M. [12] summarized and critically reviewed the existing data on taxonomy, biology, distribution and phylogeny of decapods (Potamonidae, Astacidae, Atyidae) inhabiting freshwaters in Macedonia. Recently, important nomenclatorial and taxonomic changes have been introduced in Decapoda systematics, mainly in the family Atyidae [16, 17], which contributed for updated checklist of freshwater decapods in the country [18].

Republic of Macedonia is one of the European countries where non-indigenous crayfishes, crabs and shrimps have not been introduced. According to Karaman M. [12] and Christoudoulou *et al.* [16] five indigenous decapod taxa (species and subspecies) occur in freshwater habitats in the country: noble crayfish *Astacus astacus balcanicus* S. Karaman, 1929; stone crayfish *Austropotamobius torrentium macedonicus* S. Karaman, 1929; freshwater crabs *Potamon fluviatile* (Herbst, 1785) and *P. ibericum* (Bieberstein, 1809); and freshwater shrimp *Atyaephyra stankoi* Karaman, 1972. However, insufficient information on the distribution of decapod representatives from the territory of Macedonia is available at present. Additionally, crayfishes, crabs and shrimp, like the freshwater habitats in which they are encountered, receive relatively little publicity and conservation attention in the country, in spite of their key role in the aquatic food webs and ecosystem functioning.

The aim of this study is to create a catalogue based on specimens stored in the collection of the Decapoda of the Macedonian Museum of Natural History (MMNH), in Skopje, Macedonia. In the present work we have also critically reviewed the historical data on the decapods of Macedonia. The catalogue contributed to update our knowledge on the geographical distribution, ecology and taxonomy of the freshwater decapods in Macedonia and will serve as a valuable source of information for nature conservation and the protection of decapods and their habitats.

MATERIAL AND METHODS

The current review of freshwater decapods is based on available literature data and studied material deposited in MMNH. The collection of Decapoda comprises 258 specimens gathered during a period of almost 70 years (from 1946 to 2015). Decapod crustaceans are chronologically registered and separately numbered with inventory numbers. The specimens are in a very good state of preservation in 70% ethanol. In addition, valuable material of crayfishes was donated by V. Slavevska-Stamenković in 2016 (collected during 2008-2016). All specimens were revised by the first author following the keys by Pârvulescu [19], Zaikov [20] for crayfishes and Karaman M. [12] for crabs. The redescription presented in Christodoulou *et al.* [16] was used for confirmation of the freshwater shrimp *Atyaephyra stankoi* in the collection of MMNH.

The catalogue comprises the following data: Valid taxa name, Published records, Material studied and Remarks.

The systematic presentation of taxa (species and subspecies) follows Karaman M. [12], De Jong *et al.* [21] and Christodoulou *et al.* [16]. Below the valid taxa name are listed chronologically, the original names under the taxon which was cited in literature. The genera and species are arranged alphabetically within each family.

Published records are cited in a shortened form including the respective reference, name of the watercourse and adjacent settlement or mountain. Additional information may be found in original papers.

New distributional records (Material studied) are presented in the following sequence: name of watercourse, name of adjacent settlement, date of collection, number of specimens and sex (only for crayfish specimens), name(s) of collector(s), inventory numbers of the specimens deposited in MMNH (in square brackets). The geographic information and date of collection are omitted when missing. Records are arranged according to inventory numbers.

Additional information concerning ecology, distribution, population status, threats and taxonomic changes could be found in paragraph remarks.

Abbreviation used in this cataloggue

Legator names: Biljana Rimčeska – BR, Despina Kitanova – DK, Djoko Djorgievski – Dj Dj, Emilija Stojkoska – ES, Irina Šoreva – IS, Jovan Kuševski – JK, Kiro Bogoevski – KB, Ognjanka Popovska – OP, Risto Grupče – RG, Svetozar Petkovski – SP, Snežana Stanković – SS, Trajan Petkovski – TP, Vasil Kostov – VK, Valentina Slavevska Stamenković – VSS and legator unknown- LU.

Other abbreviations: ♂ – male specimen(s), ♀ – female specimen(s), s. – specimen(s), v. – village, Mt. – mountain, leg. – legator(s).

THE CATALOGUE PRESENTATION

The catalogue presented herein includes data on five decapod taxa (Figure 1), including Brachyura (2), Astacidea (2) and Caridea (1). The nomenclature used in this section follows the decision of the International Commission on Zoological Nomenclature (ICZN 2000).

Figure 1. A–B: *Potamon fluviatile* (A) and its habitat from Ohrid Lake, v. Radožda (B); C–D: *Potamon ibericum* (C) and its habitat from the Stara River, v. Miravci (D); E–F: *Astacus astacus balcanicus* (E) and its habitat from the Pčinja River close to Macedonian-Serbian border (F); G–H: *Austropotamobius torrentium macedonicus* (G) and its habitat from Mt. Galicica (H); I–J: *Atyaephyra stankoi* (I) and its habitat from Dojran Lake, Macedonia (J); a-e. The studied species from MMNH with inventory numbers.

Order DECAPODA Latreille, 1802

Suborder PLEOCYEMATA Burkenroad, 1963

Infraorder BRACHYURA Linnaeus, 1758

Family Potamonidae Ortmann, 1896

Genus *Potamon* Savigny, 1816

***Potamon fluviatile* (Herbst, 1785)**

= *Cancer fluviatile* Herbst, 1785
= *Potamophilus edule* Latreille, 1818
= *Potamon* (*Eutelphusa*) *edule* Pretzmann, 1962
= *Potamon* (*Telphusa*) *fluviatilis* Pretzmann, 1983

Published records: Karaman M. [12]: Ohrid Lake's tributaries and springs (rare on the shore line), Crn Drim watershed.

Material studied: Ohrid Lake, v. Radožda, 7–8.10.2015, 11 s., leg. ES [5775].

Remarks: The freshwater crab *Potamon fluviatile* (Figure 1: A, a) was the first described species from the Eurasian genus *Potamon* [22]. Because the species was extremely used for human consumption, the former species' name was *P. edule* (Latin word "*edulis*" = edible) [23]. *P. fluviatile* has a highly fragmented geographic distribution over a wide area in a number of countries that have a Mediterranean coastline [24]. This species inhabits unpolluted rivers, streams and lakes throughout its range. Resent ecological survey by Barbaresi *et al.* [25] suggested that the populations of *P. fluviatile* have declined dramatically as a result of pollution, regulation and desiccation of streams, overexploitation for human consumption and introduction of exotic crayfish species.

