”BABEŞ-BOLYAI” UNIVERSITY, CLUJ-NAPOCA

FACULTY OF BIOLOGY AND GEOLOGY

STUDY OF THE EPILITHIC DIATOM COMMUNITIES FROM THE CERNA RIVER

Ph.D. THESIS

(Summary)

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CONTENT

Keywords: epilithic diatoms, Cerna River, water quality, Saprobic Index (SI), Biological Diatom Index (BDI).

This doctoral thesis is structured on five chapters and comprises 229 pages, 120 figures and nine tables. The general bibliography consists of 154 titles of which four are our personal contribution with subjects from the thesis.

Introduction

The diatoms constitute one of the most successful eukaryote photosynthesizing groups of microorganisms, widely distributed in almost all aquatic and terrestrial habitats. They are also present as endosymbionts of dinoflagellates or foraminifers [Vanormelingen *et al.*, 2008], or just on the plumage of some aquatic fowls or on the cetacean tegument [Round *et al.*, 2000]. In spite of the fact that diatoms have global importance in the biogeochemical circles and provide 20–25% of the fixed carbon and of the atmospheric oxygen, there are relatively few reliable data concerning their biology and ecology, as well as about the factors influencing their diversity and chorology.

The general aim of the present thesis is to accomplish thorough investigation upon the diatom communities inhabiting the Cerna River and its tributaries, pursuing the following targets: (1) the knowledge of the epilithic diatom flora and its diversity in the mainstream and the most important tributaries; (2) elucidation of the structure and organization of the epilithic diatom communities in the investigated streams (qualitative structure – floristic composition, specific diversity and equitability, floristic affinity); (3) highlighting the pattern of seasonal dynamics of the diatom communities from the Cerna Valley and (4) the assessment of the Cerna River's ecological state, based on the diatoms ecological preferences, Saprobic Index (SI) and Biological Diatom Index (BDI).

I. Brief History of the Algological Research in the Area of Study

The members of the *Bacillariophyta* phylum occurring in the hydrographic basin of the Cerna River were poorly documented. Mika (1880) mentioned only five diatom species and almost in the same time Schaarschmidt (1882) recorded the presence of 22 species. The phycological investigations have been resumed after a very long period by Popescu, Prunescu-Arion and Drăgăşanu (1962), Buşniţă, Brezeanu, Oltean, Popescu-Marinescu and Prunescu-Arion (1970), Nicolescu and Oltean (1986) and more recently by the present author and his coworkers (Péterfi and Sinitean, 2002; Péterfi and Sinitean, 2007; Péterfi, Voicinco and Sinitean, 2007; Péterfi, Kiss and Sinitean, 2007).

II. Materials and Methods

The benthic diatom samples were taken in 21 stations (**Fig. 1**), during an interval of approximately two years (2001 - 2003); these samples were used for quantitative processing (those from the actual Cerna River). Additional samples were collected in 2008, when the author also measured certain abiotic parameters in the field (temperature, conductivity, pH, and dissolved oxygen), employing a WTW multi 350i multi-parameter. The speed of flow was measured by using a Geopacks MFP51 flow-meter, and the GPS coordinates were determined for the sampling sites with a GPS receptor - Garmin 60 CSX.

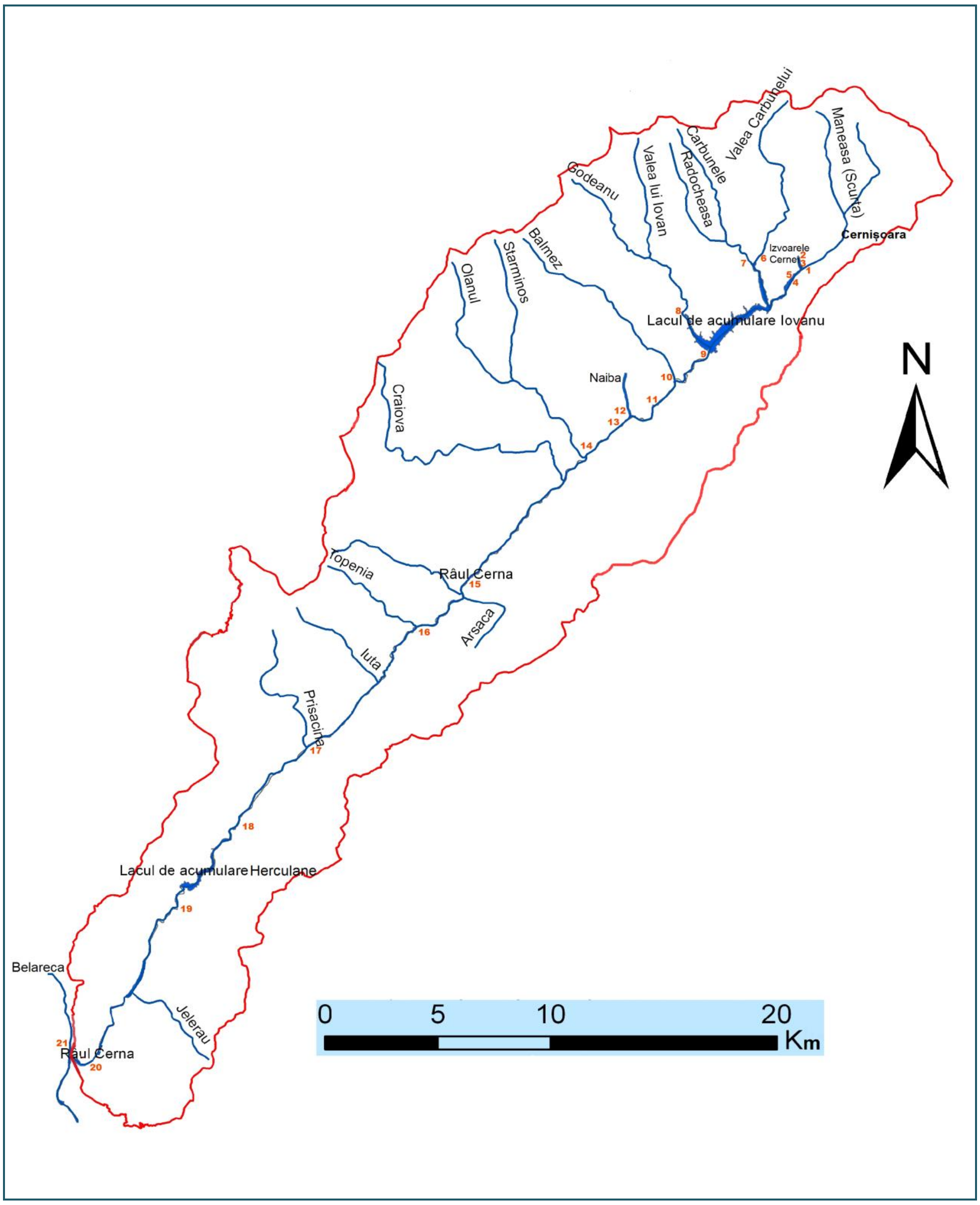

Figure 1 – Sampling sites (stations): Cernişoara river, upstream of the confluence with Cerna Springs (1), Cerna Springs, upstream (2), Cerna Springs, downstream (3), Cerna River, upstream of the confluence of Cerna Springs with Cernişoara, on the left shore (4), Cerna River, downstream of the confluence of Cerna Springs with Cernişoara, on the right shore (5), Cărbunele brook (6), Rădoteasa brook (7), Iovanu brook (8), Cerna River, downstream of the Iovanu impoundment (9), Balmeş brook, upstream of the confluence with Cerna River (10), Cerna River, upstream of Corcoaiei Gorge (11), Naiba brook, upstream of the confluence with Cerna River (12), Cerna River, upstream of Cerna-Village (13), Cerna River, downstream of Cerna-Village (14), Cerna River, upstream of the confluence with Mihalca brook (15), Cerna River, upstream of the confluence with Topenia brook (16); Cerna River, upstream of the confluence with Prisăcina brook (17), Cerna River, upstream of the Herculane impoundment (18), Cerna River, upstream of Băile Herculane (Seven Hot Springs area - 19), Cerna River, downstream of Băile Herculane and upstream of the confluence with Belareca River (20), Belareca River, downstream of Băile Herculane and upstream of the confluence with Cerna River (21) (Processing after www.domogled-cerna.ro)

The epilithic samples were collected simply by brushing the surfaces of substrata, using 3-5 different rocks or stones completely covered by the flowing water. Each sample was divided and stored in two labeled recipients and preserved in 4% formalin. Samples were subsequently treated with strong mineral acids (ex. HNO_3), followed by incineration (for six hours). The diatom frustules were mounted in colophony. The examination, taxonomic identification and the establishment of the floristic composition of the epilithic communities was done by using trinoculare microscopes (BIOROM, CETTI, OPTIKA B600, OLYMPUS BX51), immersion objectives (90x or 100x, with known IM), and using up-to-date identification books: *Süsswasserflora von Mitteleuropa* [Krammer and Lange-Bertalot **-** vol. 2/1, 1986; vol. 2/2, 1988; vol. 2/3, 1991a; vol. 2/4, 1991b; vol. 2/5, 2000], and *Diatoms of Europe* [coordinated by Lange-Bertalot - vol. 1, 2000; vol. 2, 2001; vol. 3, 2002; vol. 4, 2003]. The light micrographs have been obtained with digital cameras adapted for the microscopes (Nikon Coolpix 4500, Canon A630 or Olympus E330). The checklist and the conspectus of diatom flora were organized after the system presented in *The Diatoms* [Round *et al.*, 2000]. Each taxon is provided with a briefly description of their general prevalence and ecology, and finally referring to their report in the present study (either punctual, or more generalized).

