

Original Scientific paper
UDK 539.163:582.325.23-119(497.6)
DOI: 10.7251/afts.2019.1120.053C
COBISS.RS-ID 8100376

VERTICAL DISTRIBUTION OF DIATOMS ON MOSSES IN WELLS OF BIJEJLINA MUNICIPALITY IN BOSNIA AND HERZEGOVINA

Ćurčić Milenko¹, Milinković Dragica¹, Radivojević Dragana¹, Đurić Dijana²

¹Faculty of Education, University of East Sarajevo, Bosnia and Herzegovina,
e.mail. ljekobilje@teol.net

²Faculty of Civil Engineering Subotica, University of Novi Sad, Serbia

ABSTRACT:

Vertical distribution of species and infraspecies taxa of diatoms (Bacillariophyta) on well mosses where they live epiphytically, and a relative number of individuals per surface area unit were followed in 8 open wells with shadoof. Researches were conducted during 2015-2016 through four seasons. Sampling of algae material from well mosses that cover interior of the well was conducted on every 50 cm of depth starting from the surface (0 cm) to 200 cm.

Considering the specificity of substrate on which diatoms live in wells, and those are mosses that are especially expressed to 1,5 m depth of well and whose leaves cover each other and have an effect on light climate of micro habitat with already existing differences in intensity and quality of light, relative humidity of air, temperature of air on different depths, density of populations of certain species Bacillariophyta is in function of such ecological occasions on different well depths. It is concluded that the most abundant populations on mosses of researched wells, during most of the year, develop four aerophilic species of diatoms: *Navicula contenta* Grunow, *N. atomus* var. *atomus* (Kiitzing) Grunow, *Achnanthes lanceolata* (Brebisson) Grunow ssp. *lanceolata* var. *lanceolata* and *Amphora normanii* Rabenhorst.

Key words: *diatoms, well mosses, population density, well depth*

INTRODUCTION

Researches of vertical distribution of population of certain microphytes species are of great theoretical and practical significance. The greatest attention of vertical distribution of algae is given to planktons where extensive studies have been carried out so far. Data about research of periphyton algae in freshwater ecosystems [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], clearly show that periphyton algae have a very sensitive reaction to water depth, meaning physical and chemical factors of the environment where they live.

Vertical distribution of species and infraspecies taxa of Bacillariophyta on well mosses as well as relative number of individuals per surface area unit were followed in 8 open wells with shadoof on the territory of Bijeljina municipality in Bosnia and Herzegovina (Figure 1).

Researched wells were marked as B₁, B₃, B₄, B₆, B₇, D₁, D₃ and D₄. So far there are no exact data about this kind of research in our country and in the world, except for the research of Ćurčić [26], Jerković and Ćurčić [27,28].

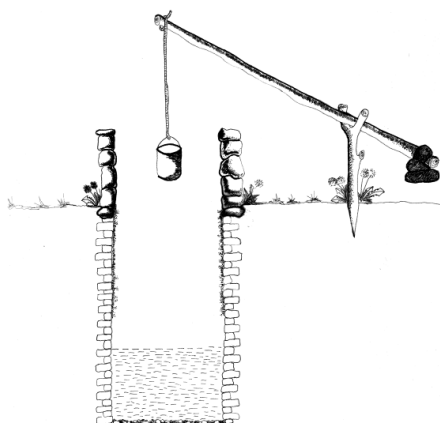


Figure 1. Vertical cross section through well with shadoof

Within these researches was noted that some species and infraspecies taxa of Bacillariophyta have different relation towards the depth of well. Vertical distribution of Bacillariophyta here is expressed through quantitative relations in a way that some taxa in certain depths develop numerous, and in others less populations on well mosses where they live epiphytically. However, it was also noted a distribution that includes a complete elimination of some taxa from certain depth.

MATERIAL AND METHODS

Researches included physical and chemical factors of the environment that are important for this type of research. Directly on the terrain were measured: light, humidity, water temperature, air temperature and pH of the environment.

Considering the nature of the environment and character of the research, sampling of material from well demanded special equipment. Difficulties were present during sampling of the material from the well walls considering the type of its construction: depth, wall in the form of a circle, worn and very unsafe well protective fence. Moss samples from well wall where diatoms live epiphytically were taken from the surface of 100 cm² with special “spoon” for moss scooping [29]. Mosses were taken on every 50 cm from wall starting from the well surface (0 cm) to 200 cm of depth. On that depth moss cover is very well expressed, although the real depth of researched wells is from 5 to 7 m. Water level in wells depends from the level of water in the nearest water courses, especially from rivers Sava and Drina, and other water biotopes in immediate surroundings of the well and from the quantity of atmospheric precipitation during the year.

After extraction from the well, mosses were put in plastic bags that were immediately labeled with all recorded data that are important for this type of research. Processing of sampled material was conducted immediately after returning from the field. Moss samples from well wall were subjected to rinsing with redistilled water, first with hands, where they were washed with soap after each sample. After that, material was mixed with glassy stick and was put to friction to walls of glass cup. Rinsing and friction lead to separation of epiphytic diatoms (Bacillariophyta) from mosses. Rinsing was always conducted in 100 ml of redistilled water. Material was processed according to Hustedt's method [30], and obtained suspension was used for making of permanent preparations. From every examined sample with micropipette was taken 0,2 ml of suspension for every preparation.