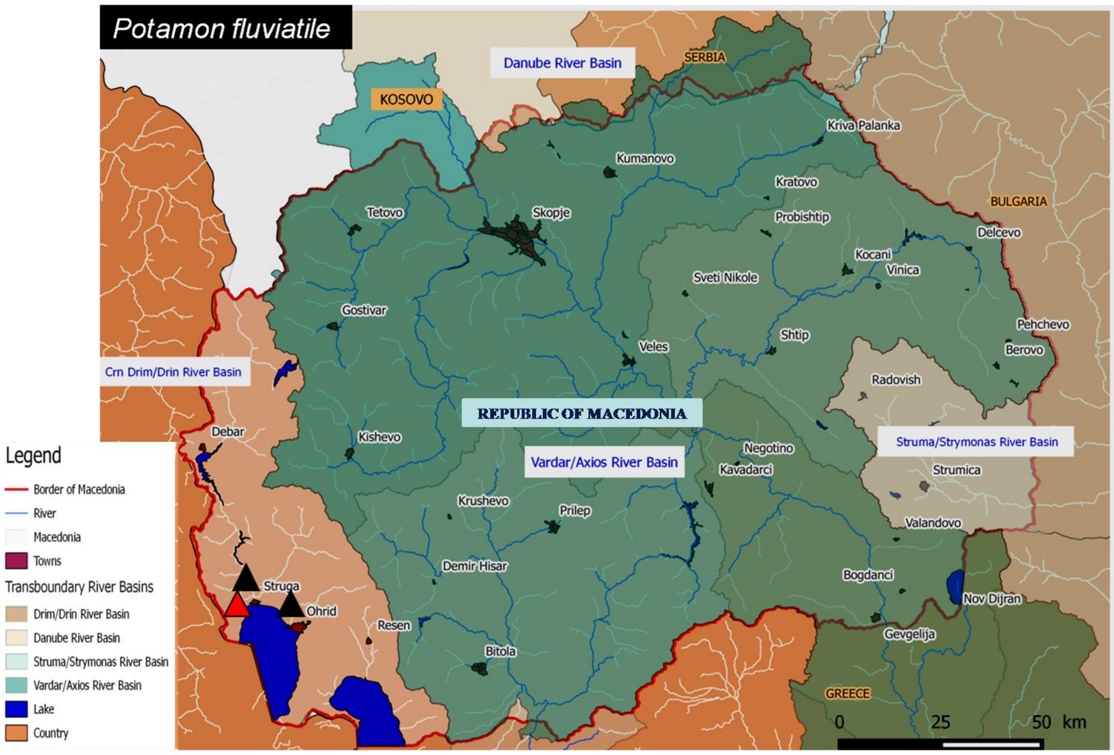

Figure 2. Distribution of *Potamon fluviatile* in Macedonia. Black triangles = published records, red triangles = material studied

Although in IUCN Red List of Threatened Species is listed as "Near Threatened" (Table 1), it is possible that the species is under higher risk of extinction on global scale [24, 25] and thus in Macedonia too. Bearing in mind that the species has a narrow geographical distribution in our country (Ohrid Lake watershed; Figures 1, 2), in our opinion, the protection should be strongly regulated on national level of legislation. Habitat protection and preservation of freshwater ecosystems are obviously the main goal for conservation of *P. fluviatile* in Macedonia.

***Potamon ibericum* (Bieberstein, 1809)**

= *Cancer ibericum* Bieberstein, 1809
= *Thelphusa intermedia taurica* Czerniavsky, 1884
= *Potamon* (*Pontipotamon*) *ibericumtauricum* Pretzmann, 1962

Published records: Karaman M. [12]: Dojran Lake spring near Toplec, lower part of the River Vardar and its tributaries, springs on Mt. Gradeška, Gevgelija valley.

Material studied: Dojran Lake, 7 s., leg. LU [2377]; 4 s., leg. LU [2391]; Gabrovo stream, 22.04.1986, 2 s., leg. SS [2392]; Dojran Lake, spring near Toplec, 28.06.1986, 2 s., leg. SS [2393]; Dojran Lake, spring near Toplec, 09.09.1988, 7 s., leg. SS [2397]; Dojran Lake, spring near Toplec, channel besides spawning place, 11.06.1997, 3 s., leg. SS [2773]; stream near v. Balakli, Mt. Gradeška, 08.05.2012, 1 s., leg. ES [5773]; Konjska Reka river, under v. Gorničet, Mt. Kožuf; 11.09.2000, 1 s., leg. ES [5774]; Stara River, v. Miravci, 11.11.2015, 2 s., leg ES [5793], Konjska Reka river, v. Konjsko, Gevgelija, 12.11.2015, 6 s., leg. ES [5794].

Remarks: Similar to *P. fluviatile*, freshwater crab *P. ibericum* (Figure 1: C, b) has a wide and highly fragmented distribution. Due to human impact there has been a distinct decline in population abundance in most parts of its range since the mid 1970's, and in some places the populations of crabs may have already disappeared [24]. Mainly, the populations are threatened by water pollution, non-purified sewages and habitat destruction, such as river-bed straightening, building of reservoir, withdrawal of water for local needs, stream channelization. Further, freshwater crabs are an important protein source and are consumed in many parts of its range [4], which significantly contributed to the decline of the populations of *P. ibericum*. Therefore, IUCN Red List of Threatened Species (Table 1) assessed the species as Near Threatened (NT), with an indication that in the future it may be close to qualifying as Vulnerable (VU) under A2 [24].

The results of this study show that in the last twenty years no specimen of *P. fluviatile* was registered in the springs near Toplec, Dojran Lake, Macedonia (Figure 3). It is possible that habitat alteration of the springs caused extinction of subpopulations of the species. In this connection we strongly recommended urgent protection of the species, at least under national regulations. Unfortunately, protection limited to local regulations often is not sufficient to preserve the species from decline.

