Rasprostranjenost slatkovodnih mahovnjaka (Bryozoa) u Hrvatskoj

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DISTRIBUTION OF FRESHWATER BRYOZOANS (BRYOZOA) IN CROATIA

Graduation Thesis

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Sveučilište u Zagrebu
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Sanja Garašić

RASPROSTRANJENOST SLATKOVODNIH MAHOVNJAKA (BRYOZOA) U HRVATSKOJ

Diplomski rad

Zagreb, 2009.

This Graduation Thesis, has been made in the Department of Zoology of Division of Biology of Faculty of Science of University of Zagreb, under the supervision of Emmy Wöss, Ph. D., subsupervision of Asst. Prof. Tatjana Bakran-Petricioli, Ph. D. and assistant supervision of Maja Novosel, Ph. D., and was given to be evaluated to the Division of Biology of Faculty of Science of University of Zagreb in order to acquire profession Professor of Biology.

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DISTRIBUTION OF FRESHWATER BRYOZOANS (BRYOZOA) IN CROATIA

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In this study first results of an ongoing survey on freshwater bryozoans on the territory of the Republic of Croatia are presented. In total, six locations which were investigated in order to find freshwater bryozoans (Bryozoa) are described: Jarun, Crna Mlaka, Žumberak, Plitvice Lakes, Lonjsko Polje, and Krka River. At the present time, 11 species of freshwater bryozoans have been recorded from these sites, ten of them belonging to the Class Phylactolaemata which occurs exclusively in freshwater: *Fredericella sultana, Hyalinella punctata, Plumatella casmiana, Plumatella emarginata, Plumatella fruticosa, Plumatella fungosa, Plumatella repens, Plumatella geimermassardi, Cristatella mucedo and Lophopus crystallinus.* Furthermore, one species of the Class Gymnolaemata, *Paludicella articulata*, was found as well. Out of about 88 freshwater bryozoan species worldwide, so far 19 have been documented in Europe. In this work the distribution of 11 species mentioned for Croatia is discussed in the relation to their occurrence in Europe.

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RASPROSTRANJENOST SLATKOVODNIH MAHOVNJAKA (BRYOZOA) U HRVATSKOJ

Sanja Garašić

Biološki odsjek, Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu, Rooseveltov trg 6, Zagreb, Hrvatska

U ovom radu o slatkovodnim mahovnjacima na području Republike Hrvatske predstavljeni su prvi rezultati istraživanja, koje je još uvijek u tijeku. Ukupno, šest lokacija je istraženo s ciljem pronalaženja slatkovodnih mahovnjaka (Bryozoa): Jarun, Crna Mlaka, Žumberak, Plitvička jezera, Lonjsko polje i Krka. Do sada je zabilježeno 11 vrsta slatkovodnih mahovnjaka na tim lokacijama, od kojih 10 vrsta pripada razredu Phylactolaemata koji se javlja isključivo u slatkim vodama: *Fredericella sultana, Hyalinella punctata, Plumatella casmiana, Plumatella emarginata, Plumatella fruticosa, Plumatella fungosa, Plumatella repens, Plumatella geimermassardi, Cristatella mucedo i Lophopus crystallinus.* Nadalje, utvrđena je i vrsta *Paludicella articulata* iz razreda Gymnolaemata.
Od 88 vrsta slatkovodnih mahovnjaka nađenih u svijetu, u Europi je zabilježeno njih 19. U ovom radu uspoređena je rasprostranjenost utvrđenih 11 vrsta mahovnjaka s njihovom rasprostranjenošću u Europi.

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1. INTRODUCTION

1.1. General features of bryozoans

Bryozoans are aquatic, suspension-feeding invertebrate animals. They are widely distributed, but even so they still remain a relatively little-studied group of invertebrates. They are colonial animals composed of numerous genetically identical zooids produced by budding. While a bryozoan colony may grow up to many centimetres or in some species, even meters in dimension, the constituent zooids are small, on the order of a few millimetres, and a dissection microscope is required to observe them properly. Zooids in freshwater bryozoans are not separated by walls as occurs in marine bryozoans, although partial septa, which function as strengthening elements, may be present between zooids in some branching or tubular species. As a consequence, zooids of freshwater bryozoans share a continuous fluid-filled body cavity, or coelomic space. This cavity is lined by a ciliated epithelial layer, called peritonium. Each zooid possesses a ciliated tentacular crown, called lophophore, which surrounds the mouth and is used in feeding (Wood & Okamura, 2005; Figure 1).

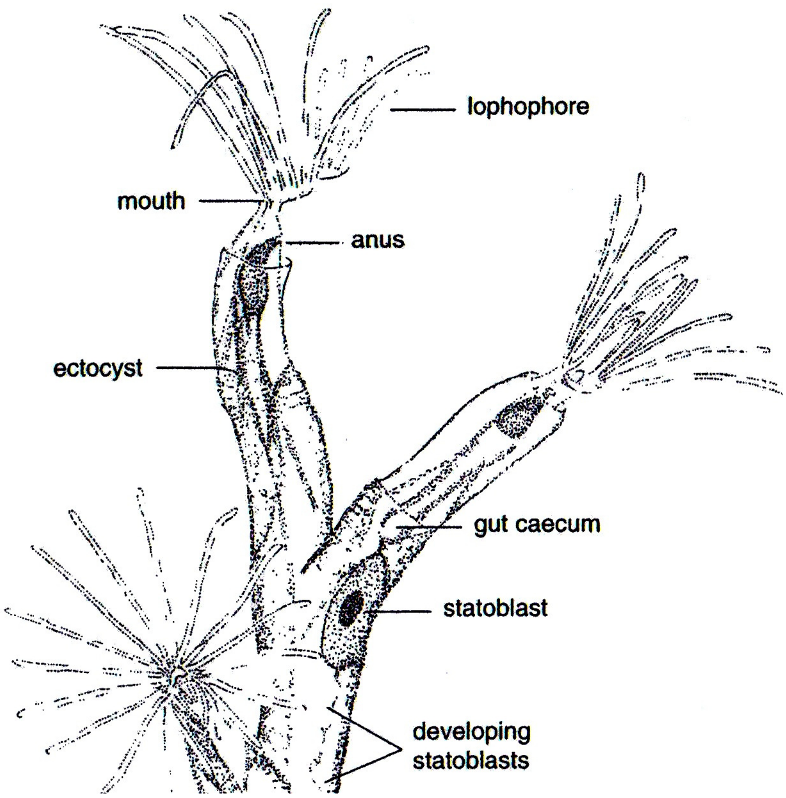

Figure 1. Zooids of *Plumatella emarginata*, showing major anatomical features (from Wood and Okamura, 2005).

1. INTRODUCTION

In general, there are three classes of freshwater bryozoans, Phylactolaemates, Gymnolaemates and Stenolaemates. In most Phylactolaemates, the lophophore is U-shaped, with longer tentacles in the outer row and shorter tentacles in the inner row. In contrast, Gymnolaemates and Stenolaemates, possess a simple, circular lophophore, consisting of a single ring of tentacles (Wood & Okamura, 2005).

Respiratory, circulatory, and excretory systems are absent in bryozoans. The reproductive organs are situated on the lining of the body wall or on the funiculus, a cord of tissue that links the stomach to the lining of the body wall. The zooidal nervous system consists of a small ganglion positioned between the mouth and the anus that supplies nerves to the various organs (Ryland, 2005).

Bryozoans are sometimes also called Ectoprocta because their anus opens outside of the lophophore. The digestive tract in general is U-shaped. The body wall of Phylactolaemate colonies is composed of living tissues called endocyst below a non-living outer layer called ectocyst which is highly variable among species. In most branching or tubular colonies the ectocyst is chitinised and a variety of organic and inorganic particles adhere to it. Such species are attached to the substratum. The ectocyst varies with age of the colony, being thin, flexible and transparent in young regions, and leathery, brittle or opaque in older regions. Non-tubular, gelatinous colonies may lack an ectocyst (e.g. *Cristatella, Lophopus Lophopodella*) or may secrete a massive jelly-like substance composed largely of water (e.g. *Pectinella*). Small gelatinous species can slowly creep across the substratum via a muscular foot or other mechanism. Increased colony size may prohibit coordination of effective creeping (Wood & Okamura, 2005).

Freshwater bryozoans exhibit great variation and complexity of life histories. Due to the instability of most freshwater environments, life-history patterns differ from those living in the sea by showing less variation in growth form, but a much greater variety in modes of reproduction (Wöss, 1996). Like other modular animals, they have a life cycle that incorporates phases of asexual and sexual reproduction.

One of the most striking characteristics of freshwater bryozoans is their extraordinary variety of forms of asexual reproduction. Propagation by fragmentation is typically for chitinous species. Fission by injury occurs in all species and additionally, in some gelatinous forms such as *Cristatella* fission occurs regularly after the colony has reached a certain size. Propagation by some form of resting stage includes hibernaculae in the case of

Gymnolaemate *Paludicella*, while different kinds of statoblasts are exclusively produced by the Phylactolaemates (Wöss, 1996).

Statoblasts are asexually-produced, dormant, highly resistant stages, which represent the main means of persistence during unfavourable winter periods or dry periods. Statoblast production typically begins partway into the summer period and peaks once or twice during late summer/early autumn. As temperature drops in the autumn, colonies degenerate, often appearing as bags or tubes full of mature statoblasts that have not yet been released (Wood & Okamura, 2005). They develop on the funiculus, and there are several types of them. Free statoblasts, often referred as floatoblasts, leave the colony and drift away with the help of gas-filled annulus. They show a variety of forms, such as hook-bearing spinoblasts in *Cristatella* or leptoblasts in *Plumatella casmiana*, which are extremely fragile and minimally sclerotised. Leptoblasts immediately germinate after release from the colony and thus cannot act as a resting stage for over-wintering in contrast to all other types of statoblasts. Sessile statoblasts are not released from colonies; instead they become cemented to the substratum with a special attachment apparatus on the side of the valve that lies on the substatum and remain stuck even after the death of the colony. Piptoblasts, also a kind of statoblasts, are characteristic for *Fredericella.* They lack such an attachament apparatus and, like sessoblasts, are unable to float (Wöss, 1996).

In the class Gymnolaemata a few species, such as *Paludicella*, isolate a small part of the colony, thicken the walls, and fill it with yolk and germinal tissue. There are apparently two types of these so-called hibernacula: one is dark, spindle-shaped, and occurring within the normal zooid walls: the other is a yellowish, irregularly shaped body attached to the substratum. Virtually nothing is known about the tolerance of hibernacula to adverse conditions. However, like statoblasts, they are capable of overwintering in a dormant stage and then germinate whenever suitable conditions return (Wood, 2005).

Sexual reproduction is limited on the summer months and it is rare. Production and subsequent fission of gametes, generates the genetic variability necessary for a species to survive in a habitats that varies from place to place and from time to time. As the colony continues its growth by budding, some zooids become sexually mature, producing eggs and spermatozoa. Fertilized eggs develop into larvae which disperse and found new colonies. Mature Stenolaemate, Gymnolaemate and Phylactolaemate zooids are most commonly hermaphroditic (both male and female reproductive organs occur in the same zooid). Among the Phylactolaemates, the fertilized egg develops in an internal embryo sac; a larva, which already contains the first polypide, is formed there, and then liberated (Ryland, 2005).

1.2. Ecology

Freshwater bryozoans live attached on natural substrata such as leaves and stems of aquatic plants, submerged tree roots, and branches, rocks, and on artificial surfaces such as pipes, walls, plastic bottles, floats and tyres. They grow most prolifically in places where they are protected from sedimentation and where low light levels prohibit overgrowth by algae, but where they can still feed from suspended matter. They are found in both running-water (lotic) and still-water (lentic) habitats. Colonies generally flourish at 15-18 ºC, although colonies of some species, such as *Fredericella sultana* or *Cristatella mucedo*, tolerate cooler temperatures. When unfavourable conditions return, colonies degenerate. However, *Fredericella* and *Lophopus crystallinus* can persist at least in some sites during the winter.
Having statoblasts as dormant phase provides bryozoans to survive winter and dry periods when colony dies. They are also the only stage in the life cycle capable of undergoing dispersal to new waterbodies, and traits such as small size, dormancy, resistance to adverse conditions, and mass production, should promote the chances of dispersal via animal vectors. Waterfowl may be especially important vectors of dispersal since large number of statoblasts accumulates in the autumn when waterfowl migrations occur. The hooks and spines of some statoblasts promote entanglement in fur and feathers. In addition, a proportion of statoblasts have been shown to subsequently hatch after passing through the digestive tracts of salamanders, frogs, turtles, and ducks and statoblasts have been collected in the guts and faeces of birds. Direct consumption of bryozoans by fish and the presence of statoblasts in fish guts suggest that considerable dispersal within interconnected waterbodies may be achieved by fish. The evidence thus suggests that both external and internal transport via animal vectors will contribute to dispersal. Such dispersal ultimately determinates species ranges and patterns of distribution across the landscape (Wood & Okamura, 2005).

1.2.1. Bryozoan feeding

Bryozoans create strong currents with their U-shaped lophophores and by that accelerate particles towards their mouth. In that way processed water is vented considerable distances away from colony surfaces, through excurrent regions where lophophores are absent. This processing of water leads to efficiency in feeding, by minimizing the recirculation of water that has previously been filtered, and because the overlapping feeding currents extend into higher regions of the water column where mixing will be greater and food-depleted waters will be more rapidly replenished. Bryozoans mainly feed on nanoplankton. The most predominant are single cells such as flagellates, chlorophytes and some cyanobacteria. Some diatoms, rotifers and chrysophytes are also ingested. It was noted that bryozoans ingest particles that remain undigested and identifiable in the faeces. They also ingest bacteria, the rate of ingestion is substantial, suggesting that bacteria contribute to bryozoan diets, but the lack of sustained growth on bacteria alone indicates that a mixed diet is probably essential (Wood & Okamura, 2005). Small food particles are directed to the mouth along ciliated food grooves at the base of the lophophore tentacles. Larger food items may be flicked towards the mouth by individual tentacles, and the tentacles can also show concerted activity, in which the tentacle tips are brought together to enclose active food items such as protozoans and rotifers. Growth rates are initially slow, but once the colonies are established, growth can accelerate rapidly, leading to dense cover of surfaces by bryozoan populations.