About 500 permanent preparations have been made where as fitting medium was used canada balsam index 1,53. Numerical analysis of diatoms was conducted parallel with qualitative analysis of the same. Determination and counting of individuals per surface area unit were conducted under binocular

microscope "ZEISS" with immersion lens with 1.500 magnification. Calculation of number of individuals per surface area unit was conducted according to Ćurčić's equation [29]:

$$x \text{ jed/cm}^2 = \frac{S \cdot n}{N \cdot S_1} \cdot F$$

S – surface of the cover tile;

n – number of individuals of one taxon;

N – number of visible fields on which counting was conducted;

S₁ – surface area of one visible field;

F – factor (ratio of concentrate volume in ml/surface area of substrate for sample x volume of subsample in ml).

On every permanent preparation were conducted five countings per 100 individuals of diatoms. Counting on similar way was present in researches of epiphytic pheriphyton diatoms [11,31,32,33]. Previous experiences of numerous researchers showed that absolute quantitative measurings are not possible in algae research [11,14,34,35,36 and others]. In order to gain insight into the approximate share of individual taxon, evaluation of relative abundance was conducted. According to Behre [37] this method completely satisfies the need of research from the aspect of plant cenology.

Evaluation of relative abundance was conducted according to Wegel's method [38]. Method includes the following levels of relative abundance: 1 = very rare; 2 = rare; 3 = moderately often; 5 = often; 7 = very often; 9 = mass.

RESULTS AND DISCUSSION

First researches of Bacillariophyta in wells with shadoof near Bijeljina in Bosnia and Herzegovina were conducted by Ćurčić [26], where he ascertained the presence of 15 genera with 61 species and infraspecies taxa of Bacillariophyta on mosses of walls, in buckets for scooping of well water and in sediments of well bottom. During those researches was not conducted vertical distribution of these algae on different levels of well wall.

Previous researches of Bacillariophyta flora of wells in the world are rare. They are related to wells with shadoof that are the subject of our researches. Except individual findings there are no extensive and exact data in literature about researches of Bacillariophyta flora in other types of wells. Researches of other authors are related to salt wells and fountains that have different environmental characteristics. Analyzing researches of Foged [39] and Reinhardt [40] it is obvious that the researches are about fountains and not about wells in the original sense.

During our researches of vertical distribution of diatoms on well mosses on different depths, that are the subject of this paper, were identified 89 species and infraspecies taxa of Bacillariophyta divided into 17 genera. Most dominant by number of species and infraspecies taxa are genera Navicula with 30,88 % , Nitzschia with 17,64 % and Achnanthes with 5,88%. Presence of large number of aerophilic Bacillariophyta shows a very rich flora of well ecosystems whose evolution has been in the function of long-standing anthropogenic activities. The result of large uniformity of most of physical and chemical factors in researched wells is a presence of large number of Bacillariophyta species common for all researched wells.

Their natural habitat is not well water, but mosses of well wall that are constantly or temporarily inhabited and have epiphytical way of life. Meaning, habitats of aerophilic Bacillariophyta in wells are moss associations of well wall that are more or less humid during the whole year, depending from water level in well. Humidity is the consequence of evaporation of well water, atmospheric

precipitation, and also of spilling water during scooping with well bucket. In all researched wells were identified moss associations of *Oxyrrynchio – Platyhypnidietum rusciformis* [41].

Moss community, according to Grgić [41] was built exclusively from two types of moss: *Oxyrrynchium praelongum* (Hedw.) Wstf. and *Platyhypnidium rusciforme* Fleischr. These moss associations of well wall are inhabited by diatoms which frequently build colonies or aggregates in the way of stripes, and are especially visible with scanning electron microscope. For example, *Navicula gallica* var. *gallica*, of very interesting ornament, best illustrates colonial shapes of *Naviculaceae* family on moss leaves (Figure 2).



Figure 2. *Navicula gallica* var. *gallica* on moss leaves

In terms of vertical distribution of population of individual *Bacillariophyta* taxa to 200 cm depth in researched wells was possible to differ four basic groups:

1. Species, that achieve the highest number in the surface layer (0 cm–50 cm) of well and with depth decrease the population density or completely disappear
2. Species, that achieve the highest number on depth from 100–150 cm, and moving towards the surface decrease in the population density,
3. Species, that are most numerous on depth of 200 cm and with decrease of depth become rarer or completely disappear,
4. Species ± indifferent to depth changes to 200 cm.

First group includes the largest number of taxa such as: *Navicula contenta* Grun., *Achnanthes lanceolata* (Brebisson) Grunow ssp. *lanceolata* var. *lanceolata*, *Hantzschia amphioxys* (Ehr.) Grun., *Navicula gallica* var. *gallica* (W. Smith) Lagerstedt, *Navicula mutica* var. *mutica* Kiitzing, *N. mutica* var. *ventricosa* (Kiitzing) Cleve et Grunow, *N. pupula* var. *pupula* Kiitzing, *N. nivalis* Ehrenberg, *Nitzschia hantzschiana* Rabenhorst, *N. sinuata* var. *delognei* (Grunow) Lange – Bertalot and others.