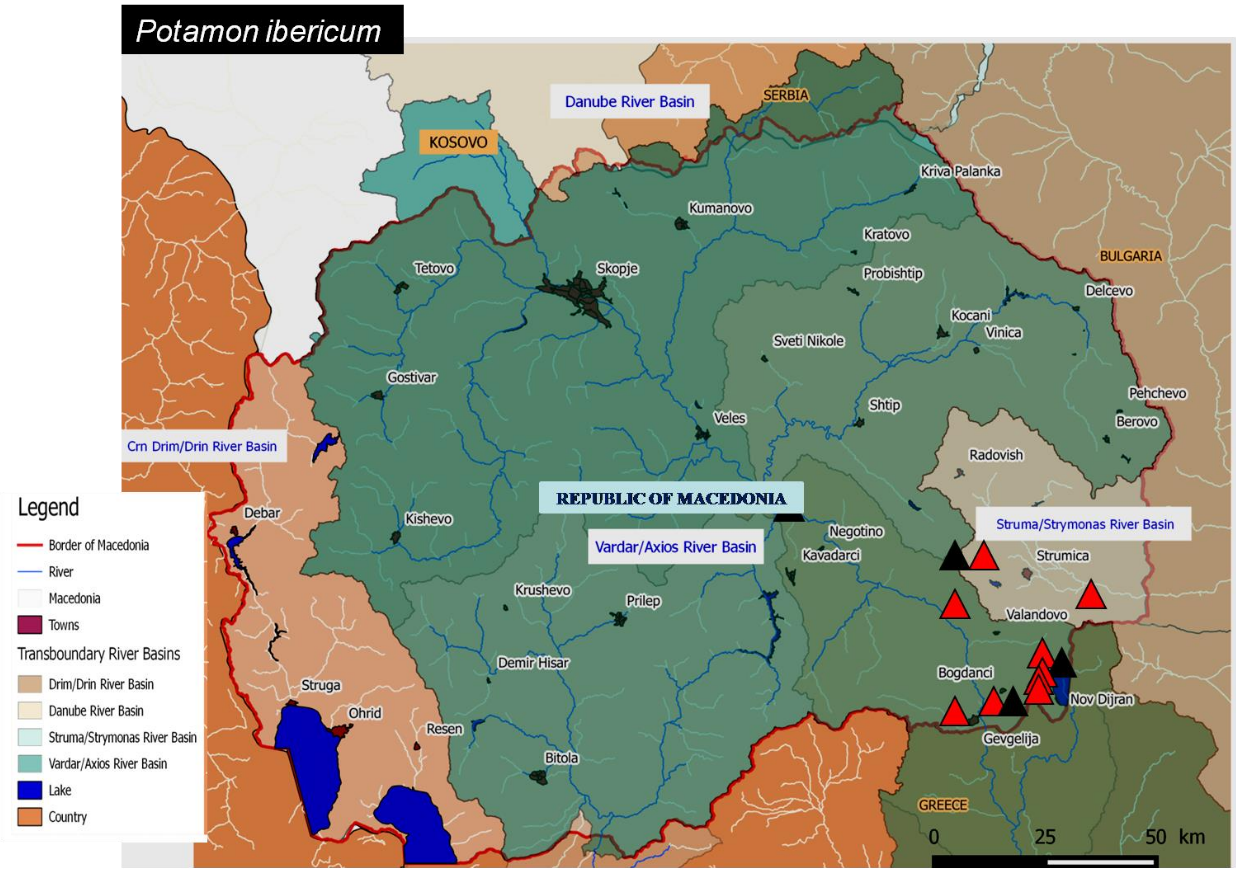

Figure 3. Distribution of *Potamon ibericum* in Macedonia. Black triangles = published records, red triangles = material studied

Infraorder ASTACIDEALatreille, 1802

Family Astacidae Latreille, 1802

Genus *Astacus* Fabricius, 1775

***Astacus astacus balcanicus* S. Karaman, 1929**

= *Potamobius fluviatilisbalcanicus* S. Karaman, 1929

= *Astacus colchicus balcanicus* M. Karaman, 1961

= *Astacus* (*Astacus*) *astacus balcanicus* M. Karaman, 1963

Published records: Karaman S. [6]: Ohrid Lake, Vardar River watershed; Holothuis [26]: Vardar River near Vazarci south of Skopje; Albrecht [9]: Ohrid Lake, Sateska River; Subchev & Gelder [27]: Dojran Lake, Skopje.

Material studied: Vardar River, Demir Kapija, Gevgelija, 27.08.1965, 5♂♂, 7♀♀, leg. KB, RG [2373]; Vardar River, Demir Kapija, Gevgelija, 27.08.1965, 3♂♂, 11♀♀, leg. KB, RG [2374]; Ohrid Lake, 20.07.1965, 4♂♂, leg. TP [2375]; Struga, 15.08.1976, 5♂♂, 1♀, leg. TP [2376]; Ohrid Lake, 20.07.1965, 12♂♂, leg. TP [2378]; Dojran Lake, 3♂♂, 1♀, leg. LU [2390]; Bregalnica River, v. Razlovci, 10.1985, 5 s., leg. JK [2399]; Mavrovica Reservoir, Sv. Nikole, 10.2013, 2♂♂, 2♀♀, leg. VSS, VK [5770]; Pčinja River, near border with Serbia,18.07.2009, 1♂, leg. VSS [5785].

Remarks: *Astacus astacus* (Figure 1: E, c) is indigenous and widespread crayfish throughout Europe [28]. This species occurs in rivers, lakes, ponds and reservoirs, where shelter availability like, stones, logs, roots and aquatic vegetation prevail [29]. Populations of noble crayfish are at risk of becoming endangered as a result of various stressors such as: i) habitat alteration and degradation, ii) pollution, iii) increased siltation, iv) overexploitation, v) the virulent disease commonly known as crayfish plague, caused by pathogen oomycete *Aphanomyces astaci* and vi) competition with invasive non-indigenous crayfish species [30, 31]. Therefore, IUCN Red List of Threatened Species classifies the noble crayfish as a vulnerable species (VU) with a decreasing population trend [32]. The noble crayfish is further included in the Bern Convention (Appendix III) and listed in the EU Habitat Directive 92/43/EEC (Appendix V).

