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# Ecological and Distributional Donsideration of the Bryophyte Vegetation of Urban Areas: Case Study on Belgrade Bryophytes

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## ABSTRACT

An ecological and distributional approach of the urban bryoflora of the city of Belgrade has been made. Many different parameters and indices have been analyzed with aim to infer the significance and get better idea on the bryophytes within the urban areas. Mosses significantly dominate over liverwort species in urban conditions, and the most common life forms are turfs and rough mats. Small spores (less than 20μm) are abundant if sex reproduction is present among mosses. Urban environment conditions decrease sex and increase vegetative reproductive effort by producing many kind of vegetative propagules in the most of the species recorded. As expected, due to geographical position and climate, dominant distribution types within urban bryophyte flora of Belgrade is temperate.

**Key Words:** ecology, distribution, mosses, urban flora, Belgrade

## INTRODUCTION

Urban areas increase rapidly in modern world. Urbanizations comprise many ecological situations which differ among each other in rather small space and time scale. Though, the small size of the microhabitats can not offer potentially many resources for the proper development of huge plants. However, small plants like bryophytes i.e. liverworts and mosses are widely adapted to such sites and even more appreciate the absence of other competitive plants. Therefore, bryophyte flora of urban areas represents significant part of the city vegetation.

Besides, bryophytes collect trace elements even micro-dust [1], rise the urban environmental quality and produce through photosynthesis a part of city oxygen even over the winter due to their ever-green life span.

Urban bryophyte flora was studied superfluous mainly from floristical point of view. Very few data can be found on distributional and ecological consideration of urban bryophytes.

The city of Belgrade (serb. Beograd) is the capital of Serbia having about 2 million inhabitants (ca. 21% of the Serbian population). It is located in the south-eastern of Europe, where the Pannonian plain meets the Balkan Peninsula, at the confluence of the Sava and Danube rivers (44°49'14" North, 20°27'44" East). Belgrade lies 116.75 metres (383 ft) above sea level. The city has an urban area of 360 square km² (139 sq miles), while together with its metropolitan area it covers 3,223 km² (1,244.4 sq miles). Central Belgrade has hilly terrain, while the highest point of Belgrade proper is Torlak Hill at 303 m (994 ft).

The mountains of Avala (511 m (1,677 ft)) and Kosmaj (628 m (2,060 ft)) lie south of the city. Across the Sava and Danube, the land is mostly flat, consisting of alluvial plains and loess cliffs and plateaus.

It is one of the oldest cities in Europe and since ancient times it has been an important traffic focal point, an intersection of the roads of Eastern and Western Europe. Its territory is divided into 17 municipalities and covers 3.6% of the territory of Serbia.

Belgrade has a moderate continental climate with a year-round average temperature of 11.7°C (53.1 °F) and four well defined seasons (detailed climate diagram in [2]).

The hottest month is July, with an average temperature of +22.1 °C (71.8 °F). There are, on average, 31 days a year when the temperature is above 30 °C, and 95 days when the temperature is above 25 °C. Belgrade receives about 700 millimeters (27.56 inches) of precipitation a year. The average annual number of sunny hours is 2,096. The sunniest months are July and August, with an average of about 10 sunny hours a day, while December and January are the gloomiest, with an average of 2–2.3 sunny hours a day.The highest ever recorded temperature in Belgrade was +43,1°C, while on the other end, the lowest temperature was -21 °C**.** Mean atmospheric pressure in Belgrade is 1,001 millibars and mean relative humidity is 69.5%**.**

Autumn is longer than spring, with longer sunny and warm periods - the so-called Indian summer. Winter is not so severe, with an average of 21 days with temperature below zero. January is the coldest month, with average temperature of 0.4°C. Spring is short and rainy. Summers arrives abruptly and is hot and dry.

Hydrological network of Belgrade is well developed. Geology is mainly limestone, but loess, sandstone and even some serpentine fragments can be found and substrate over are very diverse.

Previously, there are a few sporadically bryophyte records from the wide area of Belgrade [3, 4]. Grdović and Stevanović [5] give contribution to the urban bryoflora of downtown area in Belgrade citing 58 species. However, the total ammount of Belgrade bryophyte flora is 204 species [2], of which 187 are mosses and 23 liverworts.

