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Shallows of the lower Danube as additional sources of potamoplankton

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Abstract

This paper presents studies on the algal flora of the Bulgarian Danube section during three summer periods (1980–1982) and during the four seasons of 1987/1988. The following variables were investigated: 1) species composition of the river phytoplankton and the phytobenthos; 2) frequency quotients of the species; 3) number of species at the investigated sites; 4) phytoplankton numbers and biomass; 5) floristic similarity between the sites. The data show the existence of a dynamic connection between phytoplankton and phytobenthos. The shallows in the midstream and river arms play an important role as potamoplankton sources during the periods of low waters. It is comparable with the role of the adjacent wetlands to which previously priority was given. This is especially so below 597th river kilometer.

Introduction

The origin of the Danubian plankton has been the subject of several works. Most of these concern the zooplankton and show its allochthonous character (e.g. Naidenow, 1966, 1984). The origin of the Danubian phytoplankton was extensively discussed by Wawrik (1962). It is autochthonous in her opinion. Later, Czernin-Chudenitz (1966) showed the renewal of the phytoplankton from branches with slower velocity as characteristic of the Upper Danube. He considered the adjacent basins to be only locally important for many of the allochthonous algae quickly die in the main river. Popescu-Marinescu (1985) came to a similar conclusion for the Lower Danuble (Romanian section) where the discharges from adjacent basins are, in any case, small and periodic in nature. For the Lower Danube in the Bulgarian stretch, the role of the shallows for the development of the phytoplankton was proposed to be comparable with that of the adjacent basins in the period of low waters (Draganov & Stoyneva, 1991; Stoyneva, 1991). The development of many euplanktonic algae in the side-arms of the Middle Danube (Hungarian section) was observed by Kiss (1987) also in low water periods. Many planktonic species were described from the side-arms of the Middle Danube both in the Slovakian and Hungarian sections (e.g. Juris, 1967; Hindák, 1978, 1980; Hortobágyi, 1979).

Mention may also be made of the paper by Oltean (1960). He showed, on one hand, the prevalence of species of pseudo- and tychoplanktonic diatoms in the Romanian Danube section, when writing that their tearing off from the substratum in the observed quantities is most probably not occasional. On the other hand, he concluded that the adjacent basins had a strong influence on the diatom flora. Later, however, Godeanu (1985) mentioned the prevalence of autochthonous riverine forms for the same stretch.

Description of sites studied

The Bulgarian Danube section is located between 846th and 375th river kilometres (Fig. 1) and is a typical lowland, temperate and nutrient rich river. Chemically, the water is of the calcium bicarbonate/sulphate type with an ambient pH in the range 7.5–8.0 (Russew, 1979). Maximum water temperatures are generally experienced in August, varying between 16.2 and 28.2 °C (mean maximum: 23.7; Petkov, 1981). The discharge has two distinct maxima, one during May and one in December, with a minimum during September–October. This minimum at the 833rd kilometer is 2379 $m^3 s^{-1}$ and 2612 $m^3 s^{-1}$ at 375th kilometer. The average slope is 4 to 4.4 cm km^{-1} and the average velocity in the midstream is about 0.9 m s^{-1}. The river bed has an average width of 0.8 km but varies from 0.5 to 7.2 km. Single deep arms with depth up to 15 m are followed by sets of shallow arms where many islands are formed (Fig. 2). The bottom is covered by sand (65%), gravel (25%), silt (6%) and clay (4%), and the gravel tends to decrease from west to east in favour of sands (Russew, 1979). During the periods of swall discharge a lot of these sands are visible as separate sand strips or as strips at the 'noses' of the islands (Fig. 2c, a).

Materials and methods

The algal flora of the Bulgarian Danube section was studied during three summer (1st–15th August) periods (1980–1982) and during the four seasons of 1987/1988. The samples were collected both from the phytoplankton and from the phytobenthos of the river at the following river kilometres: 791, 786, 784, 741, 720, 714, 712, 699, 673, 626, 597, 595, 564, 554, 547, 545, 501, 483, 446, 433, 426, 396, 386. Additional sites for phytoplankton sampling were located at 795, 793, 787, 770, 763, 762, 745, 743, 706, 694, 685, 637, 636, 598, 582, 560, 557, 550, 538, 518, 498, 495, 491, 488, 454, 431, 392 and 375 river kilometres, and for the phytobenthos – at 802, 776, 764, 732, 653, 636.7, 461, 424 and 421 river kilometres.