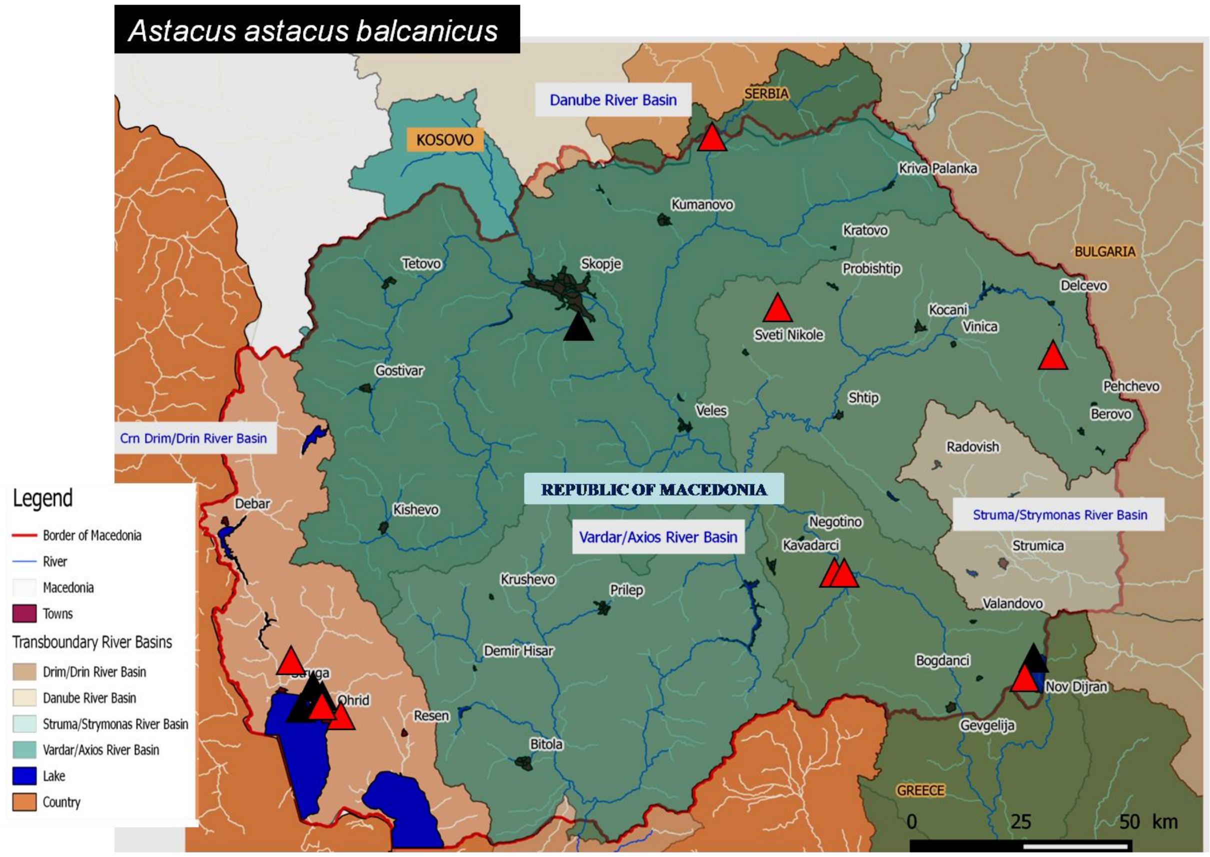

Figure 4. Distribution of *Astacus astacus balcanicus* in Macedonia. Black triangles = published records, red triangles = material studied

The results presented in this Catalogue indicate that the current status of the noble crayfish (in Macedonia accepted as *A. a. balcanicus*) is alarming. In comparison with the stone crayfish, *A. astacus* is rarer, with restricted and fragmented distribution, mainly in the Vardar and Drim drainage systems (Figure 4). Although the species' status is 'protected wild species' in Macedonia, it is only formally protected by local regulations [33].

Moreover, recent molecular-based studies covering a large portion of distribution range of *A. astacus* confirmed that the Balkans were relatively unaffected by geological events during the glacial cycles and that genetic diversity is more conserved in comparison to Central Europe [30, 34]. Taking into consideration that an analysed material from Macedonia is missing, increased data set should be used to resolve the large-scale genetic structure of noble crayfish.

Genus *Austropotamobius* Skorikov, 1908

***Austropotamobius torrentium macedonicus* S. Karaman, 1929**

= *Potamobius torrentium macedonicus* S. Karaman, 1929

= *Austropotamobius* (*Austropotamobius*) *torrentium macedonicus,* Bott, 1950

Published records: Karaman S. [6]: Treska Gorge near Skopje, mountain springs in the Vardar River watershed; Karaman M. [12]: mountain springs without specification of the settlement; Albrecht [9]: Treska River, the village of Bukovo; Subchev [35]: Skopska Crna Gora (Karadah Mt.).

Material studied: Lipkovo, v. Goshince, 19.09.1979, 1♂, 2♀♀, leg. TP [2379]; Belchishko wetland, 04.10.1978, 1♀, leg. SP [2380]; Matica spring, v. Cer, Kičevo, 17.09.1981, 2♂♂, 2♀♀, leg. SS [2381]; v. Raec, 19.10.1970, 1♂, 1♀, leg. TP [2382]; captured spring between v. Bansko and v. Gabrovo, 27.06.1986, 11♂♂, 5♀♀, leg. SP [2383]; spring before v. Kolešino, 06.06.1986, 2♀♀, leg. Gj Gj [2384]; v. Bansko, 22.12.1987, 7♂♂, leg. TP [2394]; spring above v. Smolare, Mt. Belasica, 08.07.1986, 1♂, leg. SP [2396]; Lipkovska Reka river, v. Gošince, 17.07.1979, 4♂♂, 3♀♀, leg. TP [2398]; Demir Hisar, v. Brezovo toward v. Zasle, 28.07.2013, 1♀, leg. ES [5771]; Mt. Kozuf, Visoka Čuka (Konjarnik), 17.07.2002, 1♀, leg. ZN [5772]; Ratevska Reka River, 07.2013, 1♂, 1♀, leg. VK, VSS [5781]; Orevovečka Reka river, after fishpond, 11.09.2011, 1♀, leg. BR [5782]; Orevovechka Reka River, after fishpond, 12.08.2011, 1♂, leg. BR [5783]; Mala Livada River, 11.09.2011, 1♀, leg. BR [5784]; Bezgašteska Reka river, 30.05.2015, 1♂, 1♀, leg. BR, VSS [5786]; Plavaja river, 06.06.2016, 1 s., leg. BR, VSS [5787]; Zelenogradska Reka river, Mt. Osogovo, 08.2008, 1 s., leg. VSS [5788]; Brajčinska Reka river (upstream), 07.2010, 1♀, leg. IS [5789]; Zrnovska Reka river, 05.2015, 2♀♀, leg. VSS [5790]; Bregalnica river, v. Mačevo, 13.06.2015, 1♂, leg. VSS, DK [5791]; Pehčevska river, 14.06.2015, 1♀, leg. VSS, DK [5792].