1.2.2. Predation on Bryozoa

Being attached and apparently defenceless, freshwater bryozoans appear to be vulnerable to attack by predators and parasites. However, relatively little is known about predation on bryozoans and much of our knowledge is based on anecdotal observations. A variety of benthic invertebrates often congregate where bryozoan growth is dense and many have been noted to consume bryozoans, but rates and levels of consumption by different predators have not been determined. Okamura (1997) found that colonies of *Cristatella mucedo* attracted aggregations of chironomid larvae, trichopteran larvae, isopods, haliplid beetles, snails, flatworms, and water mites. Vertebrate predators include fish which directly or incidentally consume bryozoans. Although bryozoans appear to be defenceless, *Lophopodella* *carteri* is toxic to fish and salamander larvae. Experiments suggest the toxin is present in body tissues, since tissue injury is required for the toxin to kill fish. The pattern of susceptibility suggests that the toxin is specific to aquatic vertebrates possessing gills. Toxicity in other bryozoans is unknown (Wood & Okamura, 2005).

1.2.3. Parasitism on Bryozoa

Recent investigations have resulted in the significant discovery that freshwater bryozoans are hosts of myxozoan parasites. Myxozoans may have been observed first in freshwater bryozoans by Korotneff (1892), but this was followed by a long period of taxonomic confusion. It was not until 1996 that sac-like stages freely circulating in the bodycavity of *Cristatella mucedo* were determined to be myxozoans. Ultrastructural study revealed that these parasites represented a new species, and Canning et al. (1996) designated the name *Tetracapsula bryozoides*. A few years later, similar sac-like myxozoans were detected in body cavities of *Pectinella magnifica*, *Cristatella mucedo* and *Plumatella rugosa* in the USA and in *Fredericella sultana* and *Plumatella emarginata* in the UK and France. These parasites were indistinguishable from the parasites which cause Proliferative Kidney Disease (PKD) - a devastating disease of salmonids in farms and hatcheries. This discovery ended the long search for the source of the disease, as it is not transmitted from fish to fish. Feist et al. (2001) subsequently confirmed bryozoans as hosts of the causative agent of PKD, by showing that rainbow trout (*Oncorhynchus mykiss*) developed PKD if they cohabited with infected bryozoans or were exposed to mature parasites released from bryozoan colonies. Canning et al. (1999) named the parasite *Tetracapsula bryosalmonae* on the basis of ultrastructure and sequence information. The discovery of these two bryozoan parasites resulted in the description of a new Class (the Malacosporea) within the Phylum Myxozoa.

In 1910, Schröder described an enigmatic, worm-like endoparasite that develops within the body cavities of *Plumatella fungosa* and *P. repens*. He named the parasite *Buddenbrockia plumatellae* and proposed that it was a mesozoan. Later studies resulted in the revelation that *Buddenbrockia* is a myxozoan. Furthermore, both sequence and ultrastructural data indicated that *Buddenbrockia* and *Tetracapsula bryozoides* apparently represent two stages in a common life cycle. The life cycle could involve obligate cycling between sac-like and worm-like stages or facultative expression, being induced by some cue. Myxozoans exert negative effects on their bryozoan hosts. *Tetracapsula bryozoides* (now *Buddenbrockia* *plumatellae*) compromises statoblast production and infected colonies show generalized swelling, they are typically degenerating, and exhibit slow growth. Infections with worm-like stages of *B. plumatellae* cause depressed growth and subsequent mortality of *Hyalinella punctata* colonies. Tubular colonies respond to parasitism with *B. plumatellae* by inward pinching of the peritoneum, which may serve to isolate infected from uninfected regions of colonies. These infections also appear to inhibit statoblasts production (Wood & Okamura, 2005).

It was proven that proliferation of Tetracapsula bryosalmonae is increased with temperature by provoking, accelerating and prolonging the production of infective spores from cryptic stages. PKD outbreaks will increase in both magnitude and severity in wild and farmed fishes as a result of climate-driven increases in global temperatures (Tops et al., 2006).

1.2.4. Competition among Bryozoans

The asexual spread of bryozoan colonies commonly results in contact and intermingled growth with neighbouring attached organisms such as other bryozoans and sponges (Bushnell, 1966; Wöss, 1996). Escape from competition may be one advantage of movement in gelatinous colonies. It was noted that a variety of small organisms live on freshwater bryozoans. Commonly referred to as the “aufwuchs” community, organisms congregate near or on colony surfaces. This community of organisms probably develops as a result of attraction to the microhabitat created by bryozoans feeding currents, the protective microhabitat offered by the three-dimensional structure of colonies, and the availability of a food resource in the form of moribund and decomposing colonies. Associated microorganisms include various protozoans, rotifers, gastrotriches and microcrustaceans (Wood & Okamura, 2005).

1.2.5. Biofouling bryozoans as a threat to the industry

Under certain conditions, conduits carrying unfiltered water from lakes or rivers eventually become lined with bryozoans, hydroids, sponges and many other organisms. By blocking the conduit or clogging end use devices, these animals impose serious economic costs. Bryozoans are probably the most common among the fouling animals. Three factors hinder control efforts: dormant bodies (statoblasts or hibernaculae) that tolerate harsh physical and chemical treatments; regeneration of bryozoan colonies from pockets of living tissue; easy dispersal of them through air and water. Because of these resilient mechanisms, it requires surprisingly high concentrations of biocides to kill live bryozoan colonies. Often this cannot be done without inflicting serious damage on nontarget organisms (Wood, 2005).

1.3. Systematics

Bryozoans in general are separated into three classes: Stenolaemata, Gymnolaemata and Phylactolaemata. All together there are about 8000 species of bryozoans in the world. Only 88 species of that large number are freshwater bryozoans, while just 19 species live in Europe (Massard & Geimer, 2007). Most bryozoans found in freshwaters belong to the Class Phylactolaemata, although several species belonging to the Subclass Ctenostomata (Class Gymnolaemata) are found in brackish to freshwater. The Phylactolaemata is an exclusively freshwater group with a relatively small but growing number of described species (Wood & Okamura, 2005).

In general Phylactolaemates have basically cylindrical zooids, with a crescentic lophophore and an epistome (hollow flap overhanging mouth). Body wall is noncalcareous, muscular, and used for averting the lophophore. Coelom is continuous between zooids. New zooids arise by replication of polypides, and special dormant buds (statoblasts) are produced. Zooids are monomorphic. They are cosmopolitan animals, apparently primitive, but with no certain fossil record. There are about 12 genera, and 69 species.

The colony shows two general types of construction. One is branching or plumatellid type, exemplified by lower Phylactolaemates such as *Fredericella* and *Plumatella*, where the colony ramifies as branching tubes, composed of a succession of more or less distinct cystids of individual zooids. The other is the massive or lophopodid type, exemplified by higher Phylactolaemates such as *Lophophus* and *Pectinella*, where the colony is a compact gelatinous mass composed of basally united cystids of individual zooids. The statoblast morphology has been considered to be most important in elucidating the phylogeny or systematics of Phylactolaemates (Mukai, 1999).

Gymnolaemata have zooids cylindrical or squat, with a circular lophophore, and no epistome. Body wall is non-muscular, and sometimes calcified. Eversion of lophophore is dependent on deformation of body wall by extrinsic muscles. Zooids are separated by septa or duplex walls, and the pores in walls are plugged with tissue. New zooids are produced behind growing points by formation of transverse septa. Gymnolaemates are polymorphic, mainly marine animals, and they probably appear from Ordovician to present. There are about 650 genera, only 19 of them freshwater (Ryland, 2005).

Internal characters have been used less but, in Ctenostomates, the presence or absence of gizzard, number of tentacles, and colour of developing embryos are of taxonomic significance (Ryland, 2005).

Stenolaemata have cylindrical zooids, which are separated by septa. Body wall is calcified, without muscle fibres. New zooids are produced by division of septa. Stenolaemates are marine animals, with limited polymorphism, and they appear from Ordovician to present. There are about 550 genera, all marine.

1.4. Research history of freshwater bryozoans

The discovery of *Lophopus crystallinus* by Trembley in April 1741, in a pond on the country estate in the Netherlands, marked the beginning of the study of freshwater bryozoans. At first, only an occasional study of species appeared; for example Blumenbach (1779, 1780) discovered one of the most widely distributed species, *Fredericella sultana*; Pallas (1768) described *Plumatella fungosa*, also frequent species; Cuvier (1798) recorded *Cristatella mucedo*, which was regarded as the highest developed species for a long time. Allman (1856) devoted a monograph to the known species of western Europe, and introduced the name Phylactolaemata. The list of authors on this subject includes the most celebrated biologists: Linnaeus (1758, 1767), Cuvier (1798), Lamarck (1816) and De Vries (1887). Mention should be made of Marcus (1926-1958) for his biological investigation and of Cori (1941) for his magnificent paper in "Handbuch der Zoologie" which contains the entire knowledge to that date of the histology of the marine and freshwater bryozoans (Lacourt, 1968).

The most recent monograph is that of Lacourt (1968), from The Netherlands, which dealt with all species known at the time and provided complete citations of Phylactolaemate literature through the mid 1960s. Wiebach (1974) realized the importance of statoblats in distinguishing species and the value of scanning electron microscopy to reveal taxonomically important morphology (Wood & Okamura, 2005).

The sampling locations are those used in ongoing study “First survey on freshwater bryozoans from Croatia” (Wöss & Novosel). During the project, six different locations were visited up to now between June and September 2008: Jarun, Crna Mlaka, Žumberak, Plitvice Lakes, Lonjsko polje, and Krka River (Figure 2).

The exact coordinates and visiting dates of all sampling sites are given in Table 1.

All of these surveyed locations have in common several things. They are all rivers, lakes, swamps or wetlands, which contain water continuously throughout the whole year. Migratory wetland birds visit these locations, and could transport bryozoan statoblasts on their feathers or in their guts. In this way birds contribute to bryozoan distribution. Also, these waters are covered with water plants such as water-lilies, and cane which offer an excellent settlement substrate for this animal group.

Figure 2. Map of investigated locations in the Republic of Croatia: 1 – Jarun; 2 – Crna Mlaka; 3 – Žumberak; 4 – Plitvice Lakes; 5 – Lonjsko Polje; 6 – Krka River.

Table 1. Investigated locations with coordinates and sampling dates

Date (2008.)	site name		coordinates	
19.6.	JARUN	1 J island	N 45°46,761'	E 15°56.096'
		2 J canal	N 45°46.566'	E 15°55.811'
20.6.	CRNA MLAKA	1 CM canal	N 45°37.022'	E 15°44.058'
		2 CM pond	N 45°36.789'	E 15°43.957'
		3 CM pond	N 45°36.906'	E 15°43.734'
		4 CM canal	N 45°36.822'	E 15°43.812'
21.6.	ŽUMBERAK	1 Ž Rajska Lakes	N 45°47,840'	E 15°37.452'
		2 Ž Divlje Vode	N 45°50.173'	E 15°36.377'
		3 Ž Marinići Fishfarm	N 45°49.637'	E 15°35.117'
		4 Ž Dane – Kordići Pond	N 45°46.822'	E 15°30.650'
		Budinjak Pond	N 45°47.283'	E 15°29.851'
23.6.	PLITVICE LAKES	1 P - Kozjak Bridge	N 44°53.664'	E 15°36.523'
		2 P - Rječica Stream	N 44°52.445'	E 15°36.742'
24.6.		3 P - Prošćansko Lake	N 44°52.458'	E 15°36.753'
		4 P - Matica River	N 44°50.997'	E 15°36.172'
		5 P - Black River	N 44°50.606'	E 15°36.063'
		6 P - White River	N 44°50.571'	E 15°35.983'
25.6.		7 P - Batinovac Lake	N 44°50.568'	E 15°35.984'
		8 P - Okrugljak Lake	N 44°52.435'	E 15°36.025'
		9 P - pond near Galovac Lake	N 44°52.259'	E 15°36.218'
27.6.	LONJSKO POLJE	1 LP - Krapje Đol - Orlinci Pasture	N 44°52.429'	E 15°36.022'
		2 LP - Puska Rukavac - Old Sava	N 45°19,674'	E 16°47.984'
		3 LP - Mrtvaaja u Mužilovčici	N 45°23.416'	E 16°40.973'
		4 LP - Mužilovčica - Materijal Grabe	N 45°23.923'	E 16°41.484'
		5 LP - Čigoč - Old Sava	N 45°25.224'	E 16°37.282'
3.9.	KRKA RIVER	K1 - Topoljski Buk	N 44˚02.521'	E 16˚14.087'
		K2 - Krčić Fishfarm	N 44˚02.388'	E 16˚13.748'
		K3 - Sastavak	N 44˚02.345'	E 16˚11.103'
		K4 - Marasovina (Liver)	N 44˚00.620'	E 16˚05.557'
		K5 - Bilušića Buk	N 44˚00.780'	E 16˚03.610'
		K6 - Brljan - Donje Lake	N 44˚00.744'	E 16˚01.992'
4.9.		K7 - Orthodox Monastery	N 43˚57.720'	E 15˚59.521'
		K8 - Nečven Brzak	N 43˚58.504'	E 16˚01.411'
		K9 - Nečven - Orthodox Monastery	N 43˚58.350'	E 16˚00.844'
		K10 - 200m upflow Orthodox Monastery	N 43˚57.839'	E 15˚59.526'
		K11 - Verovića Bare	N 43˚57.836'	E 15˚59.532'
		K12 - Roški Waterfall	N 43˚57.833'	E 15˚59.540'
		K13 - Ribarska Cave	N 43˚56.540'	E 15˚59.484'
5.9.		K14 - Čikola River Delta	N 43˚48.565'	E 15˚59.728'
		K15 - Roški Slap downflow	N 43˚54.214'	E 15˚58.481'
		K16 - Među Gredama	N 43˚51.861'	E 15˚58.351'
		K17 - Visovac Monastery	N 43˚51.635'	E 15˚58.391'
		K18 - Skradinski Buk (harbour)	N 43˚48.136'	E 15˚58.323'
		K19 - Skradinski Buk (old channel)	N 43˚48.123'	E 15˚57.990'
6.9.		K20 - Skradinski Buk (under waterfall)	N 43˚48.132'	E 15˚57.995'
		K21 - Skradinski Buk (shallow water body)	N 43˚48.414'	E 15˚57.787'
		K22 - Skradinski Buk (touristic harbour)	N 43˚48.473'	E 15˚57.675'
		K23 - Skradinski Buk harbour (right bank)	N 43˚48.550'	E 15˚57.522'
		K24 - Skradinski Buk harbour (left bank)	N 43˚48.703'	E 15˚57.205'
		K25 - Skradinski Bridge	N 43˚49.121'	E 15˚56.074'

2.1. Jarun

Jarun is on the south-western part of Zagreb. It was named after the Jarun Lake formed by the Sava River. Jarun is an artificial lake that was created by digging gravel after a disastrous flood in 1964. Beside two lakes, Veliko and Malo Jezero (Big and Small Lake), Jarun has six islands too. Today Jarun is a big sporting-recreational centre. The average depth of the water body is 4 metres, and the water is clean because it is coming from gravel layers of the Sava River alluvium. The mean annual water temperature is 14,3 ºC, while the mean summer temperature is 24,1 ºC (Jarun, web page).