The data were analyzed according to the following variables: i) species composition of the river phytoplankton and phytobenthos; ii) frequency quotients of the species; iii) number of species at the investigated sites; iv) phytoplankton abundance (cell numbers l^{-1} and biomass, mg l^{-1} fresh weight); v) floristic similarity between the sites.

The species (except diatoms) were determined on Amplival microscope (magnification 1300 ×) according to the classification systems described in detail in our previous works (Draganov & Stoyneva, 1988; Stoyneva, 1991; Stoyneva & Draganov, 1991, 1994). The frequency quotients (FQ) were estimated as relation between the number of samples in which each species was found and the total number of samples (Abakumow, 1983). For the quantitative counts, the cell was taken as the unit (van Heusden, 1972; Kuzmin, 1975; Sakshaug, 1980) and the biomass was estimated according to the method of geometrical approximations (Schwoerbell, 1972; Bellinger, 1974; Willén, 1976; Rott, 1981). The counts were done in the blood-counting chamber of Thoma in 64 small squares in 8 reiterations. Floristic similarity was evaluated by the Index of Sörensen (SSI, Abel, 1989).

Results and discussion

Species composition

A total of 359 taxa were found in the phytoplankton of the Bulgarian Danube section (Stoyneva, 1991; Fig. 3). 14% of them are benthic, according to the literature.

In the phytobenthos of the river totally 265 taxa were found (Stoyneva, 1991; Fig. 4). Among them 81% are planktonic species, according to the literature.

Common for the both ecological groups were 220 taxa (Fig. 5).

It is well known that in many cases it is impossible to distinguish the 'true' from the 'false' plankton (Butcher, 1924) and most difficult is to distinguish facultative plankters from the entrained non-planktonic ones (Kisselew, 1969). The solution to this problem requires additional investigations and is not the object of this paper. Here we only mention that in the benthic samples we have found algae which according to the literature data are planktonic ones. These algae were 'trapped' by the filaments and thalli of benthic algae (e.g. *Cladophora*, *Stigeoclonium*). However, at other sites we found the same algae to develop on the bottom substratum. This concerns mainly the representatives of Chlorococcales. For example, *Scenedesmus ecornis* (Ehr.) Chod. was found among the filaments of *Cladophora glomerata* (L.) Kütz. at site located at the 673rd river kilometer, but at sites located at kilometres 699, 445 and 426 it developed on the sandy bottom of the shallows. Some of the species and especially the representatives of Cyanophyta which are known to be benthic, frequently occurred in the riverine plankton (e.g. *Leptolyngbya foveolarum* (Rabenh. ex. Gom.) Anagn et Kom., *Pseudanabaena catenata* Lauterb.).

It is a fact that 83% from the all species found in the benthos were found also in the phytoplankton, and the number of 'planktonic' organisms (according to literature data) was the highest (82%) in 1982, when the benthic samples were collected mostly at the shallow river sites.

The green algae (and especially Chlorococcales) had the highest number of taxa both in the plankton and in the benthos. Chlorococcales were 65% among the species common for the phytoplankton and phy-

Fig. 1. Map of the study area; river km are calculated from the estuary.