Remarks: *A. torrentium* (Figure 1: G, d) is relatively widespread crayfish across Europe, confined mainly to higher regions and wooded headwaters, adapted to cold water and rocky environments [36]. This species is reported to be undergoing significant population decline in most parts of its range [37, 38]. Literature data show that the main threats to the population of stone crayfish are the following: i) the presence of non-native species *Pacifastacus leniusculus* (Dana, 1852) and *Orconectes limosus* (Rafinesque, 1817); ii) the crayfish plague, caused by pathogen oomycete *Aphanomyces astaci*; iii) domestic and industrial pollution; iv) habitat loss and degradation (with damming, water abstraction, and channelization of rivers); v) agriculture and vi) eutrophication [37, 38, 39]. However, no quantitative data on the rate of decline is available and therefore IUCN Red list of Threatened Species assessed the species as "Data Deficient" [37]. The European Habitats Directive 92/43/EEC ranks *A. torrentium* in Annex II among the animal and plant species of Community interest, whose conservation requires designation of Special Areas of Conservation (Table 1). Further, the species is included in Appendix III of Bern Convention and Anex V of EU Habitat Directive 92/43/EEC and presents a protected wild species in Macedonia [33].

Compared to the *A. astacus*, the stone crayfish (in this Catalogue accepted as *A. t. macedonicus*) is more widely distributed in Macedonia (Figure 5). Its connectivity with mountainous and wooded headwaters makes it less exposed to anthropogenic pollution and habitat degradation and contributed to its lesser vulnerability. The results presented in this Catalogue contributed to update our knowledge on the geographical distribution of the *A. t. macedonicus* in Macedonia and will serve as a baseline for the process of designation and establishment of Natura 2000 network in Macedonia.

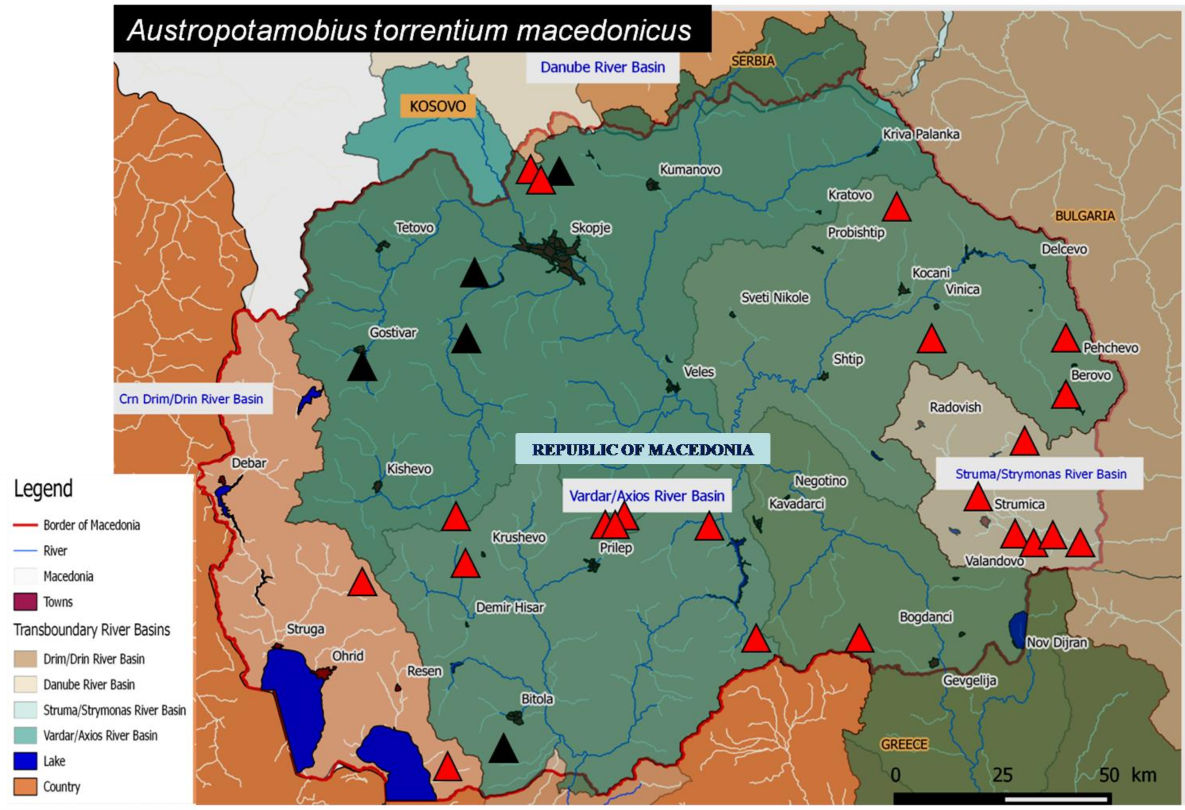

Figure 5. Distribution of *Austropotamobius torrentium macedonicus* in Macedonia. Black triangles = published records, red triangles = material studied

Infraorder CARIDEA Dana, 1852

Family Atyidae De Haan, 1849

Genus *Atyaephyra* de Brito Capello, 1867

***Atyaephyra stankoi* Karaman, 1972**

= *Atyaephyra desmaresti stankoi* Karaman, 1972

Published records: Karaman M. [15]: Dojran Lake; Karaman M. [12]: Dojran Lake, the channels in Skopje and Pelagonia valleys, downstream of spring Rasče near Skopje; Šapkarev *et al.* [40]: Dojran Lake near Nov Dojran and Kaldrma; Christodoulou *et al.*[16]: Dojran Lake.