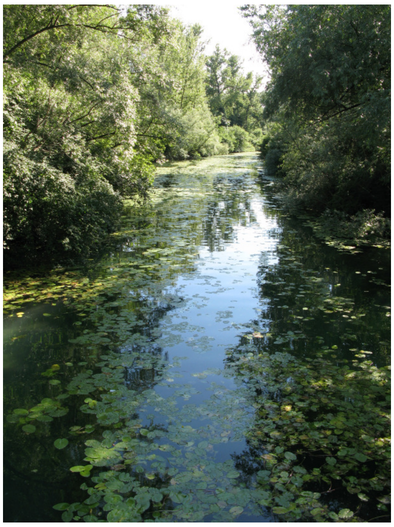

Figure 3. Canal through which Sava River flows into Jarun.

Figure 4. Island of Love, Jarun.

Jarun (Figure 3, and 4) was visited on 19. 6. 2008. Two sites were investigated. The range of water temperature was from 24,8 to 25,7 ºC, and the conductivity range was from 550 to 562 µS/cm.

<u>Site 1 J – Island of Love (N 45°46'761'', E 15°56'096'')</u>

The Island of Love is situated in the centre of Small Lake. The sampling was done by boat. The bottom was mostly sandy and some reed was found. The whole island is predominantly on a sunny position. Samples were taken from shallow parts along the margin of the entire island.

Site 2 J – Canal (N 45°46'566", E 15°55'811")

Canal is a place where River Sava flows into the Lake Jarun. The surface of water was covered with water-lilies and leaves fallen from the trees growing near the canal. The bottom was sandy. The site was less sunny then the Island because of the shadows of the trees. Samples were taken from shallow parts along the margin of the canal.

2.2. Crna Mlaka

A Special Ornithological Wildlife Sanctuary Crna Mlaka is situated in the central part of swamps, moors, and forests of the River Kupa valley, south-east from Jastrebarsko, a little town between Zagreb and Karlovac. In the area of constantly inundated land, covering 625 hectares in the territory watered by the rivers of Okićnica, Brebernica and Volavčica, the land was brought under the cultivation and fish-ponds were built. After this, the middle part of Crna Mlaka, was transformed to a very nice park with horticultural trees and bushes.

The basin of Crna Mlaka and the surroundings are characterised by the temperate continental climate. Winters are mild (minimum in January is 1 ^{o}C), and summers are warm (minimum in July 19.5 ^{o}C), while springs and autumns are temperate. Overcast is the heaviest in winter and early spring and it is decreasing throughout the year. Precipitation is unequally distributed through the year. The total amount of precipitation per year is 996.8 milimetres. It is the heaviest in November and on the beginning of the summer. The moisture level is the highest in the winter (average is 87%), and is the lowest in the summer (74%). High level of humidity in winter often causes fogs. The prevailing wind is south-eastern. South-west winds are warm and humid and they blow in the spring. Because of the richness of precipitation, water-shaped soil of low permeability developed, solid, with large water and low air retaining capacity. The above mentioned geological, water and climate characteristics of the area determined the development of vegetation adapted to the mentioned conditions (Crna Mlaka, web page).

Figure 5. Crna Mlaka.

Crna Mlaka (Figure 5) was visited on 20. 6. 2008. Four sites were investigated, and there is no special name for each of them because samples were taken just from different places of fish ponds. Locations were mostly similar in appearance; sunny position, with smelly and heavily eutrophicated water with some water-lilies on the surface and cane and reed near the margins. The range of water temperature was from 23,0 to 29,0 ºC, and the conductivity range was from 237 to 488 µS/cm.

2.3. Žumberak

Žumberak–Samoborsko gorje Nature Park extends over some 350 km² and it was established in 1999. Its main purpose is to protect and promote the natural heritage of the area. The Nature Park includes a hilly territory situated south-west of Zagreb, with the elevation range from 180 to 1,178 metres above sea level, and the highest peak of Sveta Gera. It's eastern part is very indented, and comprises the territory of the Samobor mountain with the peaks of Japetić (871 m) and Plešivica (780 m), as well as the valleys of numerous rivulets. In that area there are also a large number of rivers, small lakes, ponds and backwaters (Žumberak, webpage).

Figure 6. Žumberak, Dane-Kordići Pond.

Žumberak (Figure 6) was visited on 21. 6. 2008. Five sites were investigated. No living bryozoan colonies have been found on Žumberak location. The range of water temperature was from 16,3 to 25,2 ºC, and the conductivity range was from 75 to 457 µS/cm.

Site 1 Ž – Rajska jezera (N 45°47'840", E 15°37'452")

Rajska jezera is a clean stream, near the road from Bregana town. There is a forest from both sides of the stream, so there is not much sun.

Site 2 Ž – Fishpond Divlje vode (N 45°50'173", E 15°36'377")

Divlje vode is a trout fishpond. The bottom of the ponds is concrete so there were no plants growing there.

Site 3 Ž – Fishpond Marinići (N 45°49'637", E 15°35'117")

It was the same situation like in the fishpond Divlje vode. Water was slightly eutrophicated, the position was sunny, and bottom was concrete, without plants.

Site 4 Ž – Dane – Kordići Pond (N 45°46'822", E 15°30'650")

The pond was 100 metres away from the road, near the forest.

Site 5 Ž – Budinjak Pond (N 45°47'283", E 15°29'851")
The place was similar in characteristics like the Dane-Kordići Pond.

2.4. Plitvice Lakes

Proclaimed a National Park in 1949, the Plitvice Lakes region is among the most valuable natural heritage sites in Croatia. It is on UNESCO's list of World Natural Inheritance. The Lakes are situated where Kordun touches Lika and in the Ogulinsko-Plaščanska valley, on the very spring of the karst river Korana - at 480 to 636 metres above the sea level, on the hillside of Mala Kapela and Plješivica. Plitvice Lakes are unique geological and hydrogeological phenomena of karst. The series of 16 lakes, separated by travertine barriers are the basic phenomena of the National Park. Travertine forming plants, algae and mosses have been and still are playing an important role in their creation, thus making a very sensitive biodynamic system. Under certain physical, chemical and biological conditions, calcium carbonate ($CaCO_3$) is being extracted from the water, and then is being deposited on the bottom of the lake, and on the submerged items. It also creates underwater thresholds and barriers which are elevating above the water growing constantly in height and width. The barriers are chalky creations, which are hard, porous and fragile limestone, full of remains of microscopic organisms and petrified water mosses that are growing up at the falls. Permanent and continuous creation of travertine at the Plitvice Lakes is the fundamental phenomenon of the National Park. The length of the Plitvice Lakes is 9050 m. The weather and the climatic characteristics of the Plitvice Lakes are conditioned by the mountain pass at 700 to 800 m above the sea level, and by about 50 km of air distance from the sea, where mountain ranges placed along the coast are descending into the mild, hilly continental land. The influence of mild Adriatic climate is considerably weakened at that point, and therefore the transitional type of climate between coastal and continental is prevailing. Even if microclimatic conditions are not the same all over the National Park, they still have, due to the relief of the ground, a common characteristic such as pleasant and sunny summer and relatively long, severe and snowrich winter (Plitvice Lakes, webpage).

Figure 7. Plitvice Lakes.

Figure 8. Plitvice Lakes, Batinovac Lake.

Plitvice (Figure 7, and 8) were visited from 23. 06. to 25. 06. 2008. Nine sites were investigated. The range of water temperature was from 9,2 to 21,9 ºC, and the conductivity range was from 391 to 552 µS/cm.

Site 1 P – Kozjački mostovi (N 44°53'664", E 15°36'523")

The water was shallow, clean and lentic.

Site 2 P – Rječica Creek (N 44°52'445", E 15°36'742")

Creek was situated in the forest. A lot of trees grew in it so a lot of old branches and leaves were found in the still water.

Site 3 P – Prošćansko Lake (N 44°52'458", E 15°36'753")

The lake was surrounded with forest so there was a lot of old branches and leaves in the water.

Site 4 P – Matica River (N 44°50'997", E 15°36'172")

Site 5 P – Black River (N 44°50'606", E 15°36'063")

Site 6 P – White River (N 44°50'571", E 15°35'983")

The water temperature of the River Matica, Black River, and White River was much lower, and the water was less eutrophicated then in the Plitvice Lakes below.

Site 7 P – Batinovac (N 44°50'568", E 15°35'984")

There was shallow water in the forest.

Site 8 P – Lake Okrugljak (N 44°52'435", E 15°36'025")

The site was characterized by low eutrophicated water.

Site 9 P – Lake Galovac

In this site a diver took samples from the bottom of the lake (1-4 meters).

2.5. Lonjsko Polje

Lonjsko Polje is a Nature Park declared in 1990. It is the largest protected wetland in Croatia. It is on the Ramsar list of wetlands that are of great international importance, particularly as natural habitats of waterfowl. According to the EU Bird Directive, the area is one of the Important Bird Areas (IBAs). Lonjsko Polje consists of three floodplains - Lonjsko, Mokro and Paganovo Polje. The Sava, Una, Kupa and Strug rivers all come together in the area of the nature park. Because of their extremely complex dynamics, floods are completely unpredictable in the area, or rather, have to be expected at any time of the year. If there are high water levels in all of the rivers at the same time, enormous quantities of water come together and result in floods. Life is bursting in Lonjsko Polje. Among such richness of species (550 plant species, 41 fish species, 238 bird species, 58 mammal species) it is important to mention many water plants like water-lily, and reed. Wetland birds like storks are of great significance too. Because of the large number of stork nests, the village Čigoć, was given the title "European Stork Village". Lonjsko Polje is a protected nesting place for endangered wetland bird spoonbill (*Platalea leucorodia*; Lonjsko polje, webpage).

Figure 9. Lonjsko polje, Krapje Đol.

Figure 10. Lonjsko polje, Mužilovčica.

Lonjsko polje (Figure 9, and 10) was visited on 27. 06. 2008. Five sites were investigated. The range of water temperature was from 27,6 to 31,1 ºC, and the conductivity range was from 338 to 447 µS/cm.

<u>Site 1 LP –Krapje đol (N 44°52'429", E 15°36'022")</u>

Krapje đol is a big swamp, full of reed. The water body was heavily eutrophicated and full of leeches, because cattle come to drink there. It is protected nesting site of the wetland bird spoonbill (*Platalea leucorodia*).

Site 2 LP – Puska Rukavac (N 45°19'674", E 16°47'984")

Site 3 LP – Tišina u Mužilovčici (N 45°23'416", E 16°40'973")

Site 4 LP – Mužilovčica Grabe (N 45°23'923", E 16°41'484")

Site 5 LP – Čigoć (N 45°25'224", E 16°37'282")

These sites were swamps with reed.

2.6. Krka River

Krka is a river in Croatia's region Dalmatia, with length of about 73 km. It is famous for its numerous waterfalls. It was proclaimed a National Park in 1985. The Krka National Park is located entirely within the territory of Šibenik - Knin County and encompasses an area of 109 km^2 along the Krka River: two kilometres downriver from Knin to Skradin and the lower part of the Čikola River. From the flooded part of the mouth, it is 72.5 km in length making the Krka the 22nd longest river in Croatia. The source of the Krka River is at the base of the Dinaric Mountains, 3.5 kilometres north-east of the base of Knin and 22 metres below Topoljski Slap, Veliki Buk and Krčić Slap, which are noisy cascades in the winter but run dry during the summer. The length of the freshwater section of the river is 49 km and that of the brackish section is 23.5 km. Significant tributaries of the Krka River include Krčić, Kosovčica, Orašnica, Butišnica and Čikola with Vrb. With its seven travertine waterfalls and a total drop of 242 meters, the Krka River is a natural and karstic phenomenon. Limestone deposits from dissolved calcium bicarbonate build up to form travertine barriers or thresholds and create waterfalls. The depositing of travertine is a constant and dynamic process, involving physiochemical factors and organisms living in the water. The sedimentation of travertine only occurs in water containing dissolved calcium bicarbonate, so that the main prerequisite for travertine deposit is sufficient calcium bicarbonate in the water (Krka River, web page).