Second group includes: *Navicula atomus* var. *atomus* (Kiitzing) Grunow, *Achnanthes conspicua* A. Mayer, *Caloneis bacillum* (Grunow) Cleve, *Diploneis oblongella* (Naegeli) Cleve – Euler, *Nitzschia debilis* (Arnott) Grunow in Cleve.

Third group includes: *Amphora normanii* Rabh., *Eunotia soleirolii* (Kiitzing) Rabenhorst, *E. paralella* var. *angusta* Grunow, *Achnanthes clevei* var. *clevei* Grunow in Cleve et Grunow, *Amphora pediculus* (Kiitzing) Grunow.

Fourth group includes (most species belong to fourth group): *Navicula seminulum* Grunow, *N. veneta* Kiitzing, *N. elginensis* var. *elginensis* (Gregory) Ralfs in Pritchard, *Nitzschia amphibia* f. *amphibia* Grunow, *N. palea* (Kiitzing) W. Smith, *N. inconspicua* Grunow and others.

Relatively high uniformity of wells regarding climatic, edaphic and orographic factors, conditions that vertical variations in presence of certain Bacillariophyta taxa are not particularly sharp. If put in relation of middle value of total number of Bacillariophyta taxa, on certain depths of well can be seen that the number, depending from the well, is approximately the same (Table 1). Regarding vertical distribution of total number of individuals it is concluded that the highest number is on depth of 50 cm and that it successively decreases in most of the wells with the increase of depth of 200 cm (Table2.).

Table 1. Middle values (x) of number of Bacillariophyta taxa on certain depths of researched wells

Well \ Depth	0 cm	50 cm	100 cm	150 cm	200 cm
B ₁	5,58	5,75	5,16	8,08	7,66
B ₃	8,08	6,33	7,75	7,75	7,33
B ₄	9,08	6,75	8,16	7,91	9,50
B ₆	8,83	11,08	8,66	8,91	8,91
B ₇	12,16	10,83	8,91	10,08	8,83
D ₁	8,58	7,75	8,58	7,58	9,50
D ₃	11,58	11,00	11,83	9,83	10,41
D ₄	12,25	11,25	11,16	10,08	11,08

Table 2: Vertical distribution of total number of individuals (x) of Bacillariophyta on all levels of researched well

Well \ Depth	0 cm	50 cm	100 cm	150 cm	200 cm
B ₁	224327	350483	117540	96480	75750
B ₃	223425	349858	201916	99387	68207
B ₄	358643	313888	275056	151804	144875
B ₆	168574	301801	423965	386637	183703
B ₇	381822	453762	266830	168870	127201
D ₁	113668	223895	299699	210888	147896
D ₃	136170	121479	119714	111263	76713
D ₄	160762	171785	250030	147811	155860

Despite the fact that all researched wells show great similarity regarding chemical and physical factors, they still differ in some physical factors such as the intensity of light and relative humidity of air on researched levels from 0 cm–200 cm. It was possible to expect that those differences would have an impact on distribution of Bacillariophyta. However, qualitative analysis showed that Bacillariophyta have dispersing distribution in every researched well. It showed that most of the Bacillariophyta, in relation to conditions in wells, have relatively high ecological valence.

Based on just qualitative composition of Bacillariophyta exact data cannot be obtained. Species, however, in limits of their ecological valences, maintain density of populations of certain combinations of biotope factors and combinations of their quantitative relations. Seasonal aspects of presence of certain Bacillariophyta populations in researched wells showed the dispersion and distribution of certain taxa. Comparative overview of levels in researched wells best illustrates this. It will be illustrated on two researched wells: D₁ and B₆.

W E L L D₁ – 0 cm

Basic features of this "micro habitat" give massive population development of *Navicula contenta* concluded on the base of estimation of relative abundance [38]. Massive development *N. contenta* (9) achieves from VII-IX month, very often (7) from X–XII, II–IV, and in VI month, and medium abundant – moderately often (3) in I and V month. Populations of *N. pupula* var. *pupula* and *N. seminulum* are medium abundant (3) during the whole year, while populations of *N. atomus* var. *atomus*, *N. mutica* var. *mutica*, *Amphora normanii*, *Nitzschia amphibia*, *Hantzschia amphioxys* and others are less abundant – rare (2) mostly during the whole year.

W E L L D₁ – 50 cm

Basic features of this "micro habitat" give massively developed population of *N. contenta* giving its most abundant development on this level in relation to other researched levels of well D₁, during the whole year. Also, in most part of the year, population of *N. atomus* var. *atomus* is medium abundant (3). Populations with less abundant (rare) number of individuals that are present during most part of the year are *A. normanii*, *N. mutica* var. *mutica*, *Nitzschia debilis* and others.