Up to date studies on bryophytes of urban areas are known for only a few huge urban areas (eg. Berlin and Brandenburg [6, 7], Brussels [8], Vienna [9-13], or Cologne [14].

Among southern European urban areas an extensive data on urban bryophyte floras of western Mediterranean towns in Spain [15-28], Portugal [29] and Italy [30-37] are well documented.

A few, but very important studies on urban bryophytes give insights into the biological peculiarities and significance of these plants in urban environment [1, 38-53]. In this study and distributional and ecological approach to bryophyte vegetation of the Belgrade metropolitan area is made, as a case study to bryophyte ecology within urban environment.

The study represents an extensive investigation of the urban bryophytes ecology and is the first such consideration within South Eastern Europe.

## MATERIALS AND METHODS

A bryophyte flora represented in Belgrade city area was analysed for various parameters with aim to infer and assess the ecological peculiarities of urban bryophytes.

In the analyses the nomenclature followed [54] and [55] for hepatics, and [56]. The exception is made within *Hypnum cupressiforme* complex and *Syntrichia ruraliformis* following [57].

Based on the list of urban bryophyte species of the metropolitan area of the Belgrade city [2], an analytical approach has been made to quantify the ecological situations and distributional types. For that purposes, indices were assigned to each species according to Hill et al. [58], and than statistically considered.

## RESULTS AND DISCUSSION

Due to Belgrade climate and habitat availability, as expected, mosses are pre-dominant with 88.73% of all species recorded. Hepatics are less represented (11.27%) not only because of lack of substrata but because of long dry summer. So, 23 species are presented only there where consistent microhabitat is available but in small biomass.

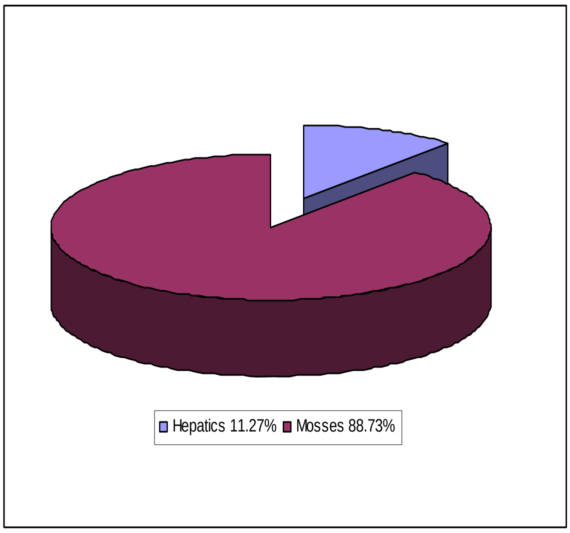


**Fig. 1.** The relationship of hepatics and mosses in the urban bryophyte flora of the Belgrade metropolitan area.

Among seven hepatic ordos, the richest is ordo Jungermanniales with 6 species. In contrast, only one species from ordo Metzgeriales was recorded.

Among nine moss ordos, 63 species from Hypnales are represented in urban bryophyte vegetation, followed by Pottiales with 39 species, which is expected having in mind that hypnalean species are well adapted to drought similarly to pottiaceus mosses which are considered as mosses of harsh environment well adopted to disturbance, pioneering and longer drought periods.

Even if one would expected that the annual life span can be predominant within urban environment, in the city of Belgrade only 1.06% of species exhibit true annual life span while 2.67% of Belgrade urban species recorded can be annual or perennial in life span.