The relatively quantitative assessment of samples (counting approximately 600 frustules/preparation) harvested in the Cerna River (stations 1, 2, 3, 4, 5, 9, 11, 13, 14, 15, 16, 17, 18, 19, and 20) and Belareca River (station 21) allowed the determination of the relative specific abundance (number of frustules/species/sample), as well as of the diversity (by calculating the $\boldsymbol{D}$ ($\boldsymbol{D_\alpha}$) index - [Jost, 2006]) and specific equitability (with the help of E equitability index of Pielou), of seasonal dynamics and diagnosis index monitoring the percentage abundance of *Achnanthes minutissima* species. The samples collected from different tributaries (sampling sites 6, 7, 8, 10, 12) were processed strictly qualitatively (recording only the species presence) and used, together with the quantitative ones, to characterize the floristic composition and floristic affinity of the epilithic communities (applying the Sørensen Index).

Other applications for which the diatom communities proved to be very useful were those regarding water quality assessment. This was done both by graphic representation of the saprobic categories of diatoms, according to the characterizations published in the algological literature of the different taxa, but especially by calculating two indices, the Saprobic Index of diatoms (SI), according to the formula introduced by Zelinka and Marvan [Prygiel *et al.*, 1999] and the Biological Diatom Index – BDI – developed by the Water Supply Agency and Cemagref, France.

III. Results and Discussions

The taxonomic analysis of the epilithic diatom communities from the Cerna River and some of its tributaries led to the identification of 360 specific and infraspecific taxa, namely 315 species, three subspecies, 41 varieties and one form, distributed in 46 genera, 24 families, 13 orders, five subclasses and three classes. The best represented family was Naviculaceae, and the best represented genus was *Navicula*, with 65 specific and infraspecifice taxa; the following genera, in descending order are: *Nitzschia* (42 taxa), *Cymbella* (34 taxa), *Pinnularia* (23 taxa), *Achnanthes* and *Gomphonema* (19 taxa), *Fragilaria* (14 taxa), *Eunotia*, *Cocconeis* (13 taxa each) and *Surirella* (12 taxa), the other genera being represented by less than ten taxa, many of them by only one species (**Fig. 2**).

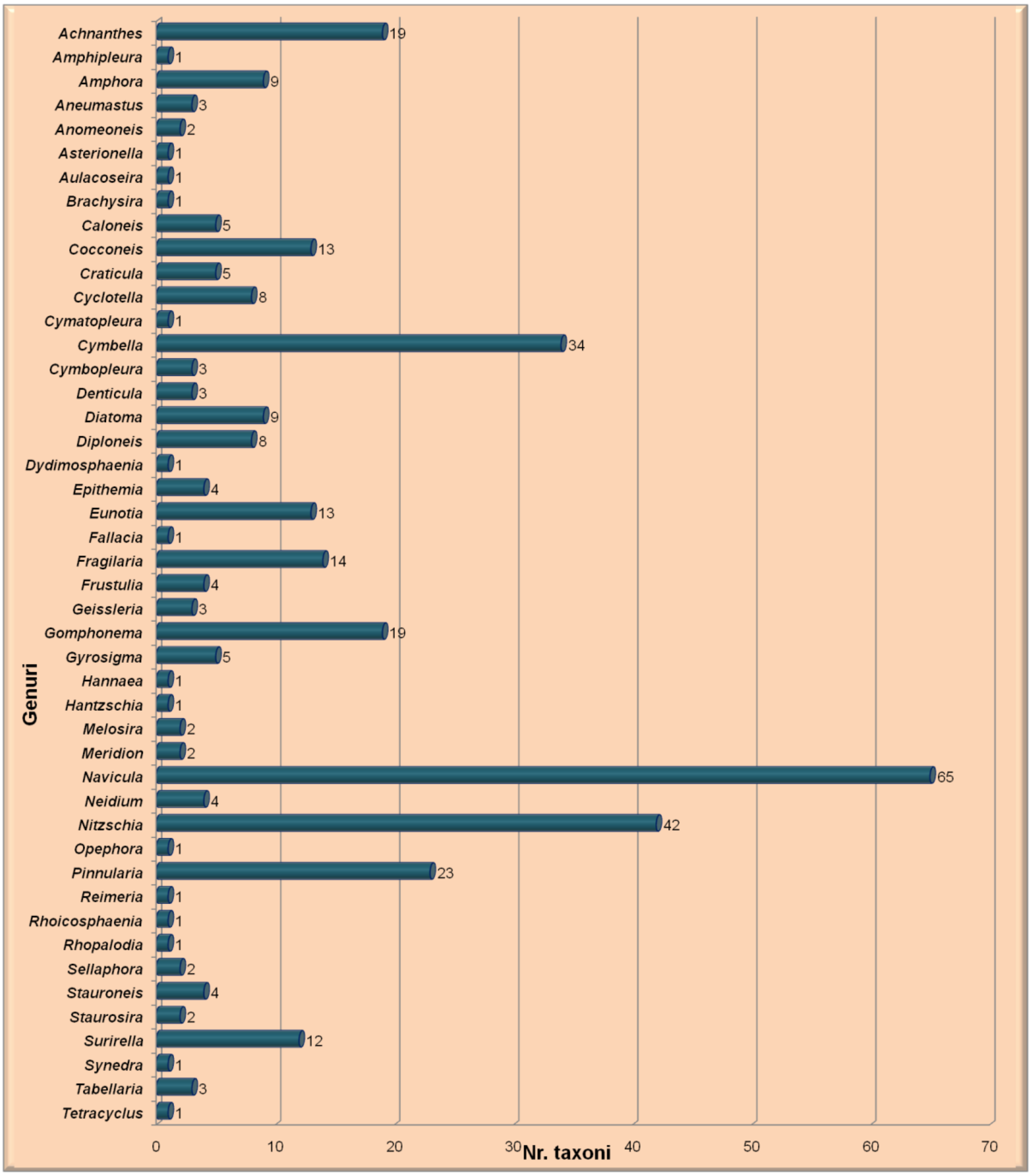

Figure 2 – The distribution of identified diatom taxa within the various genera

The benthic communities from different sampling sites on the Cerna River basin ranges widely in the number of taxa that comprises, from 12 (May 2003, Cărbunele brook) to 67 (October 2001, upstream of Băile Herculane), with a general average of 31.74 taxa/site, exhibiting a general trend of increasing species diversity upstream to downstream.

III. 1. Floristic composition

Although the work aimed the investigation of the epilithic diatoms, the author sampled and identified the species collected from other benthic substrates. On the other hand in some of the epilithic samples appeared diatoms characteristic for other substrate types, in descending order epiphytic, epipelic, aerophile, epipsammic and edaphic. There were also detected few thermophilic ones.

Regarding the frequency of identified diatoms in the samples, the author could observe that a large number of taxa occur only up to ten times; increasingly fewer are those cited as rare, sporadic, frequent or common.

Most of the taxa are characterized as cosmopolitan (e.g. *Achnanthes minutissima*, *Amphora ovalis, Caloneis bacillum, Cocconeis placentula, Cyclotella pseudostelligera, Cymbella affinis, C. minuta, Diatoma hyemalis, Epithemia argus, Eunotia exigua, Gomphonema parvulum, Hannaea arcus, Navicula capitatoradiata, N. lanceolata, N. radiosa, N. tripunctata, Nitzschia amphibia, N. brevissima, N. palea, Pinnularia divergens, Rhoicosphenia abbreviata, Surirella splendida,* and *Synedra ulna*,), or probably cosmopolitan (*Amphipleura pellucida*, *Amphora pediculus*, *Caloneis molaris*, *Cyclotella radiosa*, *Cymbella lange-bertalotii*, *Diploneis ovalis*, *Eunotia minor*, *Gomphonema olivaceum, Navicula oppugnata, Nitzschia amplectens,* and *Reimeria sinuata*).

Far fewer are the taxa with northern-alpine distribution (*Cymbella dorsenotata*, *Diploneis parma, Fragilaria tenera,* and *Nitzschia alpina*), those widely distributed on the northern hemisphere (*Amphora fogediana*, *Aneumastus apiculatus*, and *Tabellaria binalis*), circumtemperates (*Cymbella caespitosa*, *C. compacta*), inhabiting the European continent (*Gomphonema insigne*, *Navicula helensis*) or even with pantropical area (*Diploneis subovalis*). Some diatoms have a vaguely characterized distribution, described as "limited" (*Cymbella scutariana, Gomphonema helveticum,* and *Pinnularia marchica*), indefinite (*Eunotia praerupta, Navicula brockmanii*) or less (incompletely) known (*Aneumastus apiculatus*, *Cymbella cuspidata,* and *Gomphonema minutum*). Regarding certain altitudinal preferences, most taxa are distributed in mountainous regions, followed by those occurring on the plains, and far fewer are the taxa with subalpine and alpine distribution.

With regard to preferences for the lotic or lentic nature of the water, most taxa are adapted to both aquatic habitat types, by contrast others occur in streams (*Achnanthes thermalis, Hannaea arcus,* and *Nitzschia pura*), whereas there are some mentioned inhabiting preferentially springs (*Diatoma mesodon, Rhopalodia gibba*), brooks (*Cymbella excisiformis, Navicula brockmanii*) or rivers (*Cymbella turgidula, Navicula exilis*). Other taxa are characteristic of standing waters (*Caloneis shumanniana*, *Fragilaria brevistriata,* and *Geissleria similis*), of which some are characterized specifically preferring lakes (*Asterionella formosa, Cyclotella comensis*), pools (*Pinnularia persudetica* var. *silvatica*), bogs (*Eunotia paludosa*) or ponds (*Gomphonema pumilum*).