W E L L D₁ – 100 cm

Even though on this level population of *N. contenta* have high level of abundance, it was concluded that two aspects of its dominance are present in this micro habitat. The first aspect relates to the period of XI–I and V–X months (autumn, winter, summer) when *N. contenta* is very often (7) and second aspect covers the period from II–IV month when its populations are medium abundant (3). Contrary to *N. contenta* which forms medium abundant populations from II–IV, *Amphora normanii* forms populations of higher abundance (5) in the same period. Also, populations of *A. normanii* are present during all other months in year but with medium abundant number of individuals (3). Populations of other taxa that inhabit this habitat are present with medium abundant number (3) – *N. atomus* var. *atomus* and less abundant (2) – *Caloneis bacillum*, *Diploneis oblongella*, *Nitzschia debilis*, *N. hantzschiana* and other.

W E L L D₁ – 150 cm

With increase of depth in well, population of *N. contenta* is less and less abundant in relation to previous levels of well (0,50 and 100 cm), and population of *A. normanii* is more and more abundant. Here is also possible to notice two aspects of population *N. contenta* presence. Autumn aspect (IX, X and XI month) when *N. contenta* is often (5) present in this micro habitat and aspect that includes winter, spring and summer when individuals of *N. contenta* population are present moderately often (3), when are medium abundant. Population of *Amphora normanii* expresses only one aspect and that is the aspect of dominance during the whole year with often abundant number of individuals (5). Population *N. atomus* var. *atomus* expresses larger abundance in relation to previous well depths. During summer (VI, VII and VIII month) they show greater abundance in relation to other seasons when this population is a bit less abundant.

Less abundant (2) populations that are indentified on this depth are populations of *Caloneis bacillum*, *Eunotia soleirolii*, *Nitzschia debilis*, *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata*, *Navicula pupula* var. *pupula* that have relatively rare number of individuals.

W E L L D₁ – 200 cm

High relative abundant population of *A. normanii* is noted during the whole year. Also, relatively high level of abundance is noted at population of *N. atomus* var. *atomus* during summer and autumn, while this population with less abundant number is present in winter – spring period. *N. contenta* is present during the whole year but always with medium abundant number of individuals (3). Less abundant (2) populations identified on this depth are: *C. bacillum*, *E. soleirolii*, *Nitzschia debilis*, *Achnanthes conspicua*, *A. lanceolata* ssp. *lanceolata* var. *lanceolata* and others.

On all researched levels of this well was concluded that populations with highest abundant number of individuals are *N. contenta* and *A. normanii* and that relative number of individuals of population *N. contenta* decreases going from 0–200 m of depth, while relative number of individuals of population *A. normanii* increases going from 0–200 cm of depth.

Based on the whole insight in presence of all determined Bacillariophyta taxa during the year in all researched wells, it is clearly recognizable that all researched „micro habitats“ (0 cm–200 cm) have, besides common, only for them characteristic taxa (Figure 3 and 4).