Material studied: Katlanovo wetland, drainage channel, 22.06.1946, 10 s., leg. KB [2388]; Vardar river, v. Orešani, 13.09.1951, 5 s., leg. KB [2389]; Dojran Lake, 14.09.1972, 3 s., leg. OP [5776]; Dojran Lake, Kaldrma, 01.07.1994, 36 s., leg. ES, SS [5777]; Dojran Lake, Ačikot, 02.07.1994, 7 s., leg. ES, SS [5778]; Dojran Lake, Nikolič, 09.11.1999, 28 s., leg. ES, SS [5779]; Dojran Lake, Mrdaja, 10.11.1999, 10 s., leg. ES, SS [5780].

Remarks*:* The freshwater shrimp *Atyaephyra desmarestii stankoi* (Figure 1: I, e) was described by Karaman M. [12] based on specimens from Dojran Lake (Macedonia). Later, García Muñoz *et al.* [41] argued that the subspecies *A. d. stankoi* actually presents a cryptic species in *A. desmarestii* complex without confirming its status as a distinct species. Recently, Christoudoulou *et al.* [16] and García Muñoz *et al.* [17] confirmed the taxonomical validity of *A. stankoi* based on morphological and molecular data, after studying specimens from west-central Greece and from the type locality (Dojran Lake). Additionally, the neotype of *A. stankoi* Karaman 1972, was designated by Christoudoulou *et al.* [16] to stabilize the species' taxonomy.

A. stankoi is a Balkan endemic species, widespread in west-central Greece, ranging northwards to southern Macedonia (Dojran Lake) [3]. The distribution of this species in Macedonia is presented in Figure 6. The species lives in marginal areas of rivers, lakes and streams and prefers habitats rich with aquatic vegetation [12, 40]. *A. stankoi* is included in IUCN Red List of Threatened Species as being of Least Concern (Table 1), as no information is provided on population densities and no threats to the species are identified [3].

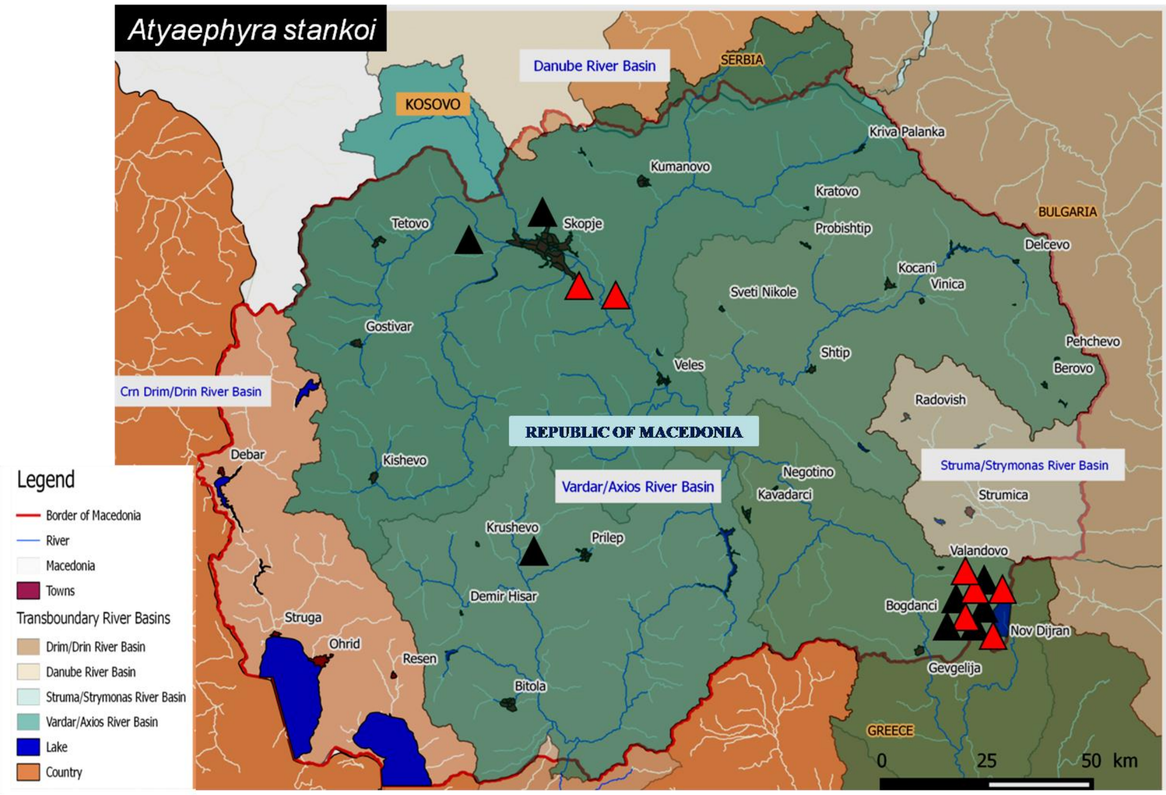

Figure 6. Distribution of *Atyaephyra stankoi* in Macedonia. Black triangles = published records, red triangles = material studied

Table 1. List of freshwater decapods in Macedonia and their associated status according to national and international criteria

Species	Habitat Directive 92/43/EEC	Bern Convention	IUCN Red List	National list
Potamon fluviatile			NT	
Potamon ibericum			NT	
Astacus astacus	V	III	VU	Yes
Austropotamobius torrentium	II/V	III	DD	Yes
Atyaephyra stankoi			LC	

The scarce knowledge of its ecology and biology, and the lack of economic value, significantly contributed to its low level of protection. The Macedonian law (Official Gazette of the Republic of Macedonia no. 139/2011, 2011) does not mention this species as a threatened one [33]. However, it is strange that despite intensive research in the macroinvertebrate fauna of Dojran Lake (Macedonia) during 2015–2016 (Slavevska-Stamenković, unpublished data) the presence of specimens of *A. stankoi* has not been registered, which indicates an urgent implication of conservation measures.