In terms of salt content of the water, some taxa are often recorded also from brackish waters (or fresh-brackish), and very few are encountered in saline waters (or with high electrolyte content), or they are oligohaline or mesohaline taxa. Many taxa request waters having certain amount of electrolytes; most of them prefer waters with medium electrolyte content, others prefer high electrolyte content, and by contrast some prefer waters with low electrolyte content. In regard to the water pH, most recorded taxa are basophilous, others prefer circumneutral or even acidic waters (acidophilous); small proportion of taxa are of extreme request (acidobiontic or alkalibiontic).

As water trophicity indicators, most taxa are specific to oligotrophic waters, followed by those characteristic to eutrophic and mesotrophic habitats, fewer taxa prefer dystrophic waters.

Achnanthes minutissima is the species markedly dominating, both qualitatively and quantitatively, the epilithic diatom communities on the Cerna River. Besides this, the following species occur in most of the samples: *Achnanthes lanceolata, Amphora pediculus, Cocconeis placentula, Cymbella affinis, C. compacta, C. minuta, C. silesiaca, Diatoma hyemalis, D. mesodon, D. vulgaris, Fragilaria capucina, Gomphonema minutum, G. parvulum, Hannaea arcus, Navicula capitatoradiata, Nitzschia palea, Reimeria sinuata, Rhoicosphenia abbreviata,* and *Synedra ulna. Didymosphenia geminata* should be remarked as invasive species in the Cerna River, reported as frequent on the middle and lower sectors, and sporadically on its upper one.

There have been detected in the Cerna River catchment area 48 diatoms, which have not yet been recorded in Romania (printed in bold):

Phylum Bacillariophyta
Class Fragilariophyceae Round
Subclass Fragilariophycidae Round
Order Fragilariales Silva
Family Fragilariaceae Greville
Opephora olsenii Möller
Order Tabellariales Round
Family Tabellariaceae Kützing
Tabellaria binalis (Ehrenberg) Grunow var. ***elliptica*** Flower
Class Bacillariophyceae Haeckel
Subclass Eunotiophycidae D. G. Mann
Order Eunotiales Silva
Family Eunotiaceae Kützing
Eunotia bilunaris (Ehrenberg) Mills var. ***mucophila*** Lange–Bertalot & Nörpel
Subclass Bacillariophycidae D. G. Mann
Order Mastogloiales D. G. Mann
Family Anomoeoneidaceae D. G. Mann
Anomeoneis brachysira (Brébisson) Grunow var. ***zellenis*** (Grunow) Krammer (*Navicula zellensis* (Grunow) Krammer)
Family Cymbellaceae Greville
Cymbella brehmii Hustedt

Cymbella cantonatii Lange–Bertalot
Cymbella dorsenotata Østrup
Cymbella excisiformis Krammer
Cymbella hillardii Manguin
Cymbella lange–bertalotii Krammer
Cymbella scutariana Krammer
Cymbella vulgata Krammer var. ***plitvicensis*** Krammer
Family Gomphonemataceae Kützing
Gomphonema pseudotenellum Lange–Bertalot
Order Achnanthales Silva
Family Achnantaceae Kützing
Achnanthes lanceolata (Brébisson) Grunow ssp. *lanceolata* (Brébisson) Grunow var. ***haynaldi*** (Schaarschmidt) Cleve
Family Cocconeidaceae Kützing
Cocconeis scutellum Ehrenberg var. ***stauroneiformis*** Rabenhorst
Order Naviculales Bessey
Suborder Neidiinae D. G. Mann
Family Neidiaceae Mereschkowsky
Neidium apiculatum Reimer
Suborder Sellaphorineae D. G. Mann
Family Pinnulariaceae D. G. Mann
Pinnularia acidophila Hofmann & Krammer
Pinnularia acoricola Hustedt
Pinnularia brébissonii (Kützing) Rabenhorst var. ***minuta*** Krammer
Pinnularia divergens W. Smith var. ***sublinearis*** Cleve
Pinnularia eifelana Krammer
Pinnularia isselana Krammer
Pinnularia persudetica Krammer var. ***silvatica*** Krammer
Pinnularia subcapitata Gregory var. ***subrostrata*** Krammer
Suborder Naviculineae Hendey
Family Naviculaceae Kützing
Hippodonta lesmonensis (Hustedt) Lange–Bertalot, Metzeltin & Witkowski (*Navicula lesmonensis* Hustedt)
Navicula alineae Lange–Bertalot
Navicula antonii Lange–Bertalot (*N. menisculus* var. *grunowii* Lange–Bertalot)
Navicula aquaedurae Lange–Bertalot
Navicula arctotenelloides Lange–Bertalot & Metzeltin
Navicula catalanogermanica Lange–Bertalot & Hofmann
Navicula gerlofii Schimanski
Navicula moskalii Metzeltin, Witkowski & Lange–Bertalot
Navicula praeterita Hustedt
Navicula stroemii Hustedt
Navicula trophicatrix Lange–Bertalot
Navicula wiesneri Lange–Bertalot (*N. heufleri* f. *minuta* Grunow)
Family Stauroneidaceae
Craticula buderi (Hustedt) Lange–Bertalot (*Navicula buderi* Hustedt)
Craticula riparia (Hustedt) Lange–Bertalot (*Navicula riparia* Hustedt) var. ***mollenhaueri*** Lange–Bertalot
Craticula vixnegligenda Lange–Bertalot
Stauroneis borrichii (Petersen) Lund
Order Bacilariales Hendey
Family Bacillariaceae Ehrenberg

Nitzschia alpina Hustedt emend. Lange–Bertalot
Nitzschia amphibia Grunow f. ***rostrata*** Hustedt
Nitzschia amplectens Hustedt
Nitzschia littorea Grunow
Nitzschia prolongata Hustedt var. ***hoenhnkii*** (Hustedt) Lange–Bertalot
Nitzschia pumila Hustedt
Nitzschia terrestris (Petersen) Hustedt
Order Surirellales D. G. Mann
Family Surirellaceae Kützing
Surirella tenuis A. Mayer

III.2. Specific diversity

Regarding the distribution of absolute diversity values, their interval ranges widely between the minimal D_{α}=1.791 (Cerna Springs, downstream, February 2002) and the maximal D_{α}=24.47 (Băile Herculane, downstream, October 2001), the average values of diveristy, depending on the season of sampling, the highest are in the autumn samples (October 2001), followed by spring samples (May 2002) and the next autumn ones (October 2002).

Following the dynamics of the average diversity values along the entire course of the Cerna River in all sampling periods (**Fig. 3**) one should notice that diversity has markedly high values in the Cernişoara rivulet, especially compared with its twin tributary – the Cerna Springs, forming together the Cerna River, where the D_{α} index has the most reduced values of the entire course. After the confluence of the two streams, the species diversity decreases on the newly formed stream, the Cerna River (especially on the right shore, influenced by the Cerna Springs), then exhibit a slight increase downstream of the first water reservoir (Iovanu) and returns to values comparable to those from the Cernişoara, upstream of Corcoaiei Gorge. The sampling site downstream Cerna-Village reports again a marked decrease of diversity, followed by a slight increae downstream the village, after which the D_{α} index decreases slightly in the next two sampling sites (upstream confluence with Mihalca, and upstream confluence with Topenia). Starting with downstream Topenia the diversity increases constantly along the river, moderately at the beginning and markedly after the second impoundment (Herculane), recording very high values in the sites upstream and downstream Băile Herculane. The diatom communities occurring in the Belareca rivulet (tributary of Cerna) show high diversity values, but somewhat lower than that on the Cerna Valley, close to the confluence. Major anthropic influences (two water reservoirs and Băile Herculane), as well as the increase of eutrophication downstream the Cerna River provide a specific diversity increase in the epilithic diatom populations of the Cerna Valley.

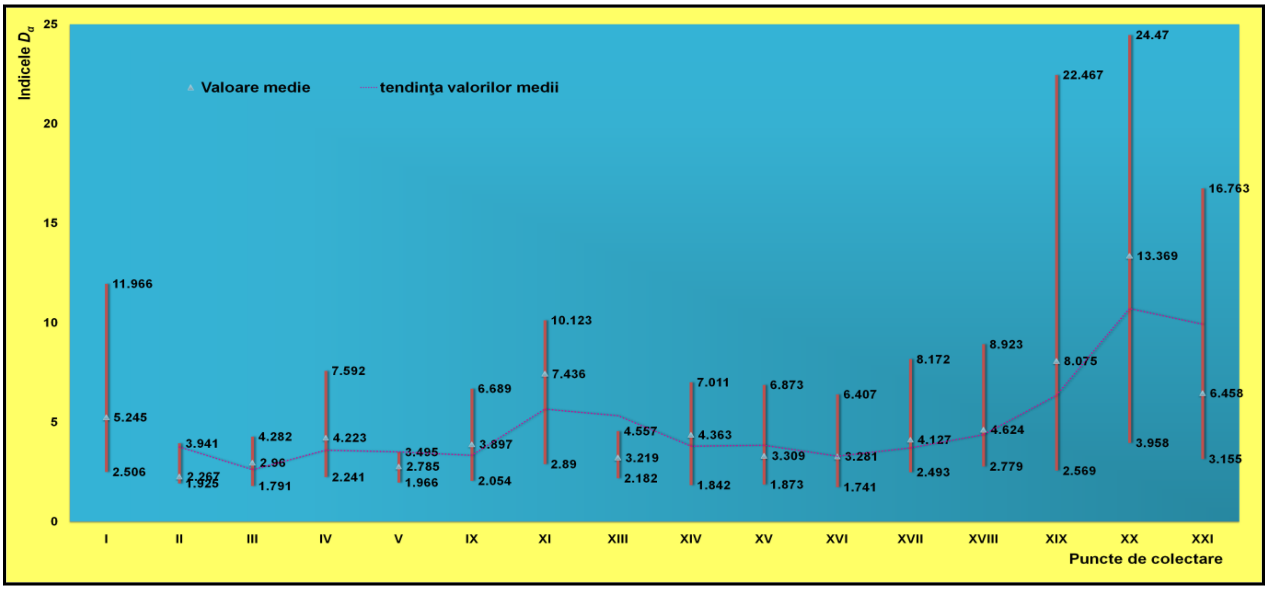

Figure 3. Dynamics of specific diversity (maximal, minimal and average values of the D_α index) from upstream to downstream, during the entire analyzed period.