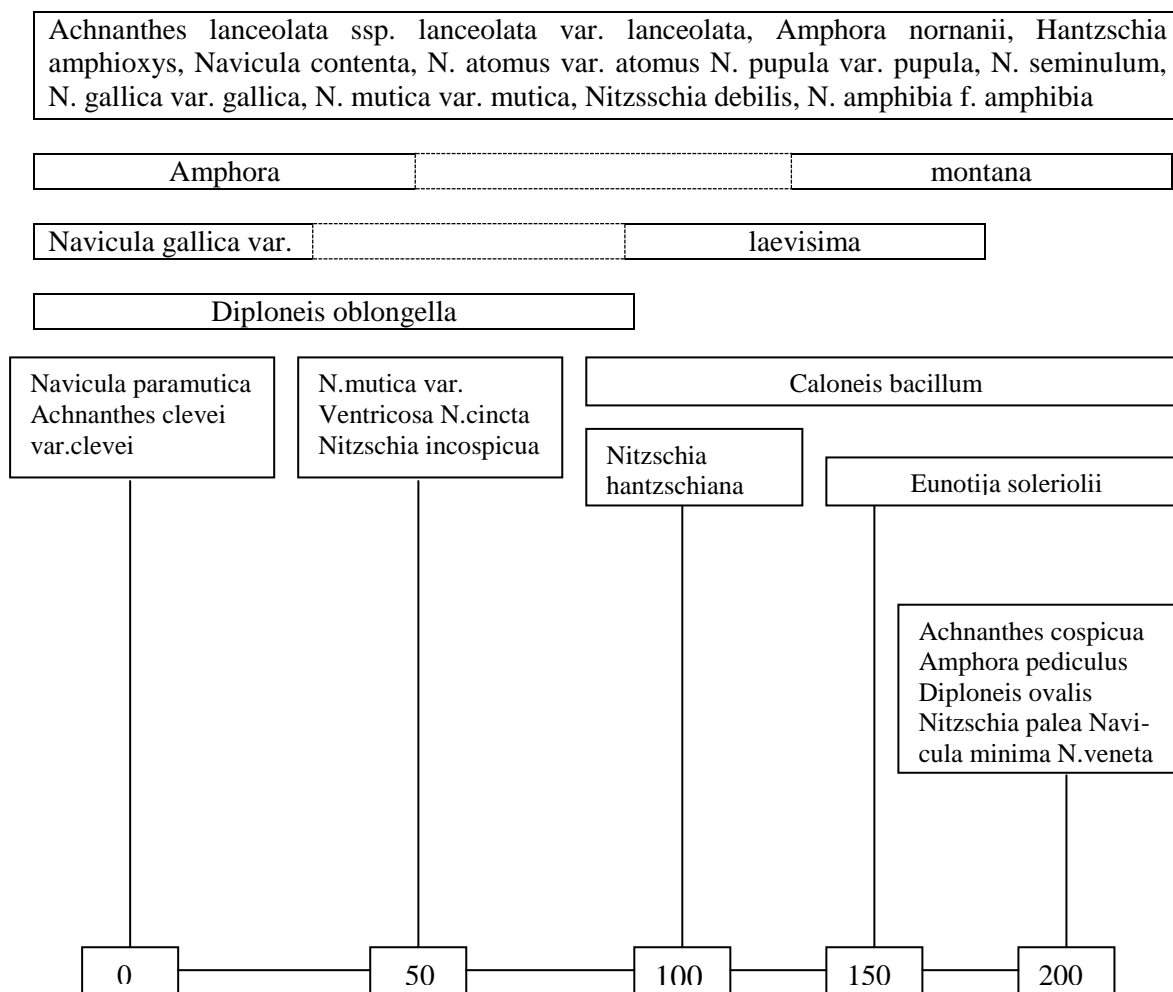


Figure 3. Zoning of well D₁ according to distribution of Bacillariophyta

WELL B₆ – 0 cm

This micro habitat is characterized by dominance of populations *Navicula contenta* and *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* in different seasons. Two aspects of presence of these populations were noted: winter – spring when population *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* is present with relatively high number of individuals (often to very often), and population *N. contenta* is present with medium abundant number of individuals (moderately often) and other summer autumn aspect is inversely proportional to winter – spring, where the number of individuals of population *N. contenta* is relatively high abundant, while population of *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* is with medium abundant number of individuals (3).

Other taxa that are identified in this micro habitat and that create their populations are with medium abundant number (3) of individuals – *N. atomus* var. *atomus*, *Hantzschia amphioxys*, *Nitzschia debilis*, *Amphora normanii*, *A. pediculus*, *Caloneis bacillum*, and are recorded only in period spring – summer. The smallest abundant populations with rare number of individuals are populations *Navicula veneta*, *N. seminulum*, *N. mutica* var. *mutica*, *N. mutica* var. *ventricosa*, *Nitzschia debilis* and *N. hantzschiana*.

WELL B₆ – 50 cm

In terms of distribution of *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* population it was concluded that this population is most abundant as well as on the previous level (0 cm) with small difference, that on this level its relatively high participation was registered also in autumn season.

According to that, population with relatively often number of individuals are identified in period from IX–XII and I–IV month, while summer aspect (V–VIII) if regarding the presence of this population shows low level of relative abundance, or population is present with rare number of individuals. *Navicula contenta* is present during the whole year with medium abundant (3) populations with the fact that populations in II, V and VI month show higher level of abundance, ie are present with often or very often number of individuals. *N. debilis* populations even present during the whole year, indicate different participation of number of individuals in different seasons. They have high level of abundance during summer (VI–VIII month) with often or very often number of individuals, while medium abundant populations of *N. debilis* are created in seasons autumn – winter – spring. Based on the size of population of *Navicula atomus* var. *atomus* can be noted two periods: winter – summer – spring when all population shows low level of abundance, meaning that individuals are present per surface area unit and period summer – autumn where population *N. atomus* var. *atomus* is medium abundant (3).

Other taxa that were identified on this level create populations with far smaller number of individuals per surface area unit, ie populations of less abundance (2). Those populations are: *A. normanii*, *H. amphioxys*, *Navicula seminulum*, *N. veneta*, *Nitzschia amphibia* and others.

W E L L B₆ – 100 cm

To this level, also, the main characteristics give *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* and *Nitzschia debilis* that develop far more abundant populations in relation to other taxa identified on this micro habitat. The most abundant *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* populations were developing during summer (VI–VIII month), while medium abundant (3) populations with moderately often number of individuals were developing during autumn, winter and spring. *Nitzschia debilis* created medium abundant population with moderately often number of individuals only during summer (VI–IX), while during autumn, winter and spring *N. debilis* populations are much less abundant, ie have often or very often number of individuals. Even *A. normanii* populations show relatively high level of abundance during summer, while during other seasons are populations with medium abundant number of individuals. *Navicula contenta* populations are most abundant during autumn (IX–XII month), while in other seasons are populations with medium abundant (3) number of individuals.

Caloneis bacillum, *Navicula veneta* and *Hantzschia amphioxys* are identified during the whole year, creating populations with low level of abundance (1–2), with very rare or rare number of individuals per surface area unit that still have optimal living conditions.

W E L L B₆ – 150 cm

On this depth *Amphora normanii* during the whole year creates populations whose level of abundance is relatively high for all seasons. *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* during spring and summer also creates populations whose level of abundance is relatively high, while during autumn and winter creates populations with medium abundant (3) number of individuals. *Nitzschia debilis* populations during most part of the year have medium abundant number of individuals (3) except in XI, XII and III month when populations are of higher abundance number of individuals (5) in relation to other months. Less abundant (2) populations on this depth are created by *Navicula veneta*, *N. seminulum*, *Nitzschia inconspicua*, *Caloneis bacillum*, *Amphora pediculus* and others, with exception of medium abundant populations in VIII, IX and X month.