Figure 11. Krka River – Skradinski Buk.

Krka (Figure 11) was visited from 3. 09. to 6. 09. of 2008. Twenty five sites were investigated. The range of water temperature was from 10,2 to 26,3 ºC, and the conductivity range was from 430 to 855 µS/cm.

Site 1 K – Topoljski buk (N 44˚02'521", E 16˚14'087")

Site 2 K – Krčić Fishfarm (N 44˚02'388", E 16˚13'748")

Site 3 K – Sastavak (N 44˚02'345", E 16˚11'103")

These sites were characterized by low eutrophicatd and cold water.

Site 4 K – Marsovina (N 44˚00'620", E 16˚05'557")

Site 5 K – Bilušića Buk (N 44˚00'780", E 16˚03'610")

Site 6 K – Brljan (N 44˚00'744", E 16˚01'992")

Site 7 K – Orthodox Monastery (N 43˚57'720", E 15˚59'521")

Site 8 K – Nečven Brzak (N 43˚58'504", E 16˚01'411")

Site 9 K – Nečven – Orthodox Monastery (N 43˚58'350", E 16˚00'844")

Site 10 K – 200 m upflow from the Orthodox Monastery (N 43˚57'839", E 15˚59'526")

Site 11 K – Verovića Bare (N 43˚57'836", E 15˚59'532")

Site 12 K – Roški Waterfall (N 43˚57'833", E 15˚59'540")

Site 13 K – Ribarska Cave (N 43˚56'540", E 15˚59'484")

Site 14 K – Čikola River Delta (N 43˚48'565", E 15˚59'728")

Site 15 K – Roški Slap downflow (N 43˚54'214", E 15˚58'481")

Site 16 K – Među Gredama (N 43˚51'861", E 15˚58'351")

Site 17 K – Visovac Monastery (N 43˚51'635", E 15˚58'391")

Site 18 K – Skradinski Buk (harbour) (N 43˚48'136", E 15˚58'323")

Site 19 K – Skradinski Buk (old channel) (N 43˚48'123", E 15˚57'990")

Site 20 K – Skradinski Buk (under the waterfall) (N 43˚48'132", E 15˚57'995")

Site 21 K – Skradinski Buk (shallow water body) (N 43˚48'414", E 15˚57'787")

These sites were characterized by slightly eutrophicated water.

Site 22 K – Skradinski Buk (touristic harbour) (N 43˚48'473", E 15˚57'675")

Site 23 K – Skradinski Buk harbour (right coast) (N 43˚48'550", E 15˚57'522")

Site 24 K – Skradinski Buk harbour (left coast) (N 43˚48'703", E 15˚57'205")

Site 25 K – Skradinski Bridge (N 43˚49'121", E 15˚56'074")

These sites were characterized by presence of brackish water.

3.1 Sampling

Most colonies of freshwater bryozoans were taken in the shallow regions of lakes, ponds, rivers and backwaters. They were found on natural substrate such as stems and leaves of aquatic plants, submerged tree roots and branches, and rocks. Whenever possible, colonies were collected by removing them together with a portion of the substrate to which they were attached. This entailed chipping thin pieces of rock with a cold chisel or using a knife to slice off thin strips of wood along with intact colonies (Wood & Okamura, 2003). On Plitvice Lakes, on Lake Galovac, sampling was obtained by SCUBA diving method.

The colonies were transported in pond-water, along with the substrate that they were attached to, to the laboratory, and later after a general determination by magnifier lens, they were preserved in 70%, respectively 96% ethyl alcohol. Later on statoblasts were isolated with special thin needle which made it possible to take out statoblast from the colony and not damage them in the same time.

3.2. Environmental measurements

Temperature and conductivity were measured in all locations, and in all sites except in Lake Galovac, on Plitvice Lakes. Oxygen levels, saturation, and pH were measured only in Plitvice Lakes, and that was done by a staff member of the National Park Maja Vurnek, B. Sc. Salinity was measured only in Krka River.

3.3 Identifying specimens

Genera were determined from colony morphology alone in several cases, however, identification to the species level almost always required the presence of statoblasts.

After a successful isolation out of the colonies, the dimensions of the various statoblasts could be measured by ocular micrometre on stereomicroscope. It is very important that resting stages for measurement were wet, because dry statoblasts shrink significantly. Both sides of the statoblasts had to be measured as the ventral and the dorsal sides are completely different. Altogether, four dimensions were measured per ventral and four dimensions per dorsal side of each statoblast: total length and total width of statoblast, and total length and total width of fenestra (N=4). Finally, statoblasts were prepared for scanning electron microscopy (SEM) by cleaning them for 20 min in household bleach diluted with water, in volume ratio 1: 4.

4.1. List of species

The species list in Croatia (Table 2) is based on preliminary results of the ongoing project "First survey on freshwater bryozoans in Croatia" (Wöss & Novosel). So far, 11 freshwater bryozoan species were identified on the territory of the Republic of Croatia, including ten Phylactolaemates and one Gymnolaemate.

Table 2. List of determined species of freshwater bryozoans in Croatia (preliminary results, Wöss & Novosel, *in prep*.)

Class Gymnolaemata, Subclass Ctenostomata

Family Paludicellidae
1. *Paludicella articulata* (Ehrenberg, 1831)

Class Phylactolaemata

Family Fredericellidae
2. *Fredericella sultana* Blumenbach, 1779
Family Plumatellidae
3. *Hyalinella punctata* (Hancock, 1850)
4. *Plumatella casmiana* Oka, 1907
5. *Plumatella emarginata* Allman, 1844
6. *Plumatella fruticosa* Allman, 1844
7. *Plumatella fungosa* (Pallas, 1768)
8. *Plumatella repens* (Linnaeus, 1758)
9. *Plumatella geimermassardi* Wood & Okamura, 2004
Family Cristatellidae
10. *Cristatella mucedo* Cuvier, 1798
Family Lophopodidae
11. *Lophopus crystallinus* (Pallas, 1768)

4.2. Distribution of the species

So far, about 90% of samples from the sites Jarun, Žumberak, Crna Mlaka, Plitvice Lakes and Lonjsko Polje have been determined (Wöss & Novosel, *in prep*.) and nine species can be recorded for those regions (Table 3). The analysis of samples of the Krka River is still in process. However, first results of Krka River show that two more species, *Fredericella sultana* and *Cristatella mucedo* can be added to the species list of freshwater bryozoans in Croatia.

Photographs of the species found in Croatia until today are given on Figure 12 to 29.

Table 3. List of freshwater bryozoan species found by localities. J - Jarun; Ž - Žumberak; CM - Crna Mlaka; P - Plitvice Lakes; LP - Lonjsko Polje; K – Krka.

SPECIES	RESEARCHED SITES *
Paludicella articulata	1P, 3P, 7P, 9P, 12K, 19K
Fredericella sultana	11K, 13K, 19K
Plumatella casmiana	2CM, 4CM, 4LP, 5LP
Plumatella emarginata	4LP, 4CM, 8K, 9K, 10K, 11K, 12K
Plumatella fruticosa	2J, 1P, 3P, 7P, 8P, 9P, 3LP, 4LP, 6K
Plumatella fungosa	4LP, 5LP, 11K
Plumatella geimermassardi	5LP
Plumatella repens	J1, J2, 1CM, 3CM, 4CM, 4Ž, 1P, 2P, 8P, 1LP, 2LP, 3LP, 4LP, 5LP,6K, 7K, 9K, 10K, 11K, 12K, 13K
Hyalinella punctata	2CM, 3LP, 4LP
Lophopus crystallinus	1LP
Cristatella mucedo	12K

* for full name of sites see Table 1.

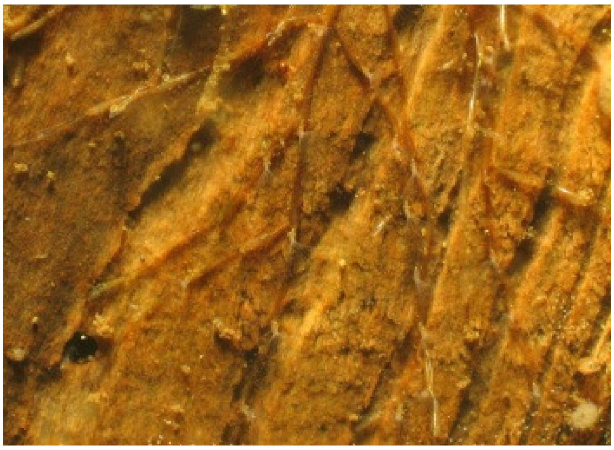

Figure 12. *Paludicella articulata* on the natural substrata (from www.bryozoans.nl).

Figure 13. Zooid of *Paludicella articulata* (from www.bryozoans.nl).

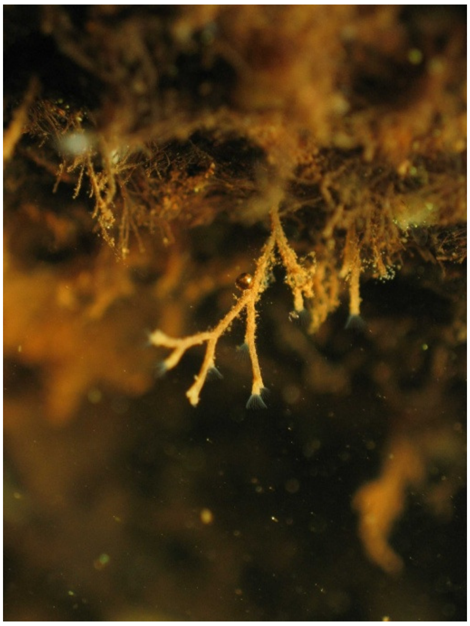

Figure 14. Colony of *Fredericella sultana* (from www.bryozoans.nl).

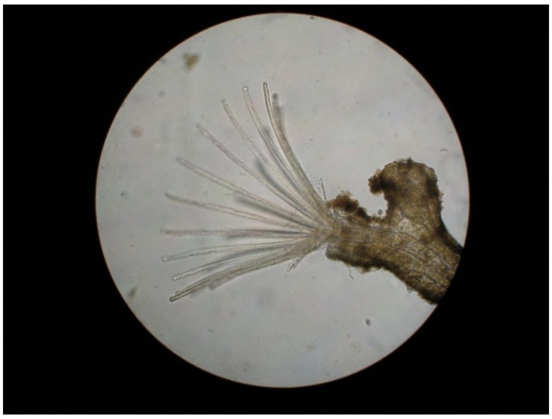

Figure 15. Zooid of *Fredericella sultana* (from www.bryozoans.nl).

Figure 16. Colony of *Plumatella casmiana* (photo Emmy Wöss).

Figure 17. Zooids of *Plumatella casmiana* (photo Emmy Wöss).

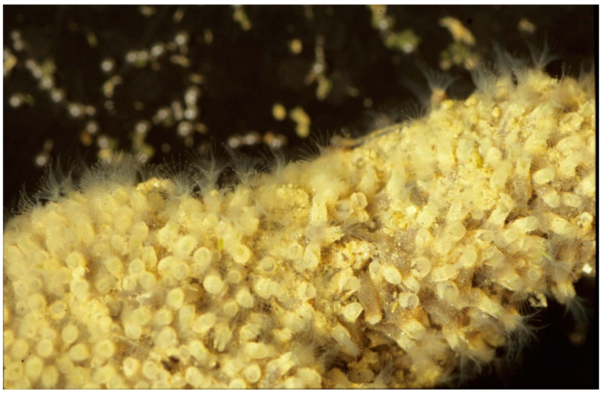

Figure 18. Colony of *Plumatella emarginata* (photo Emmy Wöss).

Figure 19. Zooids of *Plumatella emarginata* (photo Emmy Wöss).

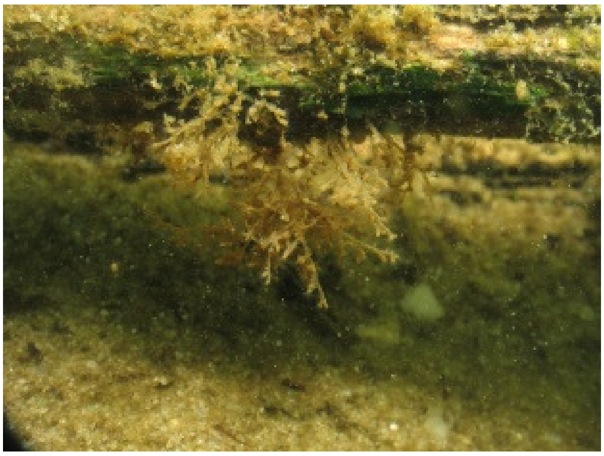

Figure 20. *Plumatella fruticosa* on the natural substrata (from www.bryozoans.nl).

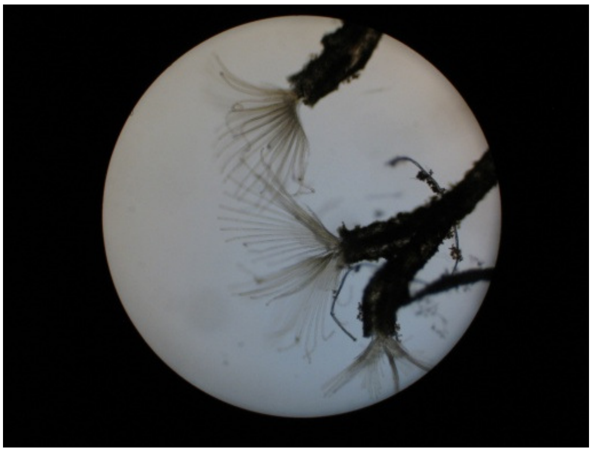

Figure 21. Zooids of *Plumatella fruticosa* (from www.bryozoans.nl).