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КАТАЛОГ НА СЛАТКОВОДНИ РАКОВИ (DECAPODA: POTAMONIDAE, ASTACIDAE, ATYIDAE) ОД РЕПУБЛИКА МАКЕДОНИЈА ВО КОЛЕКЦИЈАТА НА ПРИРОДОНАУЧНИОТ МУЗЕЈ НА МАКЕДОНИЈА

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Каталогот ги сумира податоците од колекцијата на декаподни ракови депонирана во Природонаучниот музеј на Македонија, Скопје, Република Македонија. Во трудот е даден и критички осврт на историските податоци за појавата и дистрибуцијата на декаподните претствници кои се среќаваат во земјата. Популациите на декаподните ракови на територијата на Македонија, до денес не биле континуирано проучувани, така што овој каталог може да послужи како важен извор на податоци за зачувување и заштита на декаподните ракови и нивните живеалишта.

Клучни зборови: каталог; Decapoda; Природонаучен музеј на Македонија; Македонија

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Original scientific paper

MACROPHAGE AGREGATES IN BROOK BARBEL *BARBUS* CF. *PELOPONNESIUS* SPLEEN AS INDICATORS OF ENVIRONMENTAL POLUTION

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Changes in fish macrophage aggregate centres (MACs) are a useful indicator of environmental stress. In this study we evaluated stereologically the values of these cells in the polluted sites compared to the clean site in the River Bregalnica. MACs aggregates were randomly distributed in spleen and often showed irregular form. Dominant pigment in them was hemosiderin. Relative volume of MACs aggregates showed significant higher value in brook barbel from polluted site. Total volume showed the same pattern, but differences were not significant. Our data confirm that increase in MACs aggregates may serve as to warn on potential pollution in aquatic ecosystems. However, the precaution is strongly suggested, as results were based on quantitative approach.

Key words: spleen; macrophage aggregates centres; pollution

INTRODUCTION

The environmental pollution presents a worldwide problem. According to some research in developed countries, 90% of waste waters are untreatedly discharged directly into the open water [1]. This problem is present in undeveloped counties as well. Persistence of toxic materials in aquatic ecosystems results in increased frequency of the infections, parasites and lesions in aquatic organisms, including fish [2–5]. This harmful effects are also manifested through negative influence of the toxic material upon MACs activity as well as on the whole immune system [6–8].

Pigmented MACs in fishes can be found in spleen, kidney and to a less extent in liver [9]. Number, size and pigment composition of MACs depend on various internal, i.e., endogenous factors [10–13]. Pigmented MACs also depend on the exogenous factors, namely on the presence of toxic materials in the environment [14, 16–18]. Most of the studies which investigated the influence of MACs on the environment in nature were qualitative [13].

Taking into account that MACs aggregates were good bioindicators for determination of the anthropogenous impact on environment and fish health [16], the present study aimed to investigate pigmented MACs aggregates in the brook barbell *Barbus* cf. *peloponnesius* spleen along the river of Bregalnica, both in a clean location, which was a reference site, and in the polluted ones. Stereologically (quantitatively) the amount of pigmented MACs, relative and total volume, in the selected organ was to be determined.

MATERIAL AND METHODS

Samples of brook barbel (*Barbus peloponnesius*, Valenciaennes, 1844) were collected from three locations in the River Bregalnica; the upstream, reference site (R site), which does not receive anthropogenic effluents; the site in the middle part of the river (site A), which is under the strong pollution from aquaculture and mining industry; and the site in the downstream stretch (site B), which is mainly under sewage and household water discharges. The map and detail description of the sampling area were already published by Ivanova *et al.* [19]. In total, 648 fish samples were collected by electro fishing (electro fisher Samus 725G) from all three localities according to CEN EN 14011, 2003 standard. After the capture, the fishes were transported from sampling sites to the field laboratory. The animals were sacrificed by severing the spinal cord, the dissection was made and spleen was removed, measured for weight and fixed in Bouin's fixative for 48 hours. For analysis, the sampled pieces were routinely processed and embedded into paraffin. From each piece serial sections (5 μm thick) were taken, picking some of them for analysis by a systematic random sampling approach, so to obtain a representative final set of slides (about five per spleen). Sections were stained with Perl's method [20].

From each section, approximately ten systematically sampled fields were observed and quantified at a final magnification of 400×, with the first field being randomly selected. In average, 50 fields per spleen were systematically selected and studied. A classical unbiased stereological technique based on manual point counting [21] was used to estimate the relative volume of the MACs (expressed as percentage) within the organ, according to the following formula:

$$V_V(\text{structure, reference}) = V_V(s, r) = [P(s) \times 100] \div P(r),$$

in which $V_V(s, r)$ is the percentage of the total volume of a reference space occupied by one particular given structure within that space, P(s) is the total number of test points lying over the reference space (in this study spleen tissue), and P(r) is the total number of points falling over a particular structural component. Point counting was directly made on a microscope, and for that a square lattice glass grid with 180 points was inserted into the left ocular. The total volume was calculated according to the following formula:

$$V(\text{structure}) = V_v\ (\text{structure, reference}) \times V\ (\text{reference})$$

Data were presented as group means of individual fish values, accompanied with the Coefficient of Variation (CV = SD/mean). Statistical analyses were made using the software Statistica 7.0 for Windows. Data were analyzed by ANOVA and whenever ANOVA disclosed significant results the post-hoc Tukey test was performed. Differences were considered as significant at $p<0.05$.

RESULTS AND DISCUSSION

Pigmented MACs aggregates were randomly distributed through the spleen tissue in examined brook barbel (Figure 1). The main pigment inside them was hemosiderin alone (Figure 1b), or sometimes in association with lipofuscin/ceroid. The melanin was almost absent. Such a distribution of the pigment in brook barbel spleen was in accordance with the data of the other authors [9–11]. Moreover, the hemosiderin deposition in MACs indicated to the presence of toxic materials in environment [16].

As expected from the qualitative analyses, the highest V_V(MACs, spleen) were observed in fish sampled at the sites A and B (Tab. 1). These values were significantly higher when compared with the fish taken from the R site. Total volume V_{spleen} (MACs) showed tendency to increase in polluted sites, but no significant differences were obtained, probably due to high coefficient of variation coming from strong individual variability (Tab.1).

In fishes, MACs have a function in organism defense. Numerous data show that pollution in the environment influences MACs [15–17]. It is in agreement with our data, which confirmed that MACs are good bioindicators for early detection of presence of the toxic materials in aquatic ecosystem. Fournie et al. [18] already pointed that MACs can easily reveal the difference between degraded and non-degraded environments. Most of the studies in which MACs were used as potential biomarker were based on qualitative observation. When studies were quantitative, different researchers measured different parameters and hence, a consistent conclusion about their utility is lacking. Therefore, we strongly suggest a quantitative approach in the use of MACs as a bioindicator.