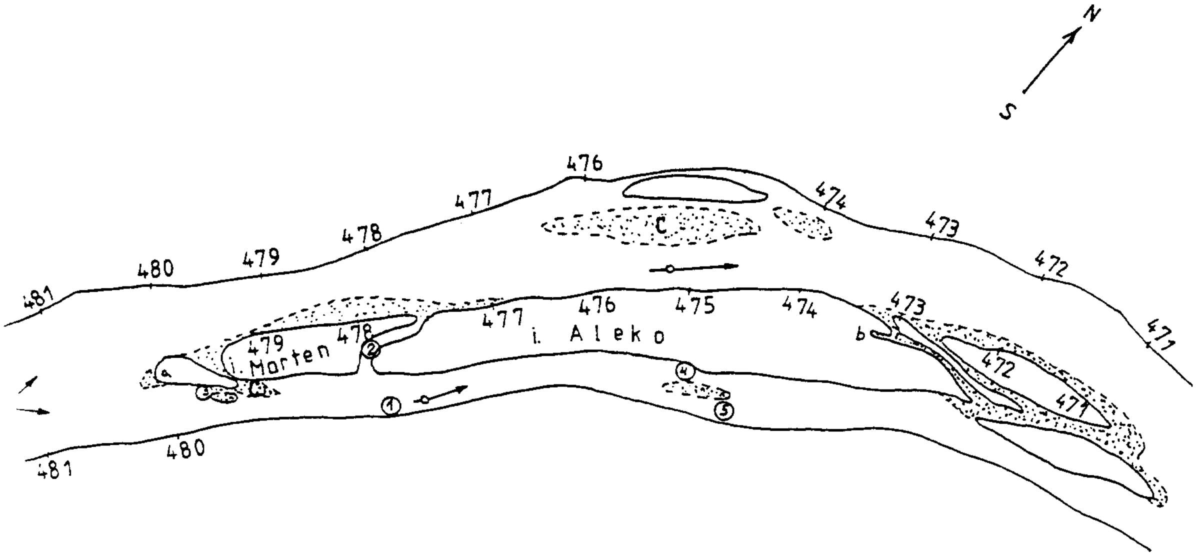

Fig. 2. Figure of a typical river stretch showing islands (a – 'nose', b – 'throat'), sand strips (c) and river arms (1–5).

tobenthos. It is well-known that chlorococcal green algae prefer shallows and river arms with slower velocity during the period of low waters (Kofoid, 1908; Vladimirova, 1978). The maximum development of these algae under conditions of high temperature and insolation (particularly in years with low discharge)