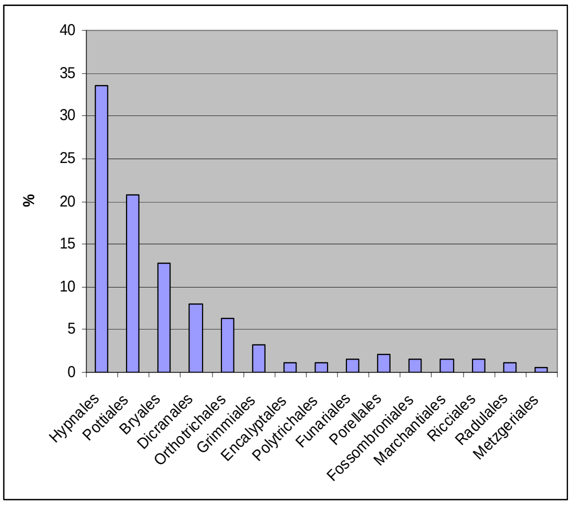


**Fig. 2.** The percentage of Belgrade bryophyte species by ordos represented in its flora.

6.38% of urban species are perennial and rarely can be found as annual forms. Constantly perennial taxa are represented with 89.89% species in urban bryophyte flora. Perennial species are predominant not only because they are more in total world bryophyte flora but due to occupation of habitats where no vascular plant competitors are present.

The spread and settle problem for annual species increase in urban environment due to barriers and habitat disconnection.

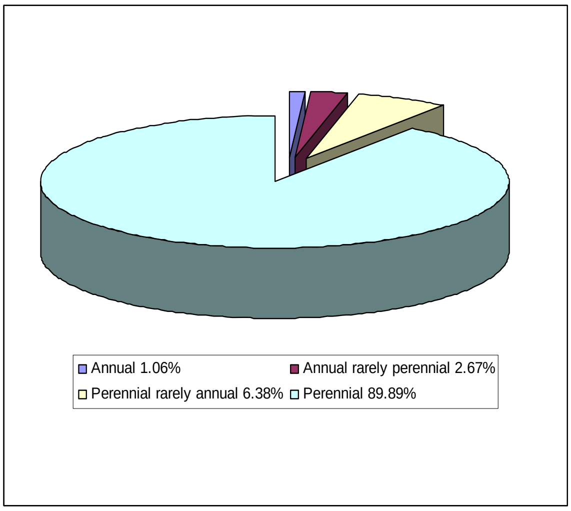


**Fig. 3.** Life span longevity among Belgrade urban bryophytes

Among the urban bryophytes of the Belgrade metropolitan area, the most common life form is turf (28.3%, vertically stems with little or no branching), followed by rough mats (21.2 %, creeping mosses with lateral branches erected).

Cushions (dome-shaped colonies), smooth mats (creeping mosses with branches lying flat) and tufts (loose cushions, not dome-shaped) are more or less equally presented with 9.5%, 11.2% and 12.3%, respectively. The less presented life form among investigated urban bryophyte flora were as expected life form adopted to the habitat types least ubiquitous in the metropolitan area of Belgrade. These life forms are: aquatic trailing (attached to substrate, 1 species), dendroid (with stolon and erect shoots, 2 species), fan (branches in plane on vertical substrate, 2 species), lemnoid (floating on the water, 2 species), solitary creeping shoots (1 species) and solitary talloid (creeping thalli forming a layer, 1 species). Among other life forms, weft (intertwining branched layers) should be mentioned with 6.3 %. Many species can form more than one life form (72 species in total) and among Belgrade bryophytes the most express transitivity to turfs (20 species), smooth mats (10 species) and wefts (10 species).

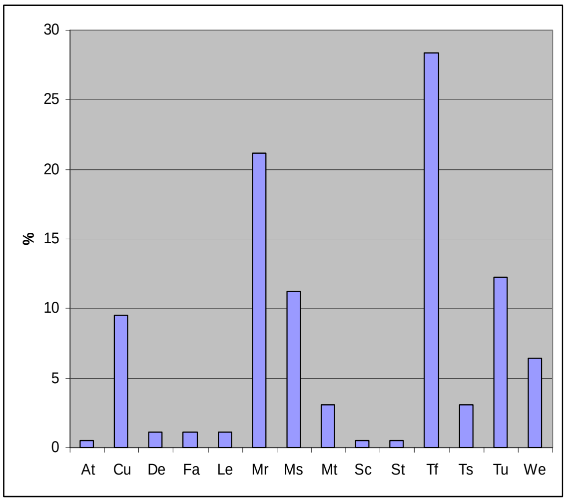


**Fig. 4.** Life forms of the urban bryophytes in Belgrade metropolitan area. At- aquatic trailing, Cu-cushion (dome-shaped colonies), De-dendroid (with stolons and erect shoots), Fa-fan (branches in plane on vertical substrate), Le-lemnoid (floating on the water), Mr- mat, rough (creeping, lateral branches erect), Ms- mat, smooth (creeping, branches, lying flat), Mt-mat, thalloid (creeping, thalii forming a layer), Sc-solitary creeping (creeping solitary shoots), St-solitary thalloid (rosette forming patch not mat), Tf-turf (vertical stems with little or no branching), Ts-turf, scattered (scattered vertical shoots), Tu-tuft (loose cushions, not dome-shaped) and We-weft (interwining branched layers).