III. 3. Specific Equitability (Dominance)

Minimal values of the Pielou Index are recorded in the Cerna sites, upstream the confluence with Topenia (0.166, in October 2002), and maximal ones downstream Băile Herculane (0.811, in February 2002). The average values of equitability follow the trends of mean diversity values (**Table 1**). Therefore, these values are higher on Cernişoara, decrease between the two sites on the Cerna Springs.

Table 1 – Pielou Equitability Index values in the analyzed sampling sites (blue – maximal values, red – minimal values)

Sampling sites / Sampling period	I	II	III	IV	V	IX	XI	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
June 2001	0.331	0.318	0.285	0.410	0.344	0.570	0.373	0.316	0.381	0.206	0.329	0.264	0.335	0.261	0.502	-
October 2001	0.559	0.281	0.390	0.505	0.399	0.426	0.609	0.353	0.524	0.329	0.522	0.573	0.535	0.557	0.798	0.443
February 2002	0.540	0.212	0.179	0.385	0.222	0.221	0.334	0.221	0.172	0.280	0.357	0.474	0.458	0.659	0.811	0.403
May 2002	0.364	0.264	0.392	0.666	0.250	0.365	0.409	0.322	0.503	0.259	0.345	0.305	-	0.796	0.736	0.349
July 2002	0.317	0.474	0.338	0.260	0.361	0.268	0.285	0.350	0.294	0.342	0.273	0.353	-	0.296	0.627	0.479
October 2002	0.541	0.334	0.486	0.431	0.358	0.278	0.560	0.269	0.295	0.228	0.166	0.270	0.272	0.490	0.675	0.732
May 2003	0.682	0.349	0.422	0.540	0.344	0.358	0.641	0.334	0.513	0.561	0.291	0.314	-	0.354	0.359	0.316
August (IX-XXI) September (I-V) 2008	0.383	0.255	0.272	0.240	0.234	0.460	0.584	0.411	0.368	0.369	0.398	0.379	0.355	0.499	0.459	-
Average value	0.464	0.312	0.345	0.429	0.314	0.368	0.474	0.322	0.381	0.322	0.335	0.366	0.391	0.489	0.621	0.453

Next the Iovanu impoundment, the Pielou Index shows moderate values increasing upstream Corcoaiei Gorge (reaching similar values like those from Cernişoara). A marked decrease follows, upstream Cerna-Village, and an increase downstream of it, followed by another decrease upstream the Mihalca tributary sampling site. The next sampling sites show continuous increase of the equitability index downstream, inconspicuous at the beginning and more pronounced below the Herculane impoundment, in that more and more taxa show significant percentages in the epilithic community structure, but it decreases in the Belareca tributary.

III.4. Floristic Affinity

The floristic affinity expressed by the Sørensen Index, for each year investigated, (**Figs. 4-7),** emphasizes that the values widely ranges, from less than 10%, for a sample group from 2002 (spring samples, May 2002, and autumn samples, November 2002), to more than 90% for the remaining samples of the same year, in one of the most interesting aggregates, including more autumn samples (October 2002), from the upper area of the Cerna course. Generally, samples with high similarity values were more frequently grouped after their consecutive arrangement along the Cerna river course, during the same sampling period, therefore distinct sample groups can be noticed for upstream, middle course and downstream. Of course, there are instances in which similarity is higher between more or less closely located samples, of different sampling periods (seasons).

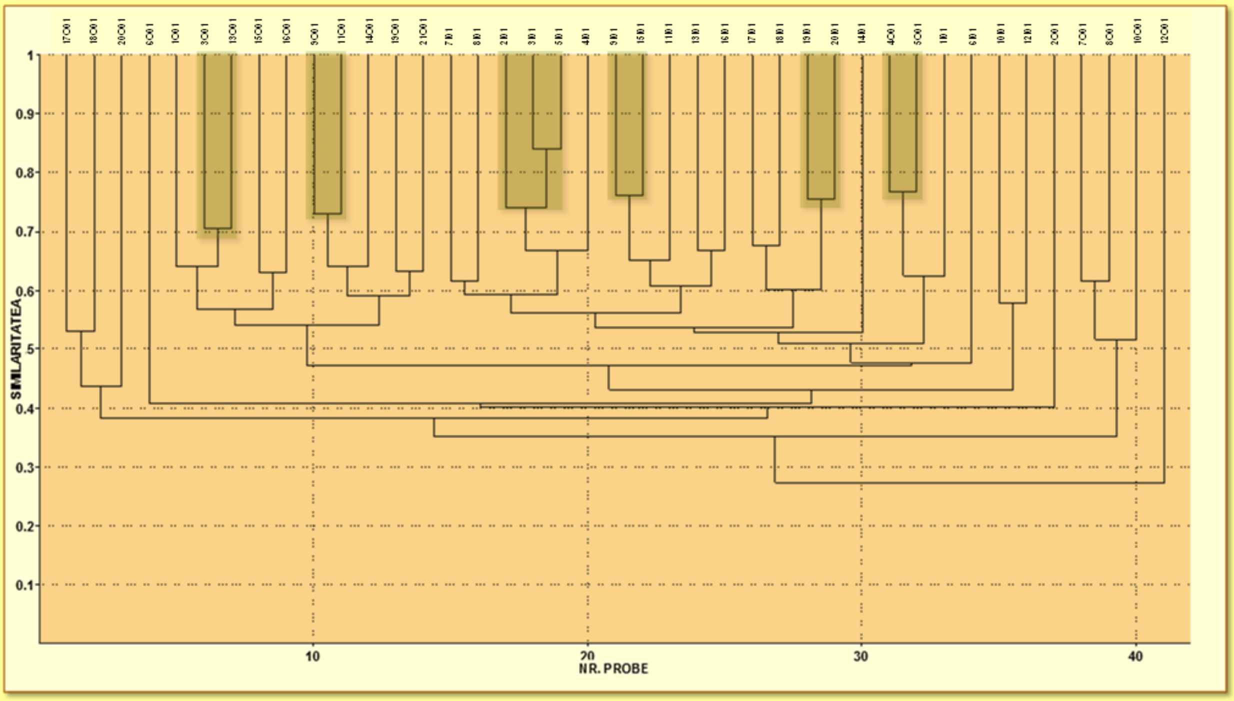

Figura 4 Dendrograma similarităţii floristice pentru comunităţile de diatomee epilitice din râul Cerna prelevate în anul 2001. 1-21 – puncte de prelevare; I01 – iunie 2001; O01 – octombrie 2001.

Analyzing the similarity of epilithic diatom communities in each investigated year, for 2001 (**Fig. 4**), the upper course of the Cerna River exhibited the highest similarity values, between the summer samples. Among the communities of 2002, there were several with higher floristic similarity values (**Fig. 5**), e.g. the autumn and winter sample groups, in between which the highest values of similarity are recorded for the entire Cerna course and for the entire sampling period, already mentioned.