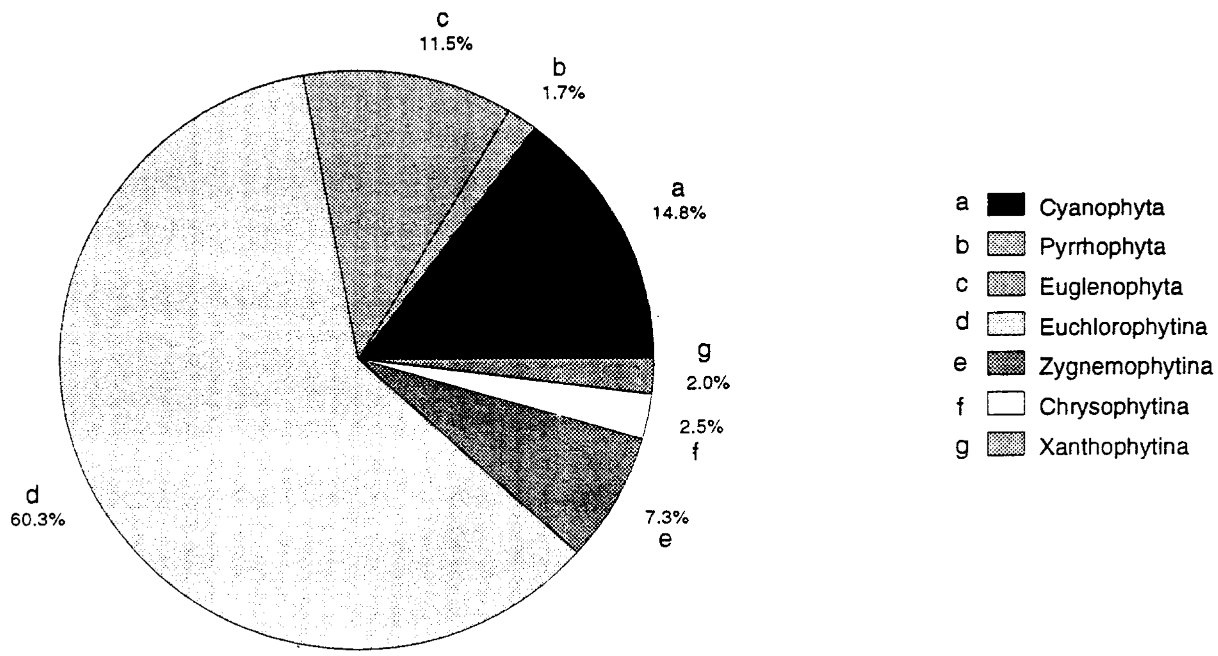

Fig. 3. Taxonomical structure (relative proportions of taxa) of the phytoplankton of the Bulgarian section of the River Danube.

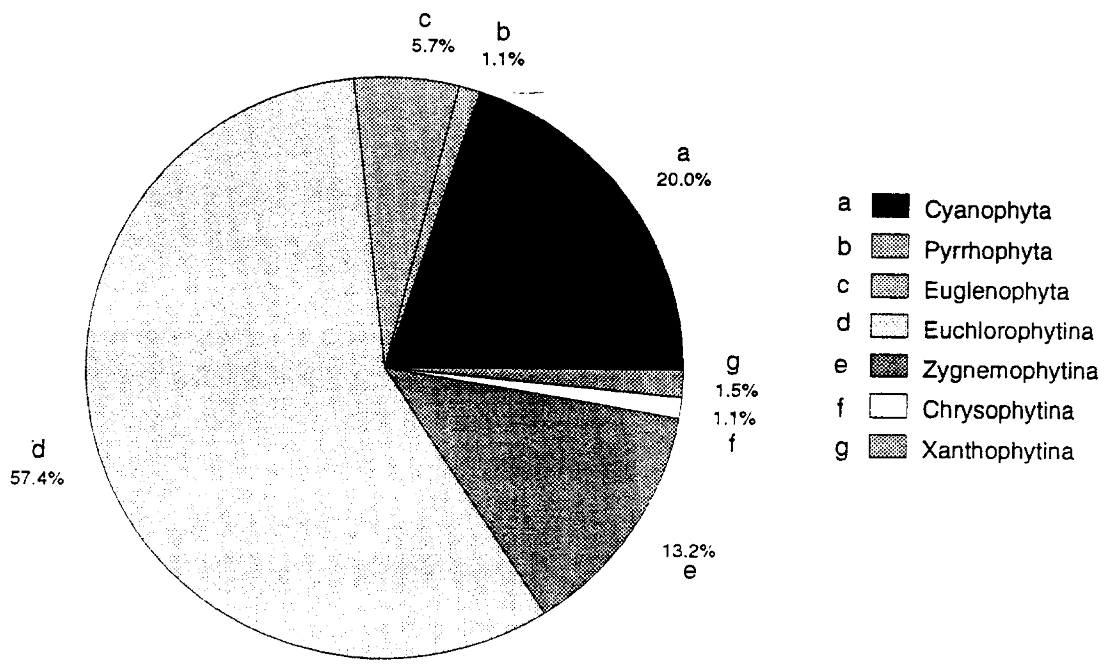

Fig. 4. Taxonomical structure (relative proportions of taxa) of the phytobenthos of the Bulgarian section of the River Danube.