W E L L B₆ – 200 cm

Absolute dominance of number in *Amphora normanii* populations in relation to populations of other taxa is noted during the whole year. *A. normanii* populations are of high abundance (5–7) which is especially expressed during winter, spring and summer. *Achnanthes lanceolata* ssp. *lanceolata* var. *lanceolata* only during summer creates populations with high level of abundance, while in other seasons creates populations with medium abundant number of individuals. Populations of less abundant taxa that are identified on this depth are *Caloneis bacillum* populations whose number is less

abundant (2) during most of the year, and only during VIII, IX and X month is determined medium abundant number of individuals in population. Amphora montana, Eunotia soleirolii, Navicula veneta, N.seminulum and others create periodical populations with less abundant (2) number of individuals.

On every researched level of this well was determined that populations with highest abundant number of individuals are Achnanthes lanceolata ssp. lanceolata var. lanceolata, Amphora normanii, Navicula contenta and Nitzschia debilis. It was also concluded that number of individuals of Achnanthes lanceolata ssp. lanceolata var. lanceolata and Navicula contenta populations decreases going from 0 cm–200 cm of depth, while relative number of individuals of Amphora normanii and Nitzschia debilis populations increases going from 0 cm–200 cm of depth.

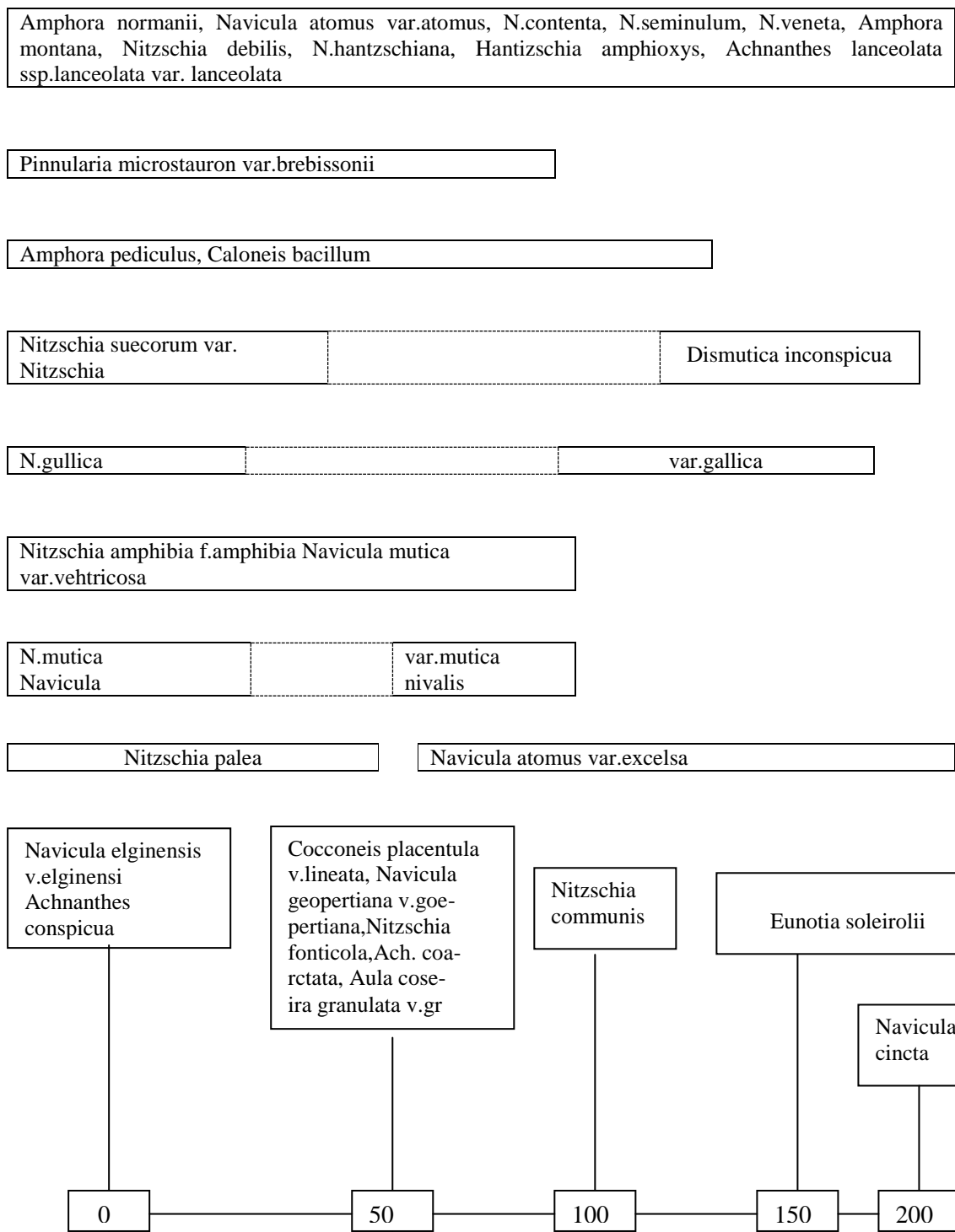


Figure 4. Zoning of well B₆ according to distribution of Bacillariophyta

CONCLUSION

As emphasized in the text, in all researched wells on mosses of well walls was identified 89 species and infraspecies taxa of Bacillariophyta. The most present Bacillariophyta taxa that belong to aerophilic epiphytes are different types and varieties of Achnanthes, Cocconeis, Gomphonema, Fragilaria, Orthoseira, Navicula, Nitzschia and Amphora.