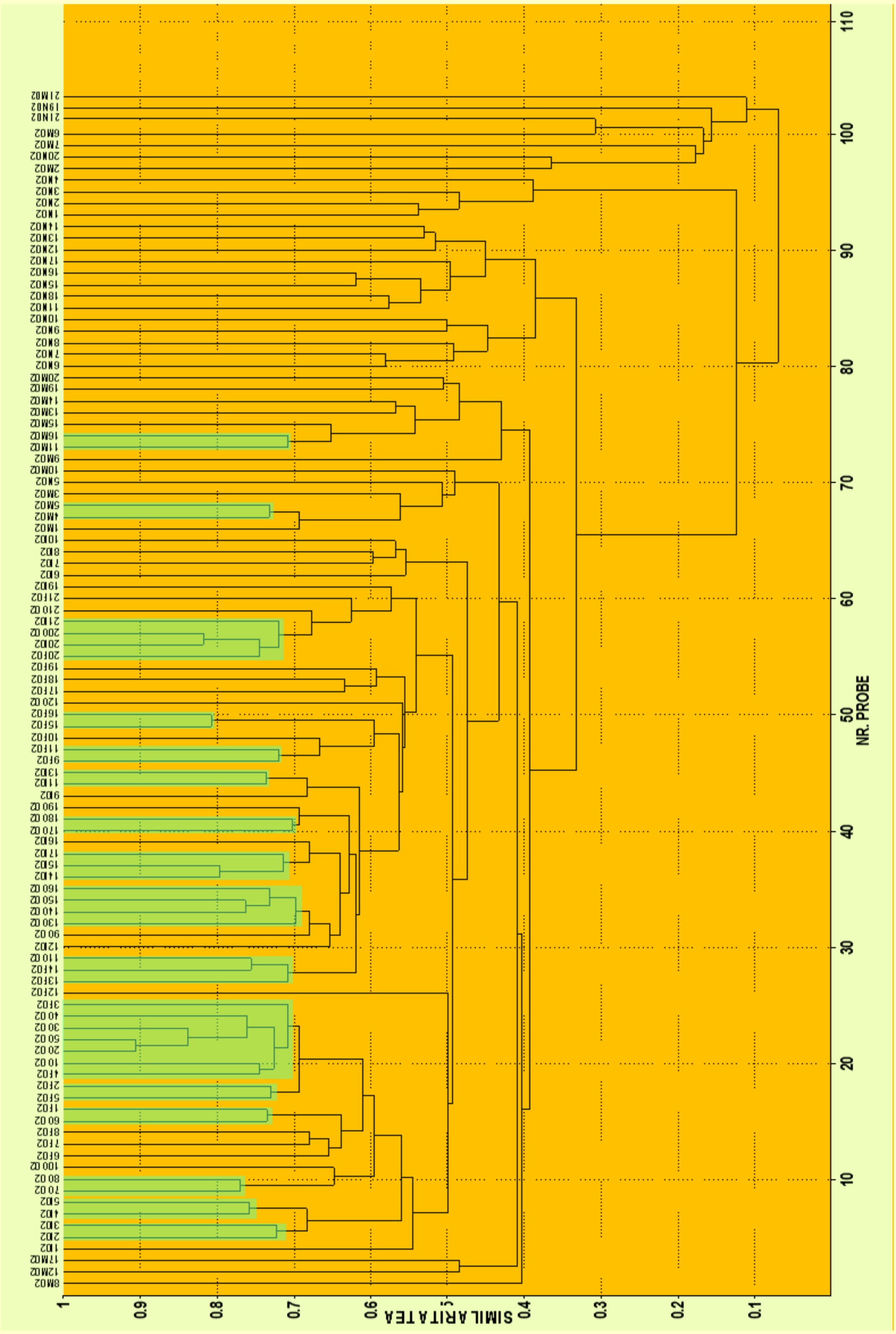

Figura 5 Dendrograma similarității floristice pentru comunitățile de diatomee epilitice din râul Cerna prelevate în anul 2002.
1-21 – puncte de prelevare; F02 – februarie 2002; M02 – mai 2002; I02 – iulie 2002; O02 – octombrie 2002; N02 – noiembrie 2002.

Among the communities sampled in 2003 (**Fig. 6**) and 2008 (**Fig. 7**), there are less with high floristic affinity, like the spring communities from the middle and lower course for 2003.

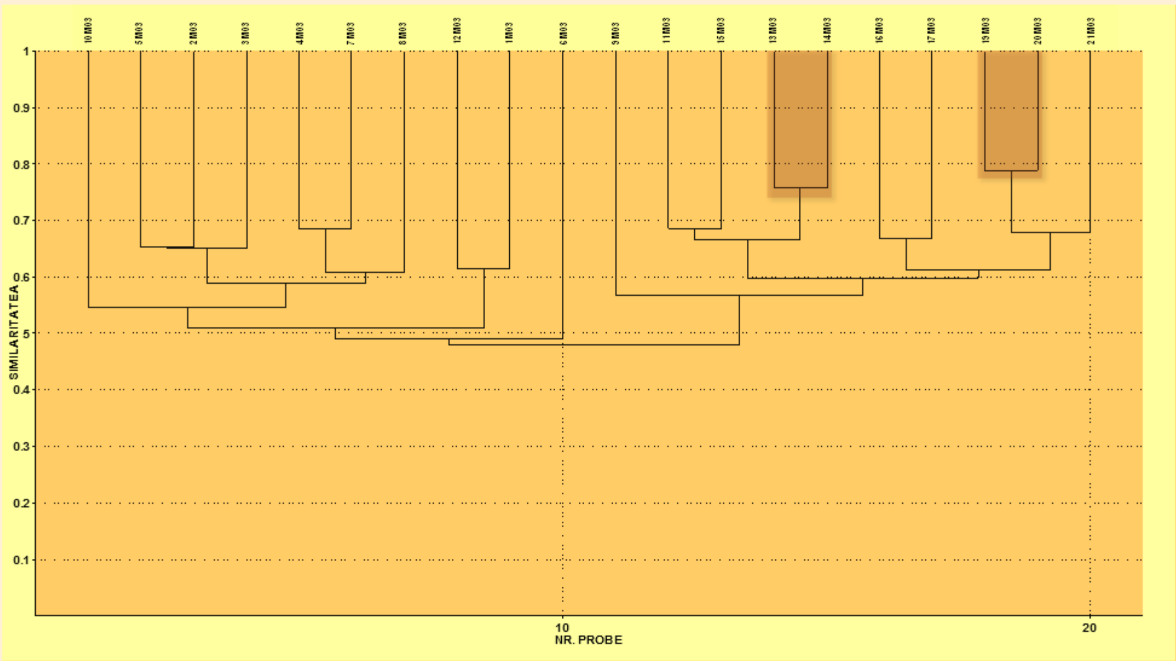

Figura 6 Dendrograma similarității floristice pentru comunitățile de diatomee epilitice din râul Cerna prelevate în anul 2003. 1-21 – puncte de prelevare; M03 – mai 2003.

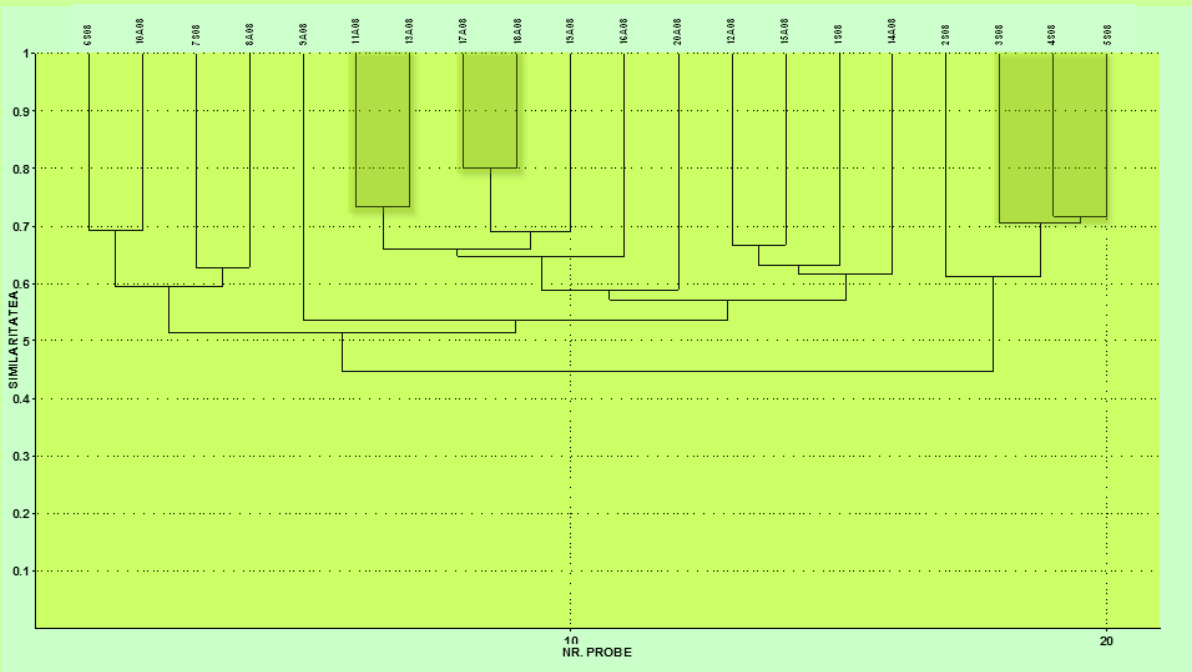

Figura 7 Dendrograma similarității floristice pentru comunitățile de diatomee epilitice din râul Cerna prelevate în anul 2008. 1-20 – puncte de prelevare; A08 – august 2008, S08 – septembrie 2008.

III. 5. Percentage Abundance of *Achnanthes minutissima* (RDA)

The proportion of this pioneer species, signaling the presence of some stress factors producing disturbances in the water course, exhibits different values, relatively randomly distributed along the Cerna River and during the sampling period. Considering all samples, prevalent are those in which the Abundance Index (RDA) shows major disturbances (40.65%), followed in decreasing order those indicating moderate (34.96%) and minor (13.82%) disturbances. The fewest are the samples without disturbances (10.57%).

III. 6. Seasonal Dynamics of Epilithic Diatom Communities from the Cerna River

Among all recorded species during the investigation the highest percentage abundances exhibited *Achnanthes minutissima* (present in 88.62% of the samples). It is remotely followed by *Cymbella minuta* and *Gomphonema minutum* (each with 2.44%), *Diatoma mesodon* (1.63%) and taxa prevalent in only one sample (0.08%): *Amphora pediculus, Cyclotella comensis, Hannaea arcus, Nitzschia inconspicua,* and *Rhoicosphenia abbreviata*. *Achnanthes minutissima* dominates numerically in all river sectors; by contrast the other species dominant in certain samples are encountered in different sectors of the Cerna River: *Diatoma mesodon* only in the upper sector, *Gomphonema minutum* in the upper and middle, *Hannaea arcus* only in the middle sector. In the lower river sector are prevalent *Amphora pediculus, Cyclotella comensis, Nitzschia inconspicua,* and *Rhoicosphenia abbreviata*. Besides these, only *Cymbella minuta* dominates equally (in one sample) in all three river sectors.