In such a harsh environment like urban microhabitats are, vegetative propagules were expected to be highly present in city bryophytes. Indeed, 23 species produce tubers, 29 gemmae, 2 species produce bulbils, 5 species are known to propagate by branch and 4 by leaves separation. Tubers are common in 7 species, while gemma production is frequent in 16 and occasional in 10 species. In total, 63 urban bryophyte species (31.5%) produce one or more vegetative propagules types.

Sexual reproduction in urban species can be decreased due to bad environmental condition, but could be as well hard by sex separation or separate sex production asimultaneously. In Belgrade bryophytes, 104 species (55.3%) are dioecious, 78 species are (41.5%) monoecious, while the rest can be combination of above mentioned or sexuality is not known at all.

Sporophyte production is not widespread among Belgrade bryophytes, however it was noticed abundant in 41 species and occasional in additional 44 species. Rarely, sporophytes have been seen in 40 species, while it was not present in 62 species. One species, *Didymodon cordatus* is not known in sporophyte phase to science as well.

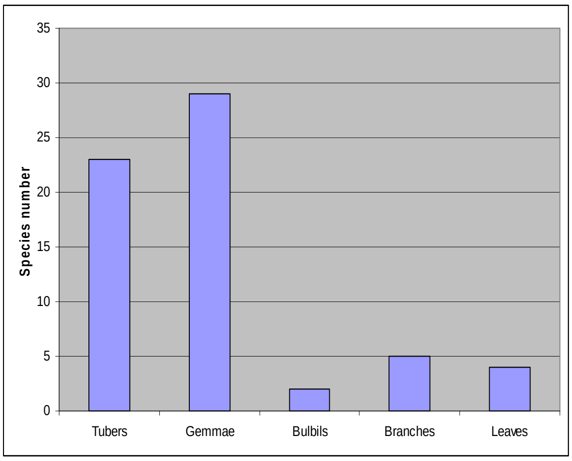


**Fig. 5.** Vegetative propagules among urban bryophytes and the number of species that produce them.

Considering spore size of Belgrade bryophytes, most species (72%) produce spores less than 20 µm in size, which is expected considering needs for easy long distance spreading in such a harsh environment like cities are. Only 5 species produce heavy spores (more than 60 µm in size).

Urban areas exibit interesting and not patterned biogeographical characteristics. So, among the bryophytes in Belgrade, the most present group is boreo-temperate (circumpolar) (20.22 %), followed by temperate (European) (12.24 %).