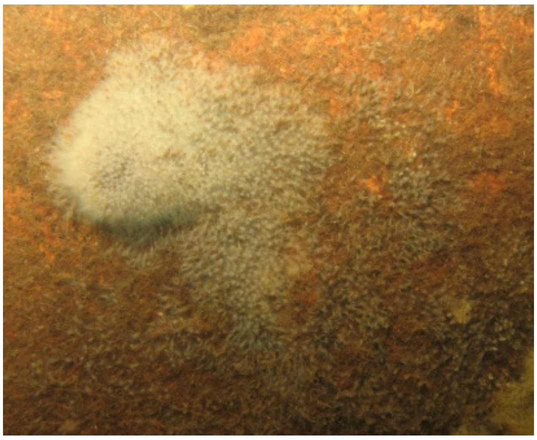

Figure 22. *Plumatella fungosa* on the natural substrata (from www.bryozoans.nl).

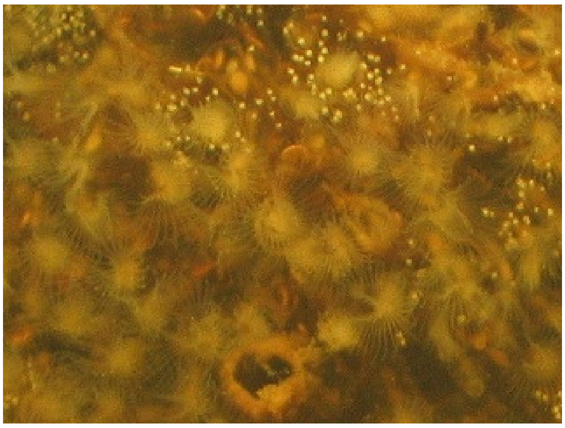

Figure 23. Zooids of *Plumatella fungosa* (from www.bryozoans.nl).

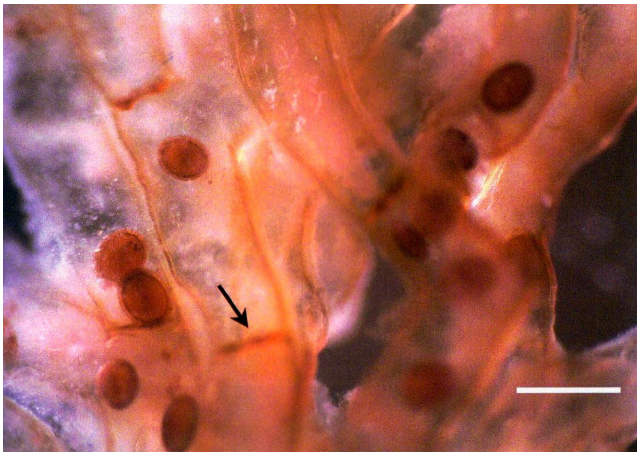

Figure 24. Tubules of *Plumatella geimermassardi* (from Taticchi, Pieroni, Gustinelli & Prearo, 2005).

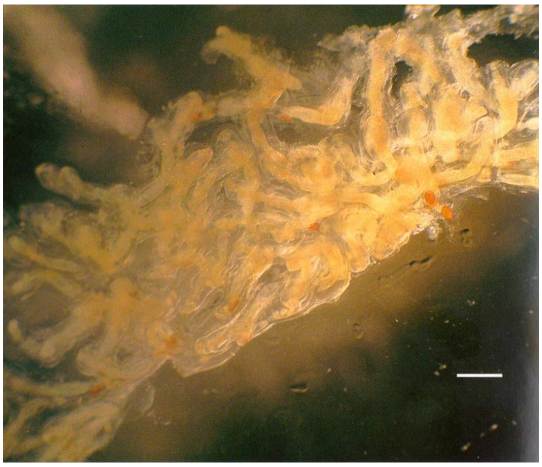

Figure 25. Colony of *Plumatella geimermassardi* (from Taticchi, Pieroni, Gustinelli & Prearo, 2005).

Figure 26. *Plumatella repens* on water lily leaf (photo Maja Novosel).

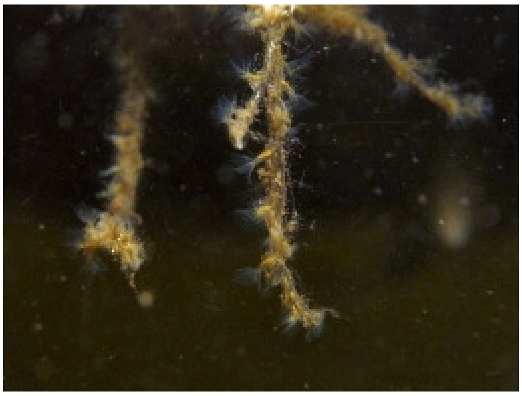

Figure 27. Colony of *Plumatella repens* (from www.bryozoans.nl).

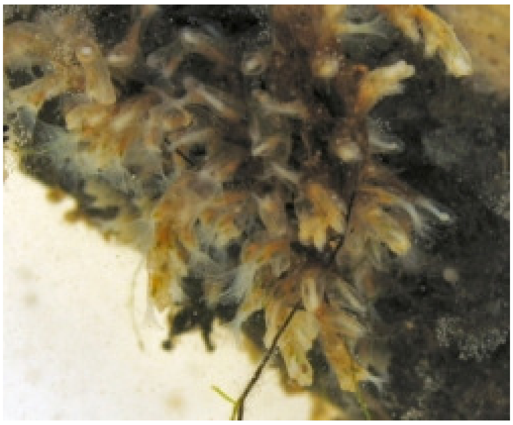

Figure 28. *Hyalnella punctata* on natural substrata (from www.bryozoans.nl).

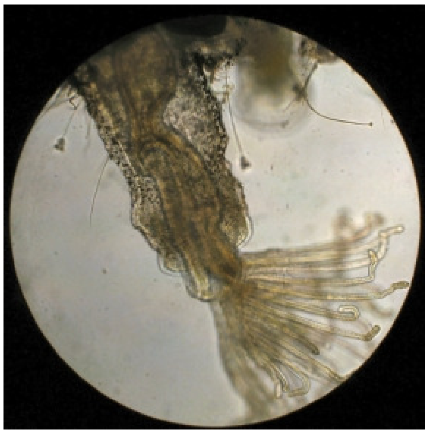

Figure 29. Zooid of *Hyalnella punctata* (from www.bryozoans.nl).

Figure 30. Sac-shaped colony of *Lophopus crystallinus* (from www.bryozoans.nl).

Figure 31. Zooid of *Lophopus crystallinus* (from www.bryozoans.nl).

Figure 32. Colony of *Cristatella mucedo* (from www.bryozoans.nl).

Figure 33. Zooids of *Cristatella mucedo*(from www.bryozoans.nl).

In the period from June to September 2008 six different locations were visited to investigate the distribution of freshwater bryozoans in Croatia. These locations were: Jarun, Crna Mlaka, Žumberak, Plitvice Lakes, Lonjsko Polje, and Krka River. At the present time, 11 species of freshwater bryozoans have been recorded from these sites: *Paludicella articulata, Fredericella sultana, Hyalinella punctata, Plumatella casmiana, Plumatella emarginata, Plumatella fruticosa, Plumatella fungosa, Plumatella repens, Plumatella geimermassardi, Cristatella mucedo*, and *Lophopus crystallinus.* Further on, the distribution of 11 species mentioned for Croatia is discussed in the relation to their occurrence in Europe.

5.1. Distribution of freshwater bryozoans in the world

Until today, 88 bryozoan species have been found in freshwater (Massard & Geimer, 2007). Sixty nine of them are Phylactolaemate and 19 are Gymnolaemate species (Figure 30).

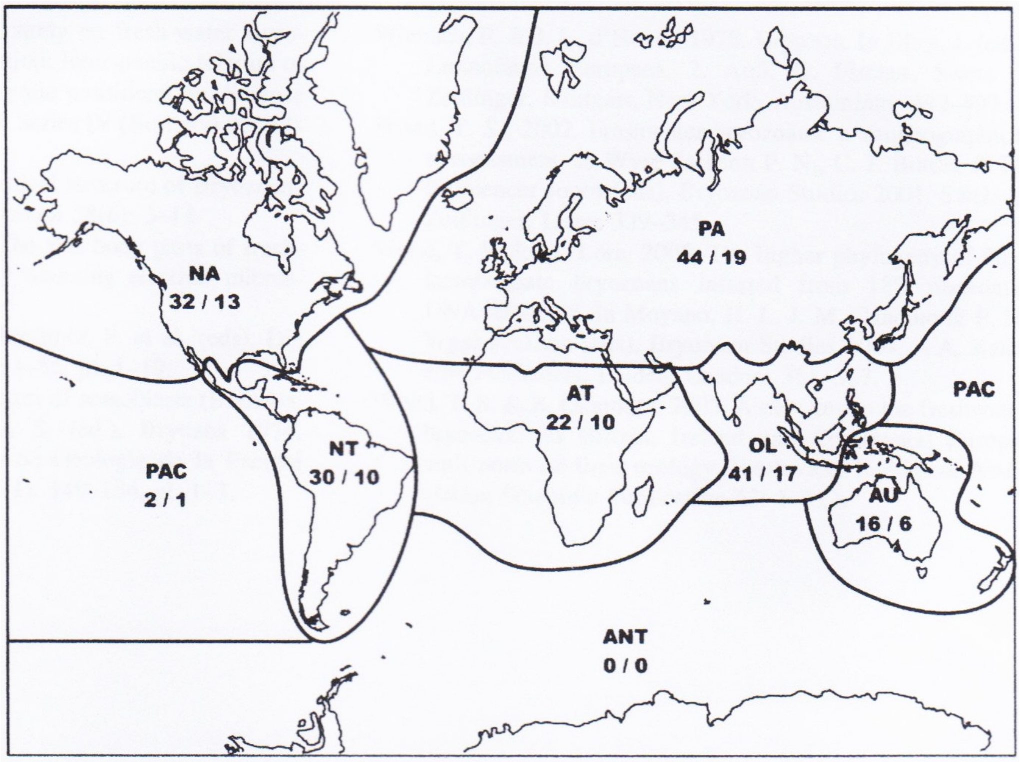

Figure 34. Zoogeographical distribution map (species/genus number per region). PA - Palaeartic; NA - Neartic; NT - Neotropical; AT - Afrotropical; OL - Oriental; AU - Australasian; PAC - Pacific Oceanic Islands; ANT - Antarctic (Massard & Geimer, 2007).

Roughly 49% of these species are confined to one zoogeographical region (Massard & Geimer, 2007). Taxonomic revisions and the re-examination of misidentified material have diminished the reported ranges of many species. The long time accepted cosmopolitan status of species like *Fredericella sultana*, *Plumatella repans* and *Plumatella emarginata* has been challenged. Only *Plumatella casmiana* now approaches cosmopolitan status, although it is not yet reported from South America. In general Asia, Africa, and South America are still largely unexplored for freshwater bryozoans (Wood, 2002).

5.2. Distribution of freshwater bryozoans in Europe in regard to the findings in Croatia

For nearly two centuries, the foundation for freshwater bryozoology has been led primarily by biologists from Britain and Europe. Five important monographs on the group have come from this region, as have seminal studies on embryology, development, physiology and systematics (Wood & Okamura, 2005).

Today there are 19 discovered species of freshwater bryozoans in Europe: *Paludicella articulata*, *Victorella pavida*, *Cristatella mucedo, Fredericella indica, Fredericella sultana*, *Internectella bulgarica, Lophopus crystallinus*, *Lophopodella carteri, Pectinella magnifica, Hyalinella punctata*, *Plumatella bombayensis*, *Plumatella casmiana*, *Plumatella emarginata*, *Plumatella fruticosa*, *Plumatella fungosa*, *Plumatella geimermassardi, Plumatella repens*, *Plumatella reticulata*, and *Plumatella rugosa* (Wood & Okamura, 2005).

Distribution in Europe in regard to the eleven species found in Croatia are given through the maps below (Figure 31 to Figure 41).

Paludicella articulata

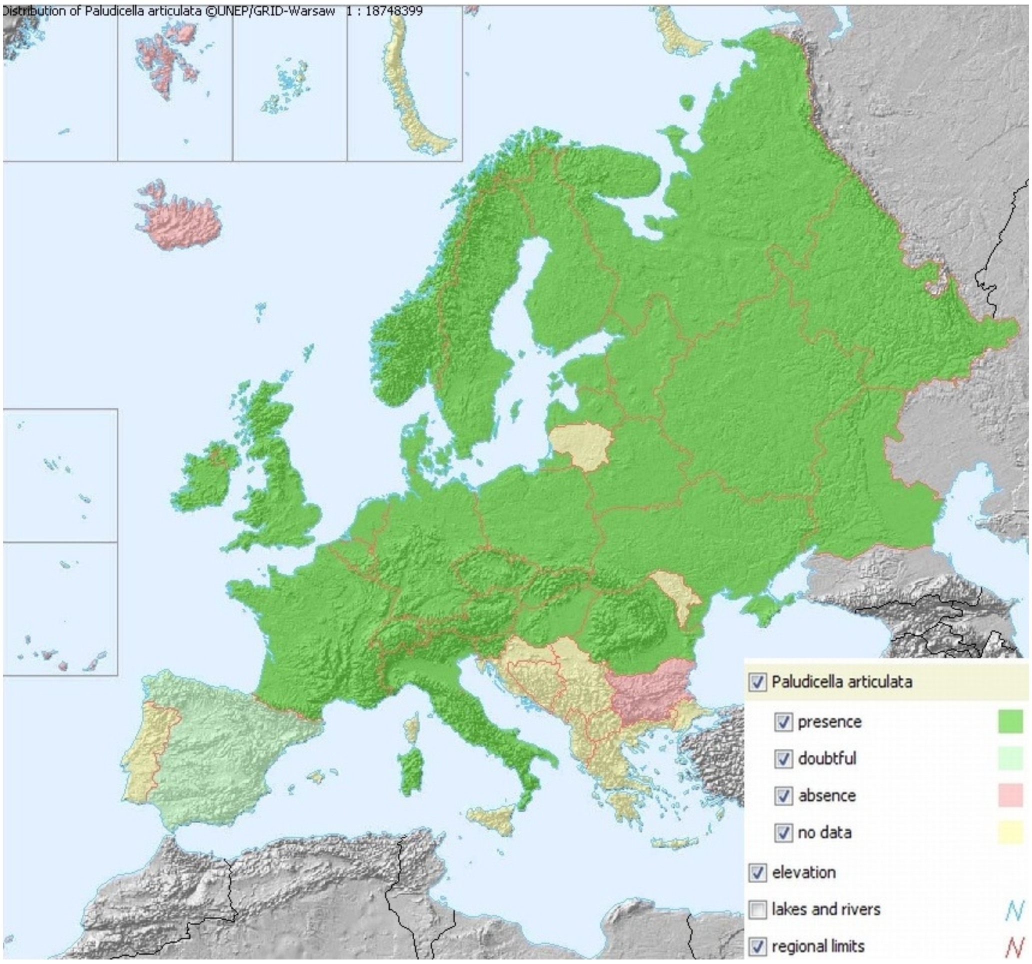

Figure 35. Distribution of *Paludicella articulata* in Europe (from www.faunaeur.org).