In the samples collected upstream of the Iovanu impoundment (upper sector, 1-5 sampling sites) in the analyzed period of time, there is an epilithic diatom community with a relatively low number of species with over 1% percentage prevalence. Thus, if analyzing for instance the communities processed form **the first sampling site (Cernişoara)** – in most of the samples dominates, with relatively high percentage (between 30 and 77%), *Achnanthes minutissima*, and, with percentages over 10%, *Cymbella minuta*, *Cocconeis placentula*, *Gomphonema minutum*, *Hannaea arcus* and *Reimeria sinuata* as codominants. In two of the samples *Gomphonema minutum* became dominant, *Achnanthes minutissima* and *Hannaea arcus* codominants (**Fig. 8**, taxa abbreviations are shown in **Annex 1**).

In the analyzed samples, from the sampling sites located between the two impoundments (Iovanu and Herculane, sampling sites 9-18), compared with those on the upstream ones, the epilithic diatom communities do not significantly become richer as taxa number with over 1% prevalence, only in isolated situations. There is also present the same dominant species, *Achnanthes minutissima*, as well as its codominants, *Cymbella minuta*, *Cocconeis pediculus*, *C. placentula, Didymosphenia geminata*, *Fragilaria capucina*, *Gomphonema minutum, Hannaea arcus,* and *Reimeria sinuata* occur.

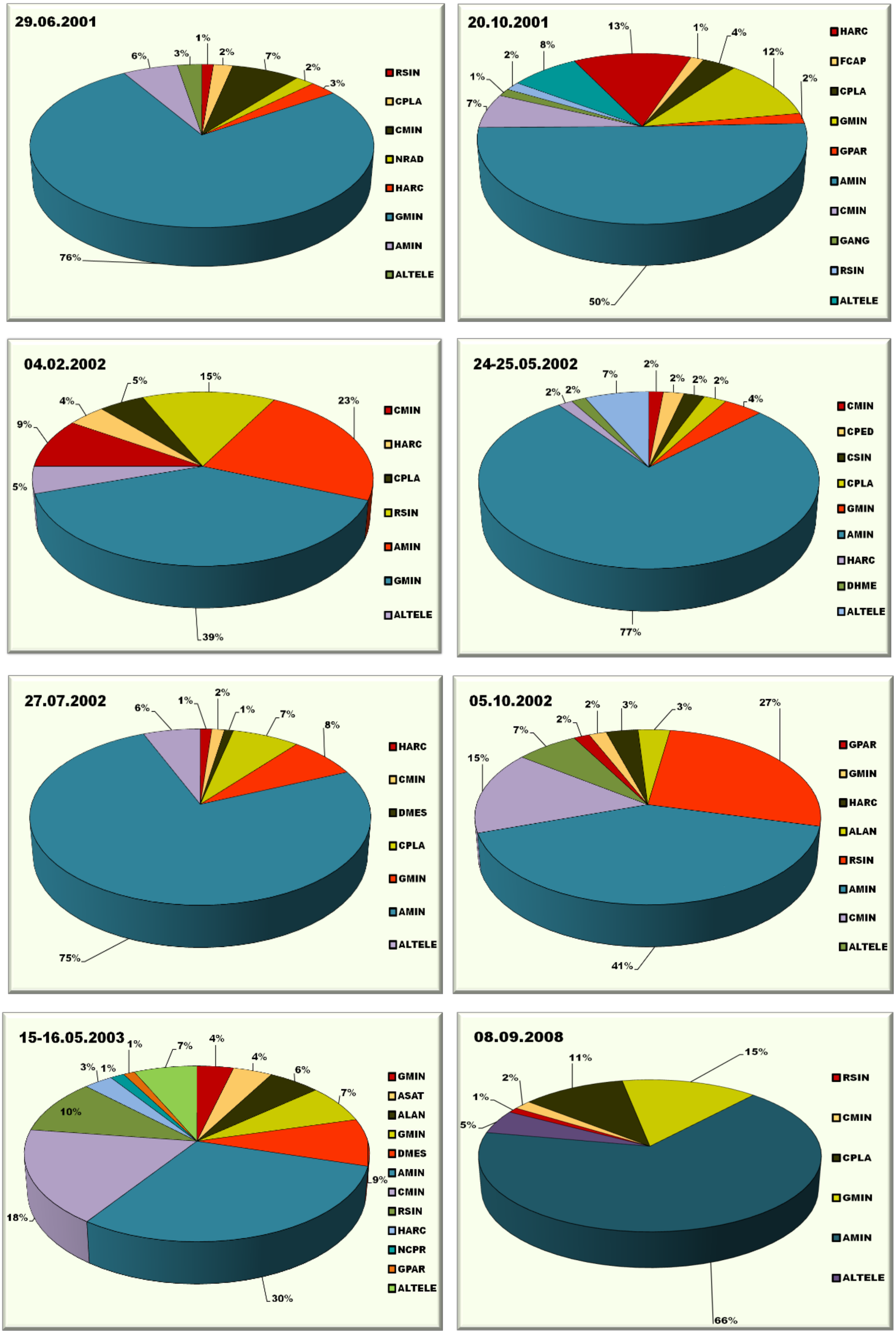

Figure 8. Percentage abundance of taxa with significant presence (≥1%), Cernişoara (sampling site 1)

In a sampling site significant for this sector (site 11, from Cerna, upstream Corcoaiei Gorge), the author observed a slight enrichment trend in the epilithic diatom community structure. Even if *Achnanthes minutissima* continues to be the dominant species in almost all the analyzed samples, especially in the summer and winter ones, in the autumn and spring samples other codominant species occur. Only in a single sample, there are different dominant species, *Gomphonema minutum*, and *Achnanthes minutissima*, *Cymbella minuta* and *Cocconeis placentula* being codominants (**Fig. 9**).

In the sampling sites from the lower sector of the Cerna River (sites 19-21) the richest diatom communities occur for the entire Cerna course. Even though *Achnanthes minutissima* dominates by its populations in most of the analyzed samples, its exclusive dominance decreases. In the structure of these communities are other dominant species, more frequent than upstream (*Amphora pediculus*, *Nitzschia inconspicua*, *Rhoicosphenia abbreviata* and *Cyclotella comensis*).

There is also the sampling site in which epilithic diatom communities have the highest specific enrichment in the entire Cerna River course (sampling site 10, on the Cerna River, downstream Băile Herculane). *Achnanthes minutissima* dominated only half of the analyzed samples (**Fig. 10**), having moderate percentages and therefore with many codominant species (*Achnanthes lanceolata* ssp. *frequentissima, A. thermalis, Cocconeis placentula,* and *Cymbella minuta*). In 50% of the samples, the communities are dominated by other species like *Amphora pediculus, Cymbella minuta,* and *Nitzschia inconspicua* (where *Achnanthes minutissima* or *Cyclotella comensis* are codominants).

III. 7. Water Quality Assessment of the Cerna River Based on Epilithic Diatom Communities

Benthic diatoms represent some of the best bioindicators among algae, because they are at the base of the food chains and among the first organisms responding to changes that may arise in the environment [Lowe *et* Pan, 1996], have short life cycles and implicitly a rapid reaction to the variations of some environmental factors; there is a great number of species, widespread in different ecosystems and geographical areas, readily useful to monitoring vast areas [Stevenson *et* Pan, 1999, cited by Lavoie *et al.,* 2009]. Their value as bioindicators is completed also by their predominance as algal group in most of the water bodies, especially on the upper and middle courses, rapid multiplication, prompt reaction to the short and long term alterations of the environment, for different impact types, numerous surviving forms (resistant spores, cysts, zygotes etc.) and diverse means of spreading, having as vectors the water, wind, animals, humans etc. [Momeu *et* Péterfi, 2007].