How big important ecological factor light is, for density and vertical distribution of Bacillariophyta, observed as a whole, can be seen in researched wells where population density of most Bacillariophyta decreases with the increase of depth where light is of weaker intensity. Exceptions are Amphora normanii, Eunotia soleirolli, E. parallela var. angusta taxa that on greater depths develop more abundant populations.

Smaller number of species have the optimum of their development on depths of 50 and 100 cm, such is the case with Navicula atomus var. atomus and Navicula contenta which develop the most abundant populations in most of the researched wells during the most of the years, while there is more of those that do not have important changes in population density on most of the researched levels.

However, at relatively uniform vertical distribution of other factors (humidity, temperature, pH), it is possible that the difference in intensity and quality of light on different depths have an effect on vertical distribution of Bacillariophyta in researched wells. Our researches show that the number of individuals per surface area unit depends from level in well where researches were conducted, ie from all present ecological opportunities that are the basic determinant of those micro habitats.

The highest average number of individuals of Bacillariophyta on mosses leaves was recorded in well B₇ on depth of 50 cm and it was 453.762 individual/cm². The smallest average number of individuals was recorded in well B₃ on level 200 cm and it was 68.207 individual/cm².

The highest average values of individuals per surface area unit are registered on well leaves of 0 cm and 50 cm, while with the increase of depth of well average number of individuals decreases. However, reduced number of individuals on depths of 150 cm and 200 cm is not just the consequence of ecological conditions on those depths, but also of mosses area that are inhabited with aerophilic

Bacillariophyta. General coverage with moss on those depths is less expressed, so in that way was reduced the total surface area that is inhabited with Bacillariophyta. Observed in general, production of Bacillariophyta in researched wells shows approximately similar seasonal fluctuations. It is generally possible to distinguish three periods: late winter with great, summer and early autumn with medium and late autumn – early winter with small intensity of production.

(Received March 2019, accepted April 2019)

REFERENCES

- [1] Kann, E. (1959). Die eulitorale Algenzone im Trausee. Arch. Hydrobiol., 55 (2), 129-192.
- [2] Sladečková, A. (1960). Limnological study of the reservoir Sedlice near Želiv. Periphyton stratification during the first yearlong period (June 1957-July 1958). Sbornik VŠCHT-Praha, (Technologie vody), 4 (2) 143-261.
- [3] Sladečková, A. (1962). Limnological investigation methods for the periphyton („Aufwuchs“) community. Bot. Rev. 28, (2) 286-350.
- [4] Sladečková, A. (1963). Limnological study of the reservoir Sedlice near Želiv. Periphyton production. Technologie vody, 7 (2) 77-133.
- [5] Neal, C. E. et al. (1968). Periphyton growth on artificial substrates in a radioactively contaminated lake. Ecology, 48 (2), 918-923.
- [6] Ertl, M. et al. (1972). Vorläufige Angaben über jahreszeitliche Untersuchungen und die vertikale Verteilung des Periphytons im mittleren Abschnitt der Donau. Arch. Hydrobiol. 5, 34-48.
- [7] Blagojević, S. (1974). Struktura perifitona u otvorenim uređajima vodovoda na dva krška izvora. Godišnjak Biol. Inst. Univ. Sarajevo 27:77-91.