Paludicella articulata is found in: Austria, Belarus, Belgium, Britain, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Northern Ireland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, Norwegian mainland, Poland, Romania, Russia, Sardinia, Slovenia, doubtful in Spanish mainland, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage).

Fredericella sultana

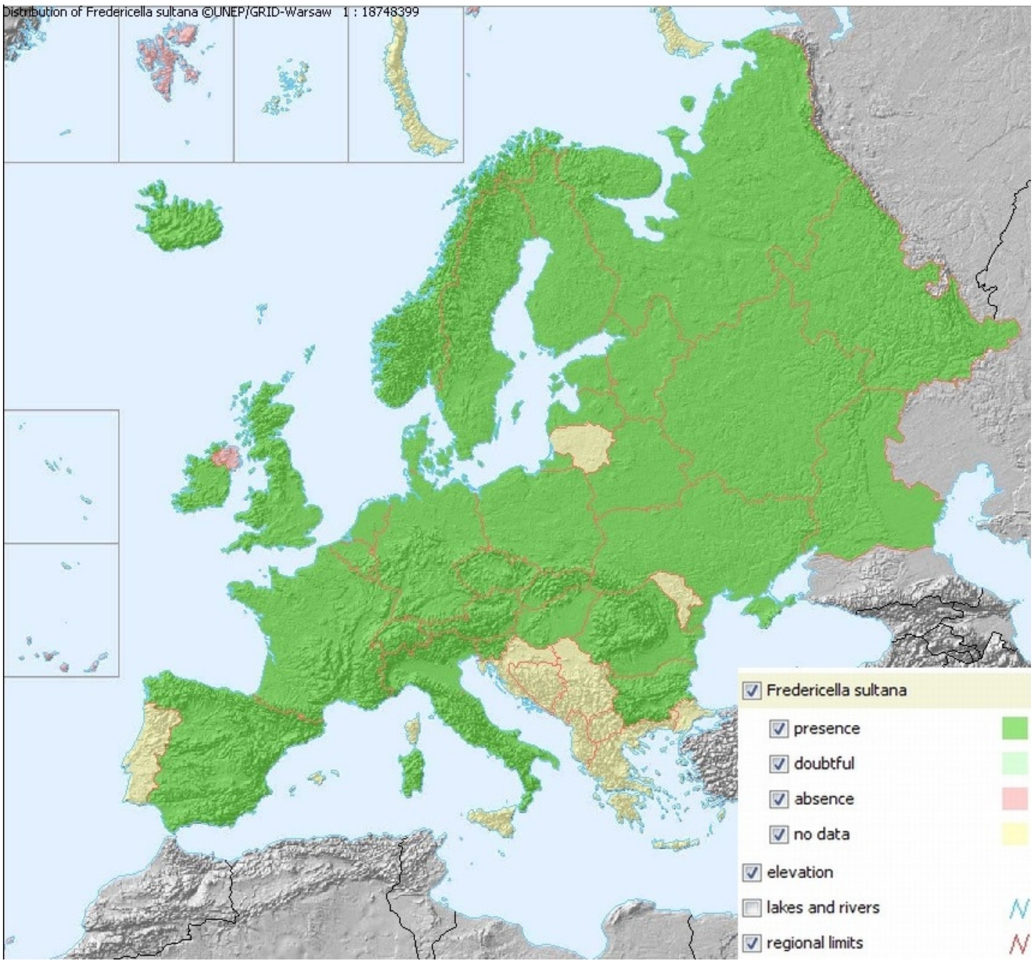

Figure 36. Distribution of *Fredericella sultana* in Europe (from www.faunaeur.org).

Fredericella sultana is found in: Austria, Belarus, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Iceland, Ireland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, Norwegian mainland, Poland, Romania, Russia, Sardinia, Slovenia, Spanish mainland, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage). *Fredericella sultana* is the most common Fredericellid in Britain, Ireland, and Europe.

Hyalinella punctata

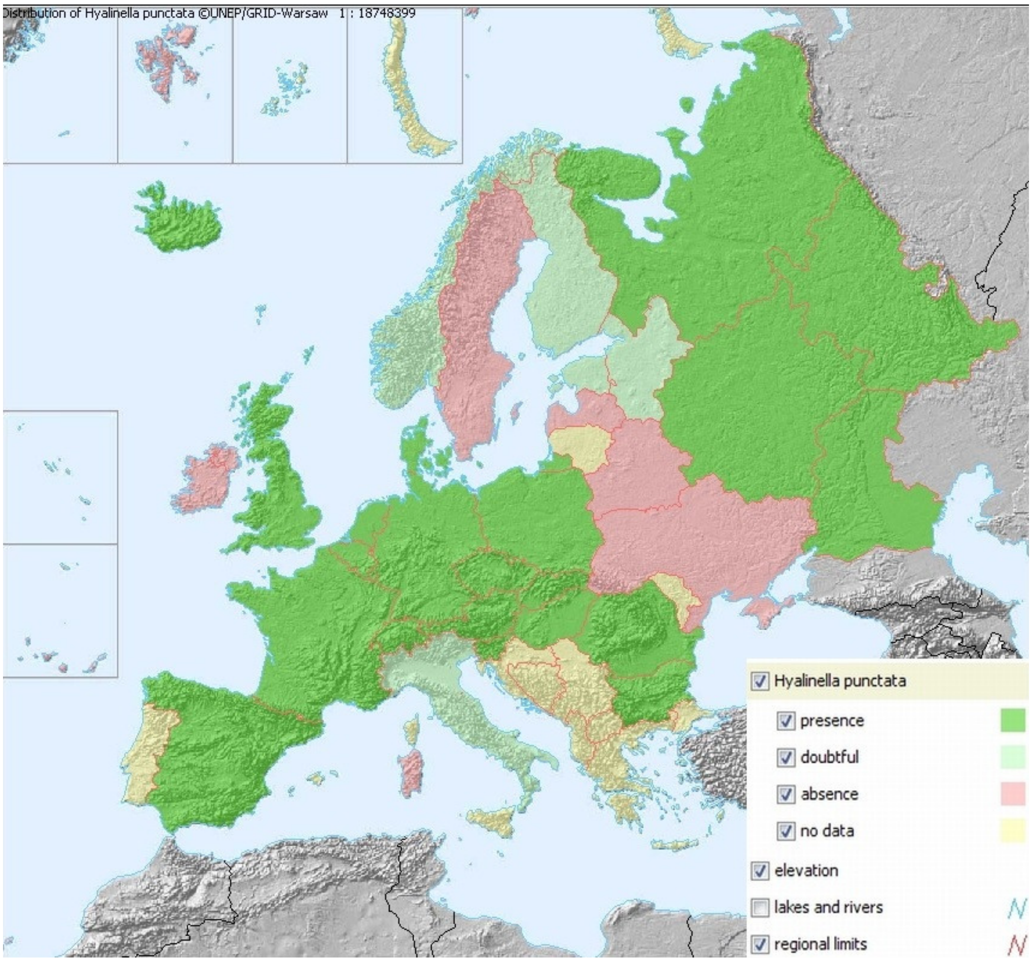

Figure 37. Distribution of *Hyalinella punctata* in Europe (from www.faunaeur.org).

Hyalinella punctata is found in: Austria, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, doubtful in Estonia, doubtful in Finland, French mainland, Germany, Hungary, Iceland, doubtful in Italian mainland, Kaliningrad Region, Luxembourg, doubtful in Norwegian mainland, Poland, Romania, Russia (doubtful in Northwest Russia), Slovakia, Slovenia, Spanish mainland, Sweden, Switzerland, and The Netherlands (Fauna Europaea, webpage).

Plumatella casmiana

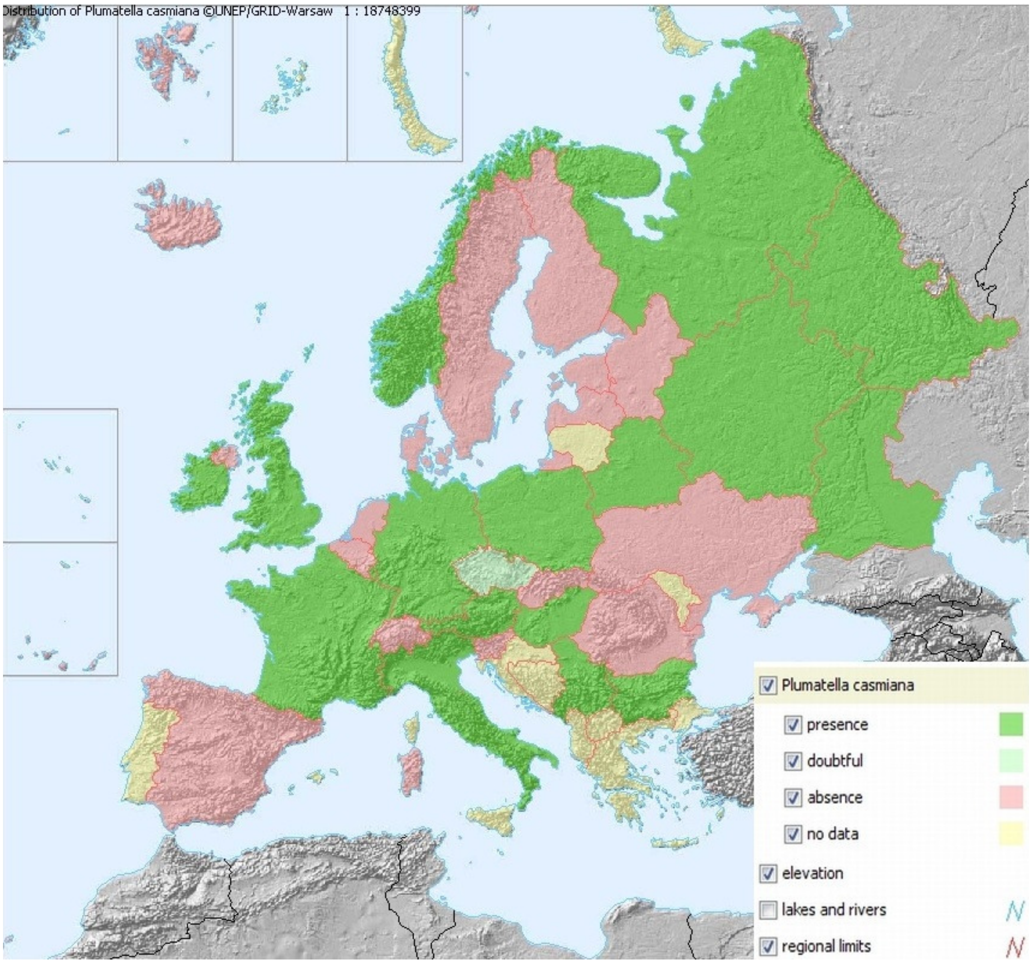

Figure 38. Distribution of *Plumatella casmiana* in Europe (from www.faunaeur.org).

Plumatella casmiana is found in: Austria, Belarus, Britain, Bulgaria, doubtful in Czech Republic, French mainland, Germany, Hungary, Ireland, Italian mainland, Luxembourg, Norwegian mainland, Poland, Russia (except Northwest Russia where it is absent), Serbia, Kosovo, Voivodina, and Montenegro (Fauna Europaea, webpage).