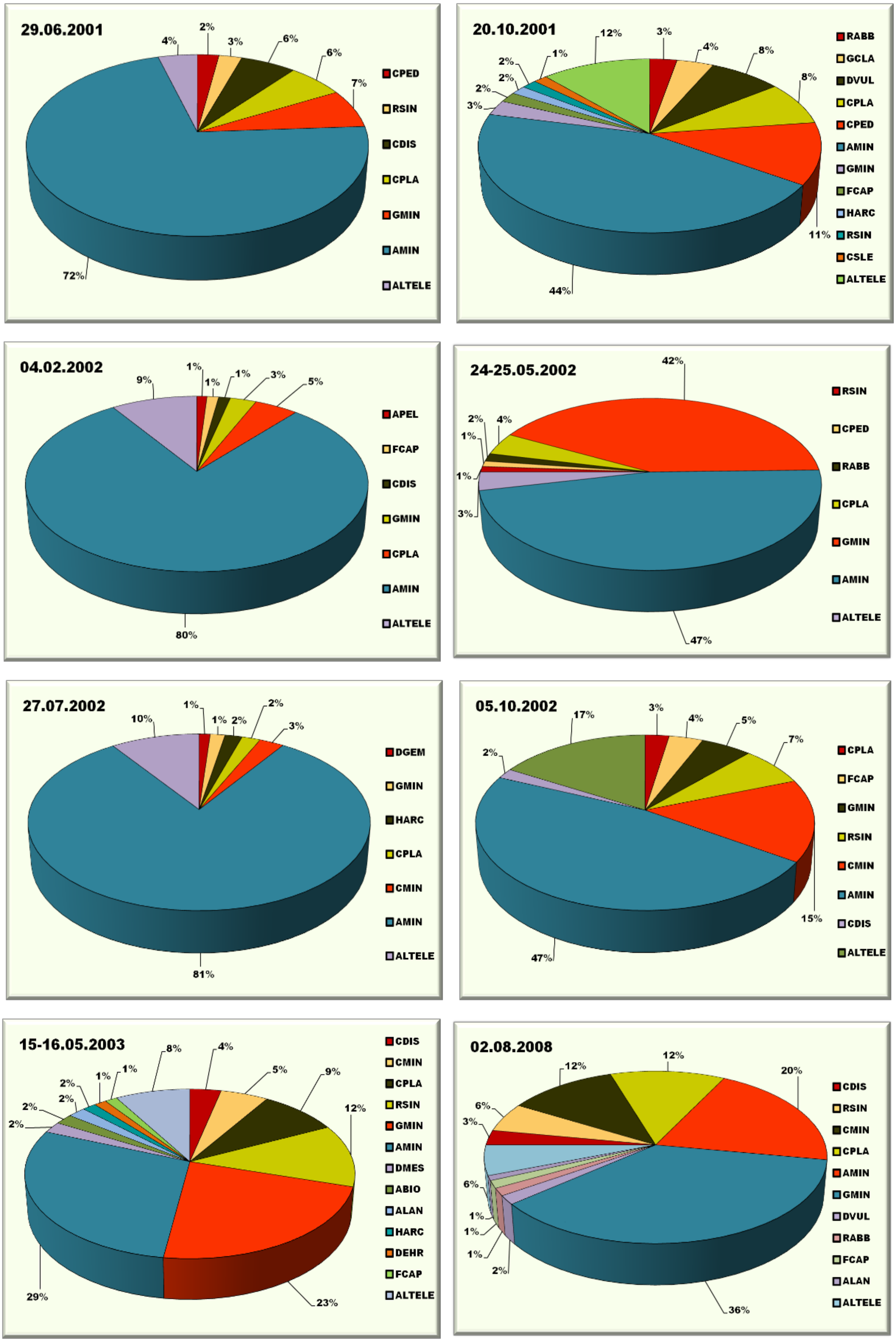

Figure 9 – Percentage abundance of taxa with significant presence (≥1%), Cerna, upstream of Corcoaiei Gorge (sampling site 11)

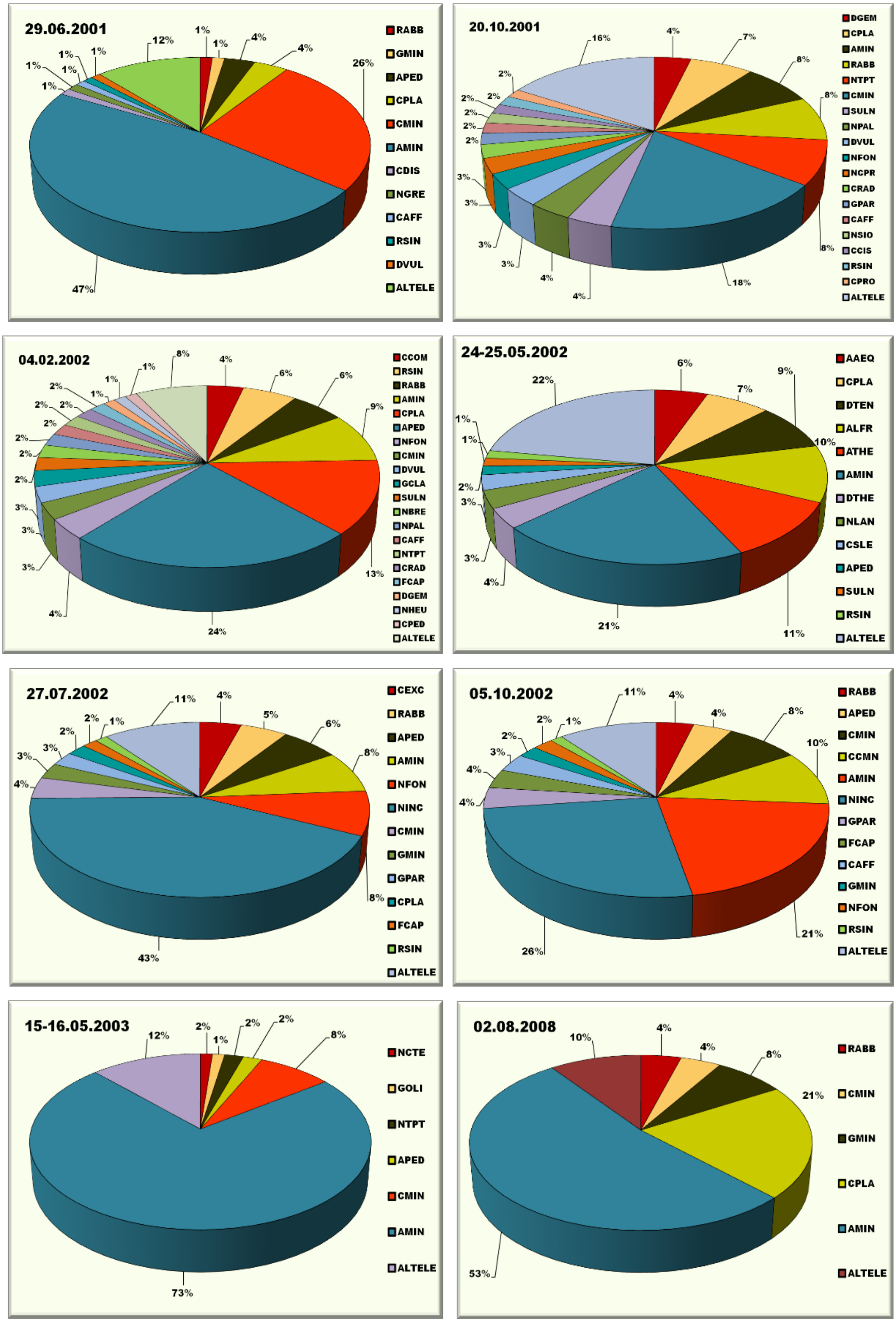

Figure 10 – Percentage abundance of taxa with significant presence (≥1%), Cerna, downstream of Băile Herculane (sampling site 20)

III. 7. 1. Water Quality Assessment Based on Saprobic Categories of Diatoms

From the saprobic categories circumscribing the identified taxa in the present study, the xenosaprobic category is represented in a reduced proportion (5.106%), whereas the oligosaprobic one is prevailing (37.447%); the β–mesosaprobic category, the last one characterizing “healthy” waters, is the second as prevalence (28.511%). Summing the three categories, approximately 71% of the total identified taxa indicate clean waters or relatively clean on the Cerna River course. The intermediate level, β – α–mesosaprobic, considered critical, is also relatively well represented (15.745%). The saprobic category characterizing “polluted” waters (α–mesosaprobic) is represented by a lower percentage (10.213%), and the polysaprobic category, meaning highly polluted waters, is the less represented – 2.979%.

III. 7. 2. Assessment of Saprobic Level of the Cerna River Water Based on the Saprobic Index

Values of the Saprobic Index (SI) range between relatively narrow intervals (1.1–1.9) in the analyzed samples. According to these values, the Cerna River waters may be ranked within three quality classes: class I (clean waters or very slightly polluted), for 9.77% of the samples, class I-II (waters with a reduced pollution), category that prevails (45.59% of the samples) and class II (moderately polluted waters), with almost equal percentage (44.64% of the samples). The mean values of SI along the whole water course, throughout the entire sampling period, rank the water of the Cerna River within class I-II (reduced pollution), with the exception of the site downstream Băile Herculane, where the waters correspond to class II (moderately polluted).

III. 7. 3. Water Quality Assessment of Cerna River Based on the Biological Diatom Index

According to the Biological Diatom Index (BDI), the Cerna waters rank within three quality classes: excellent, good and acceptable. Excellent water quality predominates (91.87%), especially on the upstream and middle sectors of the source, followed by the good water quality (6.5%), sporadically encountered on the upper and middle sectors and more often on the lower sector, and in a reduced proportion (1.63%) the acceptable water category, exclusively encountered on the lower sector of the course (**Table 2**).