- [8] Stojanov, P., (1983). Dijatomejskata flora vo tresetištata na nacionalnot park Mavrovo. Godišen zbornik Biološkiot fakultet Skopje 36.
- [9] Steinman, A. D., McIntire, C. D. (1986). Effects of current velocity and light energy on the structure of periphyton assemblages in laboratory streams. *J. Phycol.* 22, 352-361.
- [10] Stevenson, R. J., Stoermer, E. F. (1981). Quantitative differences between benthic algal communities along a depth gradient in lake Michigan. *J. Phycol.* 17, 29-36.
- [11] Main, S. P., McIntire, C. D. (1974). The distribution of epiphytic diatoms in Yaquina Estuary, Oregon. *Bot. Marina* 17: 88-99.
- [12] Brown, S.-D., Austin, A. P. (1973). Diatom Succession and Interaction Littoral Periphyton and Plankton. *Hydrobiologia*, 43, 3-4, 333-356.
- [13] Cattaneo, A., Kalf, J. (1978). Seasonal changes in the epiphyte community of natural and artificial macrophytes in lake Memphremagog. *Hydrobiologia*, 60, 2:135-144.
- [14] Hudon, C., Bourget, E. (1983). The effect of light on the vertical structure of epibenthic diatom communities. *Bot. Mar.* 26: 317-330.
- [15] Hancock, F.D. (1979). Diatom associations and Lake Kariba. *Hydrobiologia* 67, 33-50.
- [16] Rusanov, A., Stanislavskaya, E., Asc, E. (2009). Distribution of periphytic diatoms in the rivers of the Lake Ladoga basin (Northwestern Russia). *Acta Bot. Croat.* 68, 301-312.
- [17] Cantonati, M., Spitale, D. (2009). The role of environmental variables in structuring epiphytic and epilithic diatom assemblages in springs and streams of the Dolomiti Bellunesi National Park (south-eastern Alps). *Fundamental and Applied Limnology–Archiv für Hydrobiologie* 174, 117-133.
- [18] Stavreva-Veselinovska, S., Todorovska, A., (2010). Ecology of the diatomic flora in thermo-mineral springs of Katlanovska Banja in the Republic of Macedonia. *Ecologia Balkanica* 2, 1-6.
- [19] Mogna, M., Cantonati, M., Andreucci, F., Angeli, N., Berta, Graziella., Miserere, L. (2015). Diatom communities and vegetation of springs in the south-western Alps. *Acta Bot. Croat.* 74(2), 265-285.
- [20] Bertrand, J., Renon, J. P., Monnier, O. (2004). Relation " diatomees epiphytes-bryophytes" dans les tourbieres du Mont Lozere (France). *Vie et Milieu* 54, 59-70.
- [21] Krizmanić, J., Ilić, M., Vidaković, D., Subakov-Simić, G., Petrović, J., Cvetanović, K. (2015). Diatoms of the Dojkinci River (Stara Planina Nature Park, Serbia). *Acta Bot Croat.* 74 (2), 317-331.
- [22] Pavlov, A., Levkov, Z. (2013). Diversity and distribution of taxa in the genus *Eunotia* Ehrenberg (Bacillariophyta) in Macedonia. *Phytotaxa* 86, 1-117.
- [23] Kralj - Borojević, K., (2011). Diatom growth and development in periphytic communities in river Krka. PhD thesis. Faculty of Science, Zagreb.
- [24] Van De Vijver, B., Beyens, L., (1997). The epiphytic diatom flora from mosses of Stromness Bay area. *Polar Biology* 17, 492-501.
- [25] Dedić, A., Plenković-Moraj, A., Kralj-Borojević, K., Hafner, D. (2015). The first report on periphytic diatoms on artificial and natural substrate in the karstic spring Bunica, Bosnia and Hercegovina, *Acta Bot. Croat.* 74 (2) 393-406.
- [26] Ćurčić, M. (1985). Flora Diatomophyceae bunara okoline Bijeljina. Magistarski rad PMF. Sarajevo: Univerzitet u Sarajevu.
- [27] Jerković, L., Ćurčić, M. (1987). An investigation of the diatoms attached to epilithic moss communities from wells of Bosnia and Herzegovina. V *Inter. Congr. Bot.*, Berlin.
- [28] Jerković, L., Ćurčić, M. (1990). Flora of Bacillariophyta from open drinking water wells in Yugoslavia. V *Inter. Congress. ekol.* Yokohama.
- [29] Ćurčić, M. (1993). Floristička i ekološka istraživanja Bacillariophyta u bunarima na području Semberije. Doktorska disertacija. Beograd: Biološki fakultet.
- [30] Hustedt, F. (1930). Bacillariophyta in: A. Pascher, *Die Siisswasserflora Mitteleuropas*, 10: 1-466.
- [31] Millie, F. D., Lowe, R. L. (1983). Studies on Lake Erie s littoral algae; Host specificity and temporal periodicity of epiphytic diatoms. *Hydrobiologia* 99, 7-18.
- [32] Oemke, M. P., Burton, M. T., (1986). Diatom colonization dynamics in a lotic system. *Hydrobiologia* 139: 153-166.
- [33] Kadlubowska, J. Z. (1975). *Zarys algologii*. Warszawa 1975, 428-443.
- [34] Scheele, M. (1952). Systematisch-okologische Untersuchungen uber Diatomeenflora der Fulda. *Arch. Hydrobiol.*, 46, 305-423.
- [35] Backhaus, D. (1968). Okologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflüsse. Systematischautokologischer Teil. *Arch. Hydrobiol.*, (Suppl. XXXIV), 4, 251-320.
- [36] Harper, M. A. (1980). Effects of grazing on the quantity and quality of freshwater aufwuchs. *Hydrobiologia* 69, 251-259.
- [37] Behre, K. (1966). Zur Algensociologie des Siisswasser. *Arch. Hydrobiol.*, 62, 2. 125-164.
- [38] Wegel, R., (1983). Index für Limnosaprobität. *Gewasser Abwasser* 26.
- [39] Foged, N. (1983). Diatoms in fontains, reservoirs and some other humid and dry localities in Roma, Italy. *Nova Hedwigia*, 38: 433-469.

- [40] Reichardt, E. (1988). Diatomeen aus Brunnen und anlichen Biotopen in Latium Mittelitalien. *Senckenbergiana biol.* 68, 4/6: 419-439.
- [41] Grgić, P. (1984). Epilitska zajednica mahovina u bunarima nefropatskog područja okoline Bosanskog Šamca. III Kongres ekologa Jugoslavije, Sarajevo: Bilten društva ekologa BiH.