Plumatella emarginata

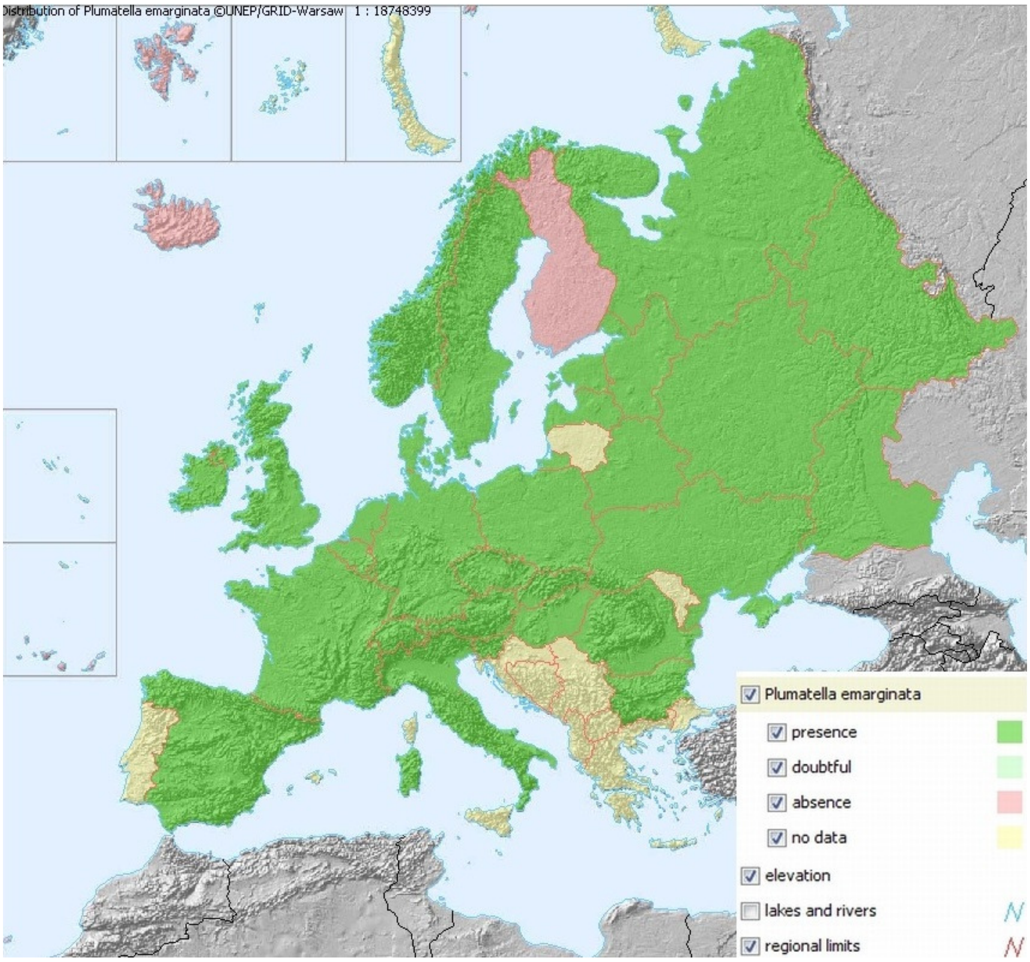

Figure 39. Distribution of *Plumatella emarginata* in Europe (from www.faunaeur.org).

Plumatella emarginata is found in: Austria, Belarus, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, Estonia, French mainland, Germany, Hungary, Ireland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, Northern Ireland, Norwegian mainland, Poland, Romania, Russia, Sardinia, Slovenia, Spanish mainland, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage).

Plumatella fruticosa

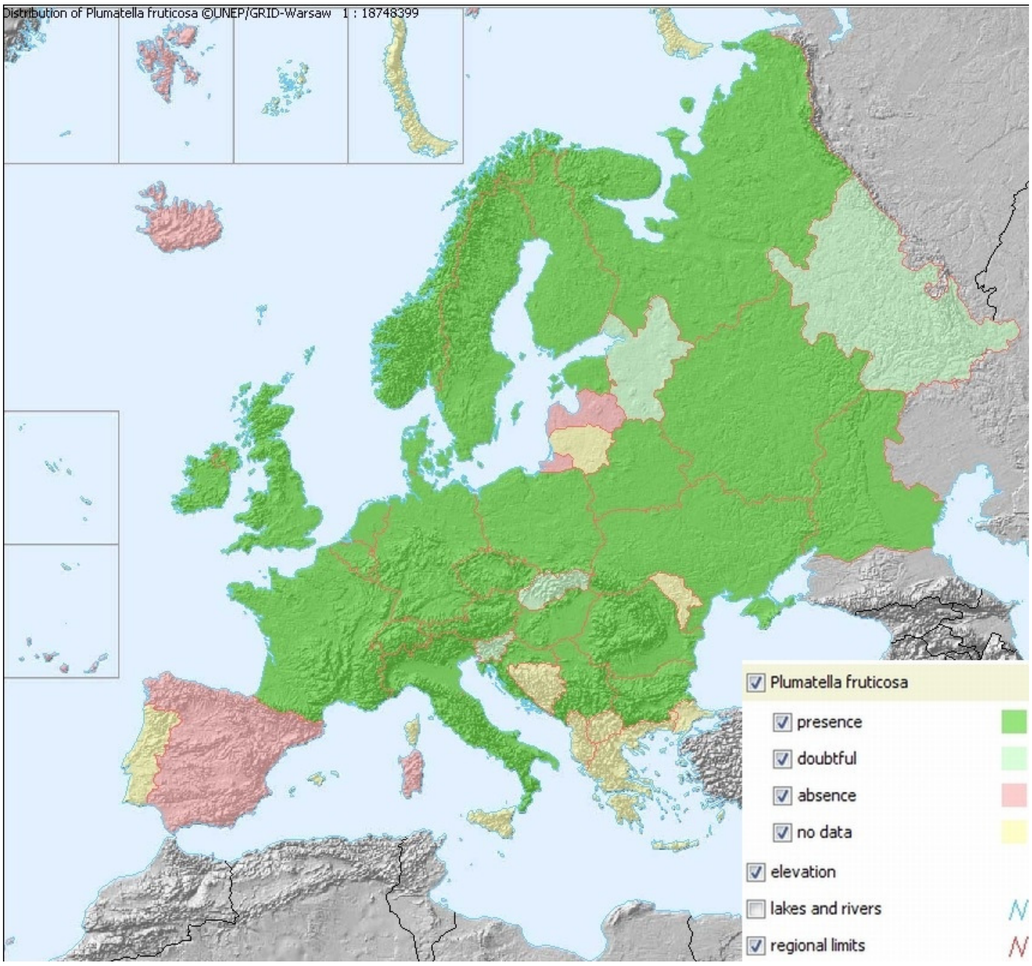

Figure 40. Distribution of *Plumatella fruticosa* in Europe (from www.faunaeur.org).

Plumatella fruticosa is found in: Austria, Belarus, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Ireland, Italian mainland, Luxembourg, Norwegian mainland, Poland, Romania, Russia (East and Northwest Russia are doubtful), doubtful in Slovakia, doubtful in Slovenia, Sweden, Switzerland, The Netherlands, Ukraine, Serbia, Kosovo, Voivodina, and Montenegro (Fauna Europaea, webpage).

Plumatella fungosa

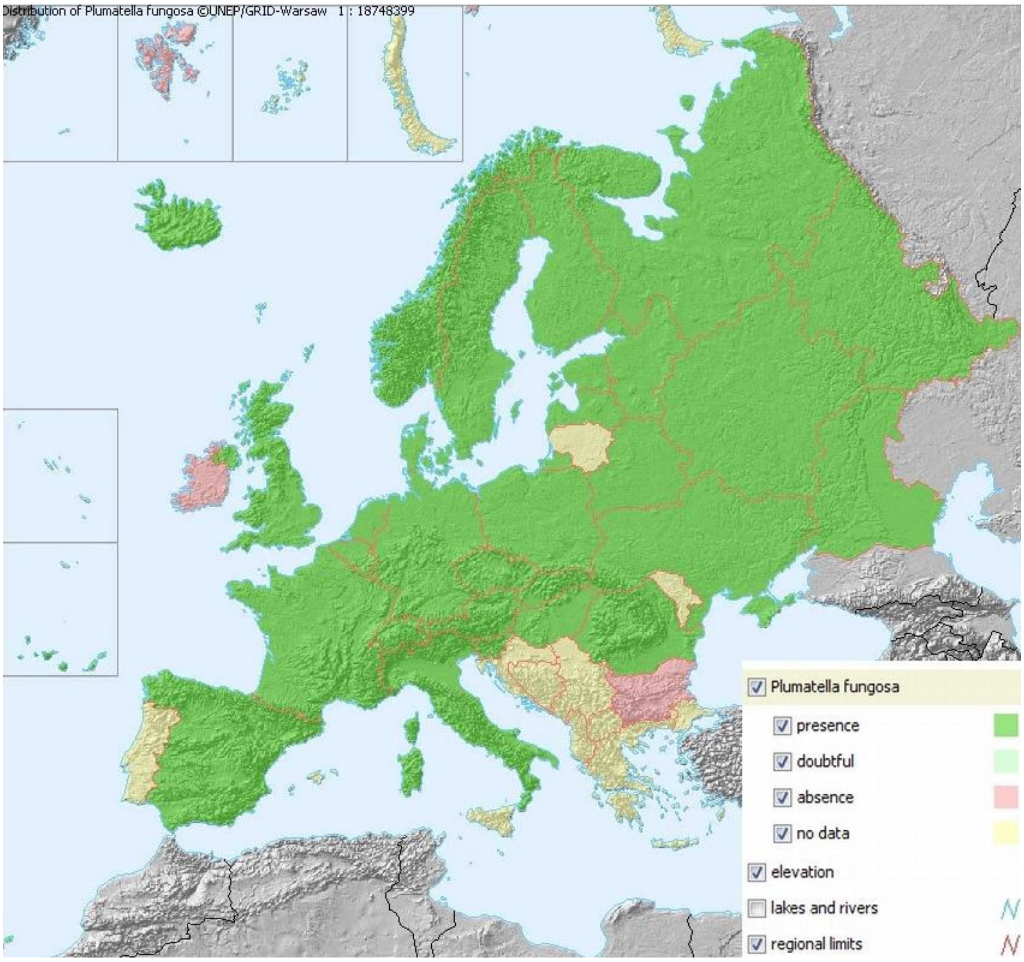

Figure 41. Distribution of *Plumatella fungosa* in Europe (from www.faunaeur.org).

Plumatella fungosa is found in: Austria, Belarus, Belgium, Britain, Canary Islands, Corsica, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Iceland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, Northern Ireland, Norwegian mainland, Poland, Romania, Russia, Sardinia, Slovenia, Spanish mainland, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage).

Plumatella repens

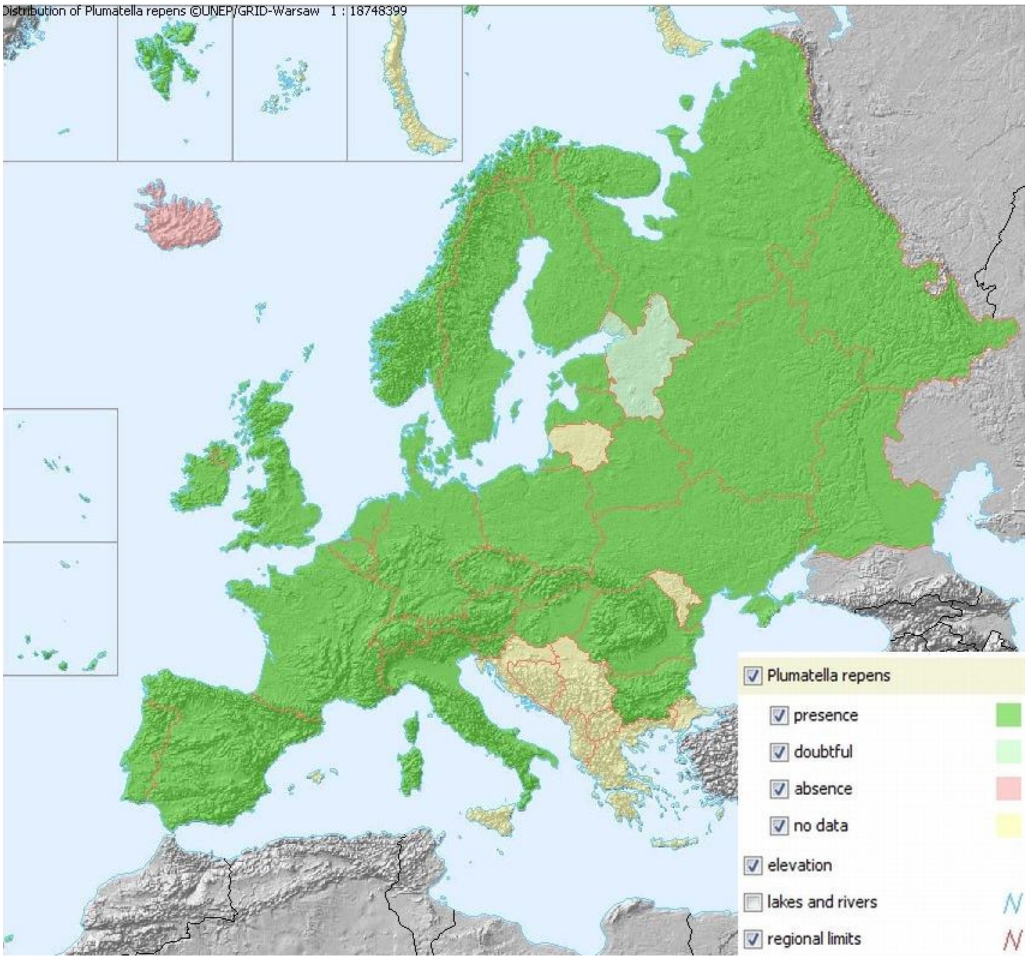

Figure 42. Distribution of *Plumatella repens* in Europe (from www.faunaeur.org).

Plumatella repens is found in: Austria, Azores, Belarus, Belgium, Britain, Bulgaria, Canary Islands, Corsica, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Ireland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, North Ireland, Norwegian mainland, Poland, Portuguese mainland, Romania, Russia, (except Northwest Russia where it is doubtful), Sardinia, Slovakia, Slovenia, Spanish mainland, Svalbard & Jan Mayen, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage).