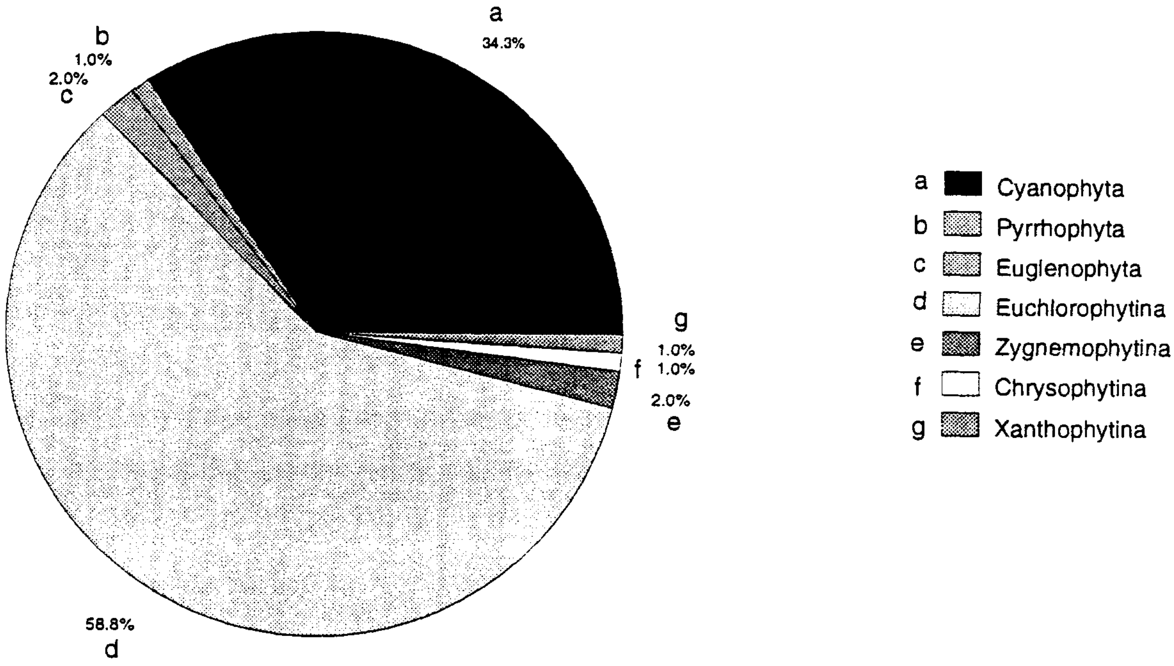

Fig. 5. Common species (relative proportions) for the phytoplankton and phytobenthos arranged in taxonomical groups

has been described by Butcher (1924). Hortobágyi (1969a, b) found more species of Chlorococcales, and especially of the genus *Scenedesmus*, in the phytobenthos than in the phytoplankton of some tropical waters. Our investigation also confirmed the development of many representatives of Chlorococcales in the algal mats that cover the bottom of the river shallows. Such algae, for example, are: *Coelastrum microporum* Näg., *Crucigenia tetrapedia* (Kirchn.) W. et G. S. West, *Monoraphidium arcuatum* (Korš.) Hind., *M. contortum* (Thur.) Kom.-Legn., *Pediastrum boryanum* (Turp.) Menegh., *P. tetras* (Ehr.) Ralfs, *Scenedesmus acuminatus* (Lag.) Chod., *Sc. communis* Hegew., *Tetraedron minimum* (A. Br.) Hansg., etc.

Variations of the species number

The number of species at different sampling sites varied markedly mainly because of the point impact on the Danube water. Normally, it decreased below large cities or particular sources of pollution. However, in general, the number of species significantly increased in the section between the towns of Svishtov and Silistra (from 545th to 375th river kilometer). E.g., (from 791st to 598th river kilometer) during the summer of 1982 was 37, whereas between Svishtov and Silistra it was 55. The corresponding numbers during the summer of 1987 were 37 and 57 respectively (Fig. 6). The section below the town of Svishtov (545 km) was rich in shallows near and below the islands and sand strips during the period of warm low waters.

The potamoplankton enrichment from the sources to the outfall is a well-known tendency (Hynes, 1970). It is not a smooth progression, however, for at the sampling sites of the shallows or immediately below them, the number of species was always higher than at the sites above them (e.g. on the sandy bottom near the Tsibar island (720th river kilometer) 105 algal taxa were found whereas at the site located 15 kilometres above only 19 taxa were found).

This enrichment is valid with respect to the total number of species per site and to the numbers in the different taxonomical groups (Stoyneva & Draganov, 1991). The enrichment of the phytoplankton with additional algal groups (as euglenoids, pyrrhophytes, chrysophytes, etc.) could also be connected to the presence of these shallows in the summer periods (Stoyneva, 1991).