Table 2 – Water quality of Cerna River expressed by the Biological Diatom Index (BDI) values from the analyzed sampling sites ([blue] – excellent; [green] – good; [yellow] – acceptable)

Sampling period \ Sampling sites	I	II	III	IV	V	IX	XI	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
June 2001	**16.1**	**19.0**	**19.2**	**18.1**	**18.8**	**20.0**	**18.6**	**18.9**	**18.4**	**19.3**	**18.8**	**19.4**	**19.0**	**19.5**	**18.4**	-
October 2001	**19.5**	**19.4**	**19.0**	**18.9**	**18.9**	**19.7**	**17.9**	**19.4**	**18.6**	**19.7**	**18.1**	**18.1**	**18.5**	**18.0**	**15.1**	**18.2**
February 2002	**17.7**	**19.5**	**19.7**	**18.3**	**19.4**	**19.6**	**19.1**	**19.4**	**19.6**	**19.8**	**19.5**	**18.7**	**18.9**	**12.9**	**15.6**	**18.9**
May 2002	**19.3**	**19.1**	**19.1**	**19.7**	**19.3**	**19.3**	**17.3**	**19.0**	**18.6**	**19.5**	**19.4**	**19.2**	-	**16.8**	**17.3**	**18.7**
July 2002	**19.1**	**20.0**	**19.3**	**19.4**	**18.9**	**20.0**	**19.6**	**19.2**	**19.5**	**19.5**	**19.3**	**16.4**	-	**19.4**	**10.3**	**17.4**
October2002	**18.4**	**19.1**	**18.6**	**18.8**	**19.6**	**19.5**	**18.4**	**19.5**	**19.4**	**19.7**	**19.6**	**19.5**	**19.4**	**17.3**	**13.2**	**14.7**
May 2003	**19.1**	**18.5**	**18.4**	**17.4**	**19.0**	**19.9**	**17.9**	**17.0**	**18.4**	**18.3**	**19.3**	**19.1**	-	**19.2**	**19.3**	**19.2**
August (IX-XXI) September (I-V) 2008	**18.4**	**19.2**	**19.4**	**19.4**	**19.3**	**18.2**	**16.8**	**18.7**	**19.0**	**18.7**	**18.8**	**18.8**	**18.8**	**17.6**	**17.9**	-

Conclusions

After processing and analyzing the data obtained based on the epilithic diatom communities from the Cerna River, we can formulate the following conclusions:

- A total number of 360 taxa were identified, belonging to the Phylum *Bacillariophyta*, namely 315 species and 45 infraspecific taxa, belonging to 46 genera, 24 families, 13 orders, 5 subclasses and 3 classes. Centric diatoms (Class *Coscinodiscophyceae*) are the less taxonomically represented (11 taxa), araphid pinnate diatoms (Class *Fragilariophyceae*) are better represented (34 taxa), but most taxa (315) belong to the raphid pinnate diatoms (Class *Bacillariophyceae*). The richest genus is *Navicula* (65 taxa), followed by *Nitzschia* (42) and *Cymbella* (34), but there are also numerous monospecific genera.
- From the 360 identified diatom taxa, 322 have not yet been reported for the Cerna River course and 48 are new for the Romanian flora (most of them belonging to genus *Navicula*). Newly reported taxa are similar in number in different sampling sites, with the exception of the upper course of the Cerna River where they are less, and occur in the autumn samples (October 2001).
- The number taxa per sample varies within wide ranges, from a maximum of 67 (October 2001, downstream Băile Herculane) to a minimum of 15 (June 2001, Cernişoara), showing an average of 32.9 taxa/sample. Even though the number of taxa differs relatively heterogeneously among samples harvested in different sectors of the river and different seasons, exhibiting slight tendency of increase from upstream to downstream.
- Most of the identified diatoms are cosmopolitan or probable cosmopolitan; few have northern-alpine distribution others are spread on the northern hemisphere and very few have circumtemperate, European or pantropical areas. For other species, the chorology is imprecise, incomplete or they have limited area.
- Regarding the environmental preferences of species, most taxa inhabit stagnant and running freshwaters, with mean electrolyte content and as well as in oligotrophic ones. Some of the alkaliphilic or indifferent taxa occur in brackish waters too.
- The values of the specific diversity rank between wide intervals (1.791 – 24.47) and represent a general increasing tendency from upstream to downstream on the Cerna River, being higher on the lower sector. Augmentation of eutrophication downstream of the Cerna River, coroborated with the anthropic influences (the two impoundments and human settlements), provide an increase in the specific diversity in the epilithic diatom populations. Regarding the seasonal distribution of the mean diversity values, the highest are found at the autumn samples of 2001.
- The specific equitability ranges between 0.166 and 0.811), increasing from upstream to downstream, with general dynamics similar to that of diversity (shows similar seasonal behavior: highest mean values recorded also in autumn 2001).

- High similarity among the epilithic communities have been evidenced in the dendrograms. It is more frequently manifested after their consecutive disposition on the Cerna River course, within the same sampling period and rarely after a seasonal distribution. The highest floristic affinity values exhibit the samples collected in autumn 2002, in the upper course (>90%), but communities with high similarity are also observed on the middle sector or the lower one, whereas minimal values were found in less than 10% of the cases (a group of samples joins to this one, from upstream, spring, autumn and winter of 2002). Most samples with high floristic similarity are from 2002, and seasonally, stronger association between communities could be demonstrated predominantly in the summer (June 2001, July 2002 and August 2008).
- The disturbance level of the Cerna River estimated by computing the percentage abundances of *Achnanthes minutissima* has different values, relatively randomly distributed on the course of the Cerna River and throughout the sampling period. Generally, predominant are the communities in which sign of major disturbances occur, especially those inhabiting the middle and upper courses; stress is less evident on the lower river sector. We consider this apparently unnatural, possibly an effect of the interaction between the tributaries of the Cerna River and the disposal and functionality of the two dam reservoirs on the Cerna River.
- The taxon recording the highest percentage abundances in the epilithic diatom communities is *Achnanthes minutissima*, on the entire course of the Cerna River. Other dominant taxa are present only in very few samples (*Diatoma mesodon* (on the upper sector), *Gomphonema minutum* (on the upper and middle sectors), *Hannaea arcus* (on the middle sector), *Amphora pediculus*, *Cyclotella comensis*, *Nitzschia inconspicua*, and *Rhoicosphenia abbreviata* (on the lower sector). *Cymbella minuta* dominates on all the three sectors of the river.
- The seasonal dynamics highlights the dominance of *Achnanthes minutissima* species in all the seasons and in all sectors of the Cerna River. Other species dominating as weight percentage in certain samples occur in summer (*Diatoma mesodon, Gomphonema minutum*), spring (*Cymbella minuta, Diatoma mesodon*) and winter (*Gomphonema minutum*) on the upper course, in the summer (*Cymbella minuta, Gomphonema minutum,* and *Hannaea arcus*) on the middle course and in all seasons on the lower course (autumn – *Cyclotella comensis, Cymbella minuta*, winter – *Amphora pediculus*, spring – *Rhoicosphenia abbreviata*, summer – *Nitzschia inconspicua*).
- Amongst the saprobic categories of diatoms, dominant are those specific to the oligosaprobic waters, followed by those indicating β–mesosaprobic, β–α–mesosaprobic, α–mesosaprobic, xenosaprobic and polysaprobic waters. Approximately 71% of the total identified taxa from the Cerna River indicate clean waters or relatively clean waters, 15.74% waters at critical level and 13.19% polluted waters.

- The Saprobity Index (SI) values varies between relatively narrow limits (1.1 – 1.9). According to these values, Cerna River waters can be ranked within three of the water quality classes: class I for 9.77% of the samples (autumn and spring of 2002), class I–II for most samples (45.59%, autumn of 2001, 2002, 2008, winter and summer of 2002, spring of 2003) and class II, for 44.64% of the samples (spring of 2002, 2003 and summer of 2001 and 2008). The lowest saprobes of water is found for the samples harvested in 2002 (autumn), and the highest values are for the samples from 2008. Mean values of SI from each of the sampling sites rank the Cerna River waters in the class I–II (reduced pollution), with the exception of the sampling site downstream of Băile Herculane, where waters correspond to class II (moderately organic polluted).
- The quality of the water in the Cerna River, assessed based on the Biological Diatom Index (BDI), is excellent (in 91.87% from the processed samples), good (in 6.5% of the samples) or acceptable (1.63% of the samples). On the upstream and middle sectors predominate excellent quality waters, and those of good quality are sporadically found in some summer samples, whereas on the lower course water quality remains predominantly excellent, but there are also samples for which the BDI values stand for a good and even acceptable water quality. For the seasonal distribution of the samples in which the quality is other than excellent (in all the seasons), the presence of good water sites is remarked, especially in the summer and autumn, and those with acceptable water quality in the winter and summer.

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Annex 1 – Abbreviations of taxa used for presenting the dynamics of the epilithic communities from the Cerna River

TAXON NAME - ABBREVIATION	TAXON NAME - ABBREVIATION
A. bioretii - ABIO	*Denticula tenuis* - DTEN
A. lanceolata ssp *frequentissima* - ALFR	*D.thermalis* - DTHE
A. lanceolata - ALAN	*Dydimosphaenia geminata* - DGEM
A. minutissima - AMIN	*Fragilaria capucina* - FCAP
A. subatomoides - ASAT	*G.angustum* - GANG
A. thermalis - ATHE	*G.clavatum* - GCLA
Amphipleura pellucida - APEL	*G.minutum* - GMIN
A. pediculus - APED	*G.olivaceum* - GOLI
Cocconeis disculus - CDIS	*G.parvulum* - GPAR
C. pediculus - CPED	*Hannaea arcus* - HARC
C. placentula - CPLA	*Navicula capitatoradiata* - NCPR
Cyclotella comensis - CCMN	*N. cryptotenella* - NCTE
C. radiosa - CRAD	*N. gregaria* - NGRE
Cymbella affinis - CAFF	*N. lanceolata* - NLAN
C. cistula - CCIS	*N. radiosa* - NRAD
C. compacta - CCOM	*N. tripunctata* - NTPT
C.excisa - CEXC	*Nitzschia brevissima* - NBRE
C.minuta - CMIN	*N.fonticola* - NFON
C.prostrata - CPRO	*N.heufleriana* - NHEU
C.silesiaca - CSLE	*N.inconspicua* - NINC
C. sinuata - CSIN	*N.palea* - NPAL
Diatoma ehrenbergii - DEHR	*N.sigmoidea* - NSIO
D.hyemalis - DHME	*Reimeria sinuata* - RSIN
D.mesodon - DMES	*Rhoicosphenia abbreviata* - RABB
D.vulgaris - DVUL	*Synedra ulna* - SULN