Plumatella geimermassardi

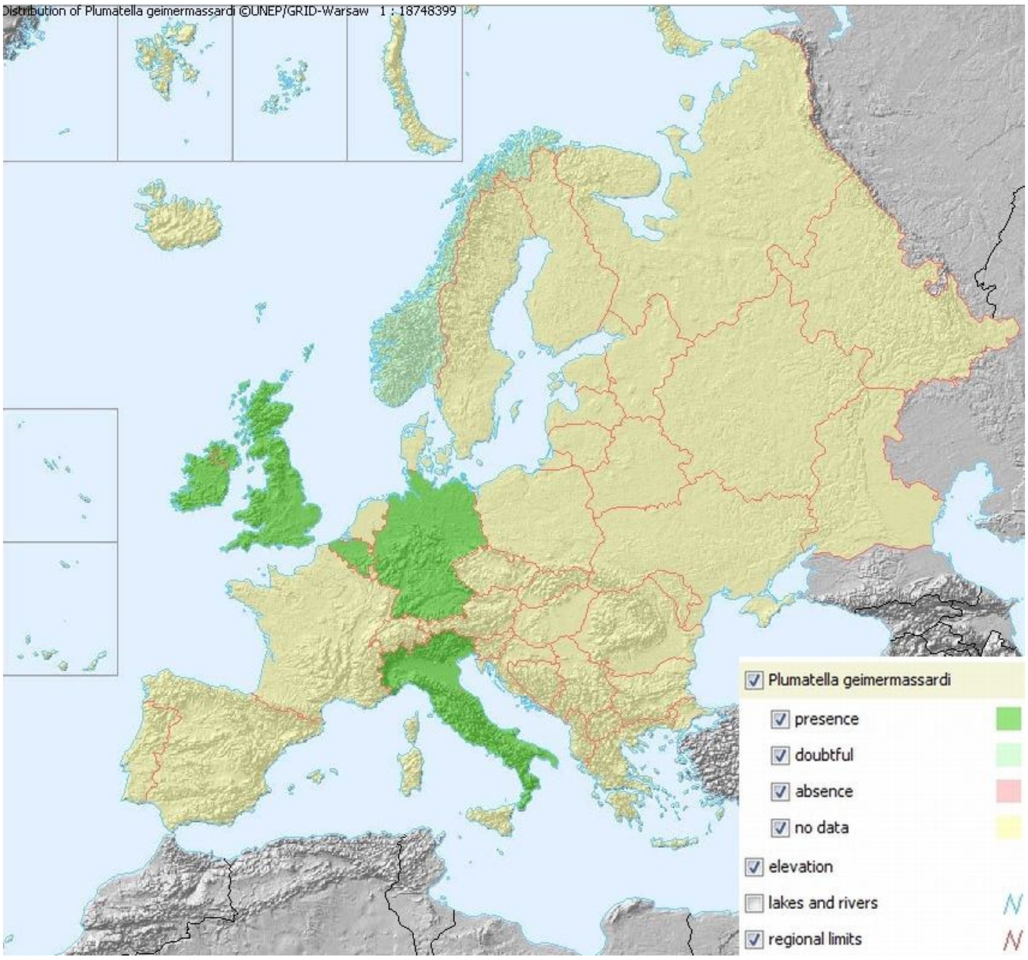

Figure 43. Distribution of *Plumatella geimermassardi* in Europe (from www.faunaeur.org).

Plumatella geimermassardi is found in: Belgium, Britain, Germany, Ireland, Italian mainland, Northern Ireland, doubtful in Norwegian mainland (Fauna Europaea, webpage).

Cristatella mucedo

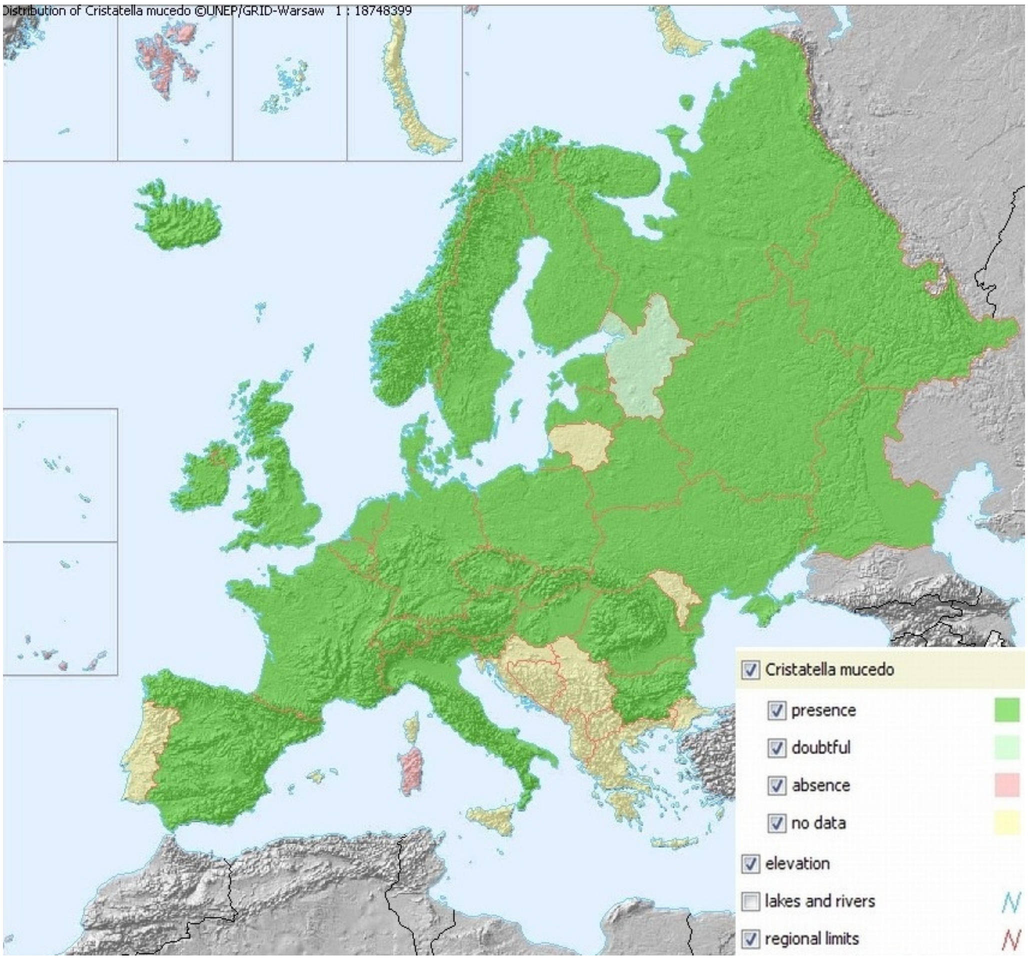

Figure 44. Distribution of *Cristatella mucedo* in Europe (from www.faunaeur.org).

Cristatella mucedo is found in: Austria, Belarus, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, Estonia, Finland, French mainland, Germany, Hungary, Iceland, Ireland, Italian mainland, Kaliningrad Region, Latvia, Luxembourg, Northern Ireland, Norwegian mainland, Poland, Romania, Russia (except Northwest Russia where it is doubtful), Slovakia, Slovenia, Spanish mainland, Sweden, Switzerland, The Netherlands and Ukraine (Fauna Europaea, webpage).

Lophopus crystallinus

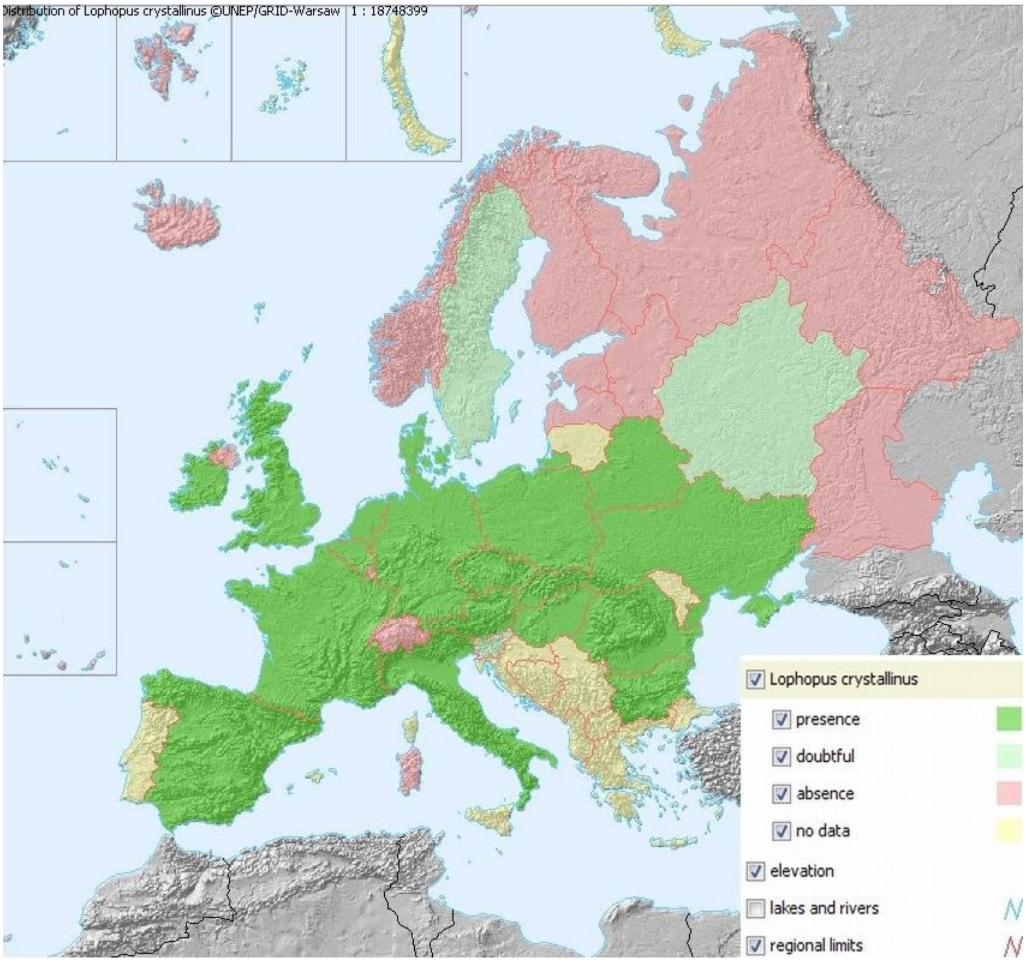

Figure 45. Distribution of *Lophopus crystallinus* in Europe (from www.faunaeur.org).

Lophopus crystallinus is found in: Austria, Belarus, Belgium, Britain, Bulgaria, Czech Republic, Danish mainland, French mainland, Germany, Hungary, Ireland, Italian mainland, Kaliningrad Region, Poland, Romania, doubtful in Central Russia, doubtful in Slovenia, Spanish mainland, doubtful in Sweden, The Netherlands, and Ukraine (Fauna Europaea, webpage).

Lophopus cristallinus occurrs throughout Europe. Although once common in the whole Britain, since 1970s it has only been encountered in four British sites and currently occurs at a single sites in Lincolnshire and Oxfordshire. It is the only bryozoan included as a priority species in the Biodiversity Action Plan which aims to conserve biodiversity within the UK, and is the only Phylactolaemate in the Red Data Book (Wood & Okamura, 2005). According to new data from the UK *Lophopus crystallinus* statoblasts were found in debris samples from sites: River Cut, River Cole, Rivers Whitewater and Hart, Loddon, Millbrook, River Colne, River Blackwater; and on Dinton Pastures: Lavell's Lake, Sundford Lake, Tufty's Corner, Blackswan Lake, Whiteswan Lake, Great Ouse, River Thames, River Kennt and River Chelmer (Okamura et al., 2007).

Bushnell (1973) pointed out the possible importance of migrating waterfowl in distributing bryozoans. It is known that birds transport statoblasts on their feathers or in their gut. Among the effective vectors of such passive dispersal would be those birds that breed in one place, and overwinter in another. However, this hipothesis requires constant monitoring of those birds and bryozoans that could be transported in this way. Some bryozoans are well adapted to varied conditions such as desiccation or cold storage, for example *Cristatella mucedo, Plumatella fruticosa* or *Fredericella sultana*. It therefore comes as no surprise that all of these species have been reported in northern regions of Europe, Asia, and North America.

Some species do not tolerate these extreme conditions, and therefore are not so widely distributed (Wood, 2002).

The information about migration routes is still insufficient. Also Asia, Africa, and South America remain little studied areas for freshwater bryozoans. In this way, theory of regularity in finding certain bryozoans in places were they should be transported by certain birds still has a lot of blankness.

However, this survey has demonstrated the distribution compatibility of freshwater bryozoans in Croatia and in Europe, and by that filled a little piece of that puzzle.

1. The locations that were sampled in order to find freshwater bryozoans in Croatia were: Jarun, Crna Mlaka, Žumberak, Plitvice Lakes, Lonjsko polje, and Krka River.
2. All together 11 different species of freshwater bryozoans were found on the territory of Croatia.
3. These freshwater species were: *Paludicella articulata, Fredericella sultana, Hyalinella punctata, Plumatella casmiana, Plumatella emarginata, Plumatella fruticosa, Plumatella fungosa, Plumatella repens, Plumatella geimermassardi, Cristatella mucedo*, and *Lophopus crystallinus.*
4. The finding of the species *Lophopus cristallinus* in Lonjsko Polje is of great importance, because it is a very rare and endangered species, listed in the Red Data Book of Great Britain.
5. Numerous rivers, lakes, swamps, marshes and similar water bodies in Croatia implie that there is a much more to be studied, and to be discovered. Due to relatively undeveloped industry water habitats in Croatia remain conserved, what in present time gives a lot of suitable habitats for freshwater bryozoans.
6. This survey has demonstrated that the distribution of bryozoans in Croatia is compatible with the one in the world, and that investigated locations fit in perfectly in the puzzle of the bryozoan distribution in general.

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Pictures of Bryozoans and their distribution maps: www.bryozoans.nl

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http://faunaeur.org

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