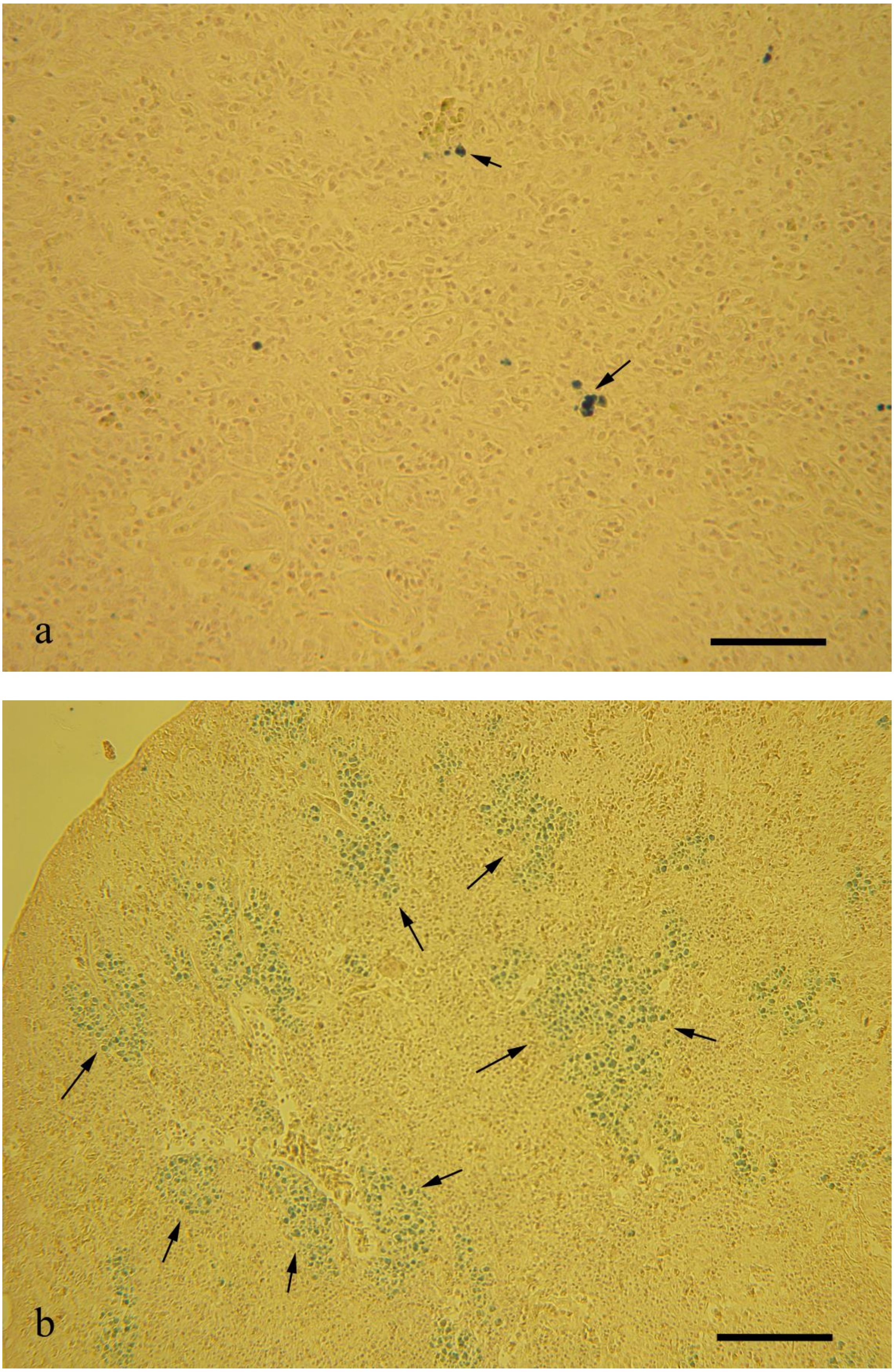

Figure 1. Light micrographs of Perl's stained sections from the spleen of barbel, showing the evident difference between (a) fish in the reference site with fewer pigmented macrophage aggregates (MACss), and (b) fish in the polluted location with much extensive accumulations pigmented MACs amidst. Bar line = 100 μm.

Table 1. Relative volume (V_V), and total volume (V) of the pigmented macrophage aggregates (MACs) in the spleen of the barbel from reference site (R site), and sampling sites affected with pollution effluent (A and B sites)

Location	V_V (MACs, spleen kidney) %	V_{spleen} (MACs) cm^3
R Site	0.93 (1.65)^a	0.02 (2.61)
A Site	2.06 (0.01) ^{b}	0.04 (1.55)
B Site	1.50 (1.02) ^{b}	0.05 (2.82)

Data are expressed as: mean (coefficient of variation).
Within a column, values with different superscript letters are significantly different ($p < 0.05$), according to the post-hoc Tukey's test.

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МАКРОФАГНИ АГРЕГАТНИ ЦЕНТРИ ВО СЛЕЗИНАТА НА МРЕНАТА *BARBUS* CF. *PELOPONNESIUS* КАКО ИНДИКАТОРИ НА ЗАГАДУВАЊЕТО НА СРЕДИНАТА

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Промените во макрофагните агрегатни центри (MACs) кај рибите се корисен индикатор за стресна состојба во животната средина. Во оваа студија со стереолошки методи направивме процена на овие клетки во загадени наспрема незагадени локалитети во реката Брегалница. MACs агрегати се расфрлени низ слезината и се често со неправилна форма. Доминантен пигмент во нив беше хемосидеринот. Релативниот волумен на агрегатите на MACs покажа статистички значително повисоки вредности во загадените локалитети. Тоталниот волумен покажа ист тренд, но разликите не беа статистички значајни. Нашите резултати потврдуваат дека зголемувањето на MACs-агрегати може да се користи како предупредување за потенцијално загадување на акватичните екосистеми. Затоа, сугерираме резултатите од ваквите истражувања да бидат од квантитативна природа.

Клучни зборови: слезина; макрофагни агрегатни центри; загадување

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