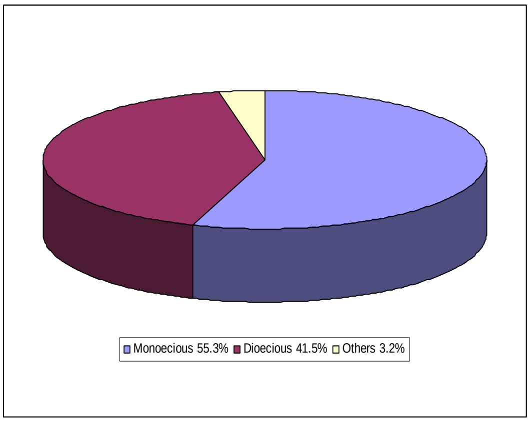


**Fig. 6.** The sex distribution ratio in urban bryophytes of Belgrade

The less presented areal types are arctic-montane (circumpolar), boreal montane (suboceanic) and boreo-arctic montane (European), each with one representative. Significant number of representatives are mediterranean-atlantic (suboceanic) (7.45%), temperate (circumpolar) (7.98%), southern-temperate (European) (5.86%), wide-temperate (circumpolar) (5.86%), boreo-temperate (European) (6.39%) and southern-temperate (circumpolar) (6.39%). In total temperate areal type predominate among Belgrade bryophytes flora with 77.13%, which is expected considering city position and its climate. It also corresponds to the major biome type of broadleaf forests with its subtype presented in metropolitan area (sensu Hill et al. [58]). Considering eastern limit category, 50 % of metropolitan bryoflora is of circumpolar distribution and 28.72 % of European. Significant numbers of species express suboceanic distribution type (10.64%). There are no representatives of hyperoceanic distribution type while there are only two oceanic taxa (1.06%).

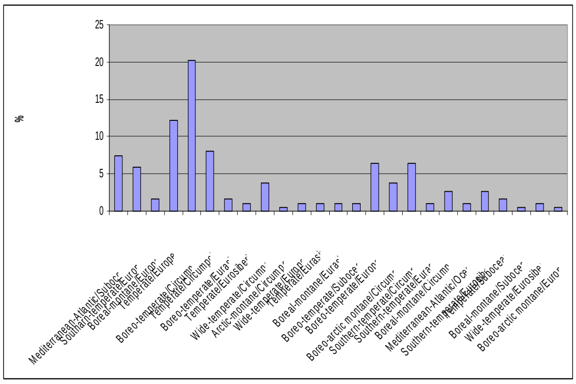


**Fig. 7.** Percentage of detailed distribution types of Belgrade bryophytes.

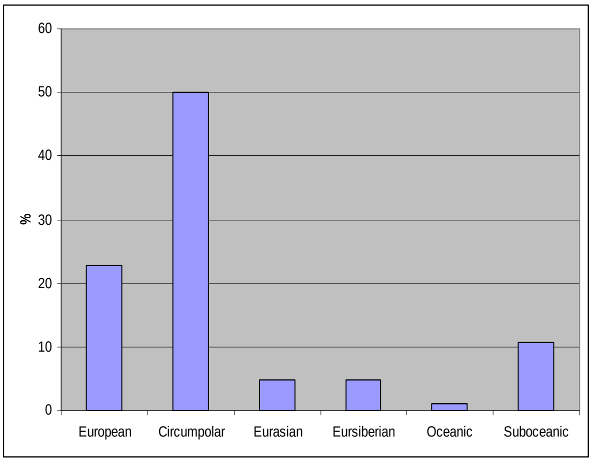


**Fig. 8.** Percentage of the main distribution types of Belgrade bryophytes.

## CONCLUSIONS

According to the indices and parameters anlysed the following characteristics of the urban bryophyte flora of Belgrade city can be drown out:

- Liverworts are significantly fewer than mosses predominantly due to large drought summer period, rather than lack of substrate

- Representatives from the pottialean and hypnelean mosses are in urban environment with the highest environment, due to its well addapted strategies or morpho-anatomy to survive longer drought period and/or pollution.

- The most abundant life form among urban mosses are turfs and rough mats, and the less abundant are aquatic trailing, dendroid and lemnoid life form.

- Urban environment conditions can decrease sex reproduction, so it is expected that high percentage of the species recorded in metropolitan area of Belgrade produce some kind of vegetative propagules or simply spread by thali divisions.

- Ca. 72% of urban species produce spores less than 20 µm, which allows easy spread, but also spores input from distant areas for settlement of new populations within urban zones.

- As expected, by the position and climate characteristics, predominate distribution type among bryophytes in Belgrade metropolitan area is temperate.

High diversity of mosses supports the hypothesis that urban environment gives uniform conditions wildlife, but for such a small organisms like bryophytes an advantage can be numerous small microhabitats with no competition of vascular plants. However, sensitive, rare and threatened species are rarely members of urban bryophyte flora with the exception if metropolitan are has more native and well protected and managed zones where some of these species can occur and survive and reproduce.

Generally, urban bryophytes tend to be very widespread, with a high likelihood of occurrence in all global regions. It is likely that human-aided dispersal, and the novelty and homogeneity of the urban environment across the world have been important factors in shaping this distribution pattern. (Essl and Lambdon, [59].

The urban areas are exactly the first place where one should expect the alien species.

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