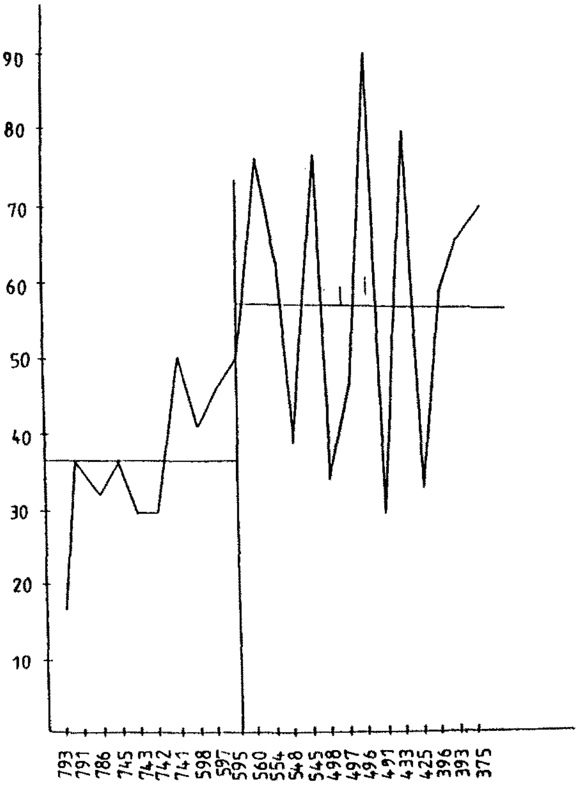

Fig. 6. Number of species at the investigated sites during 1–15th of August 1987 (NS – number of species, RK – river kilometres).

Frequency quotients

The greatest part of the algae found in the Danubian phytoplankton and phytobenthos were rarely distributed along the river course and, in fact, most of them (up to 77% for the phytoplankton and up to 36% for the phytobenthos) were found at only one site (Stoyneva, 1991). Several species had a broader distribution along the river. *Monoraphidium arcuatum* and *Scenedesmus communis* were the species with broadest distribution both in the plankton and in the benthos of the Danube.

Floristic similarity between the sites

The values of Sörensen's Index of similarity (SSI) between the different sites varied from 0 to 79% for the phytoplankton and from 0 to 75 for the phytobenthos (Stoyneva, 1991). These values showed significant seasonal changes. The highest ones were estimated only for summer periods (up to 79%) whereas for the spring, autumn and winter periods, the SSI values between the sites reached up only 57, 59 and 54% respectively.

The floristic similarity between the shallow sites (estimated on the basis of the benthos samples) or between the sites located 0.5–8 kilometers below them (estimated according to the phytoplankton samples) was higher (between 65 and 79%) than between the other sites included in this investigation (between 0 and 59%). This high degree of similarity was regularly observed wherever shallow sites were located along the river. The highest values of SSI (72 and 79%) were observed between shallow sites with similar location to the source of pollution.

Phytoplankton abundance

The quantity of the potamoplankton (measured by cell numbers and biomass) was found to increase at the shallow sites and below them. This is valid for the total phytoplankton abundance, as well as for the abundance of the different taxonomical groups (blue-green, euglenoid, pyrrhophyte, yellow-green, diatom and green algae).

The total plankton quantity increased downstream and especially in the stretch downstream of the town of Nikopol which is rich in shallows and island groups (Fig. 7). For instance, during the summer of 1987, the phytoplankton abundance between the towns of Vidin and Nikopol was on average 8.26 10^6 cells l^{-1}, whereas between the towns of Svishtov and Silistra the mean abundance was 17.47 10^6 cells l^{-1} (Fig. 7).

During the summer period of 1982 and 1987, the average cell numbers and biomass of the green algae were the highest between the cities of Svishtov and Silistra. This section, as mentioned above, is rich in shallows and river arms, alongside islands and sand strips. For example, in the summer of 1987 the average biomass of the green algae in this stretch was 0.42 mg l^{-1} while for the stretch located between the towns of Vidin and Nikopol it was only 0.19 probably, the high water temperature favoured the mass development of the algae. In the opposite case, under conditions of low but colder waters during the autumn-winter period, the quantitative distribution of the phytoplankton was much more monotonous in the Bulgarian section of the Danube (Stoyneva, 1991).

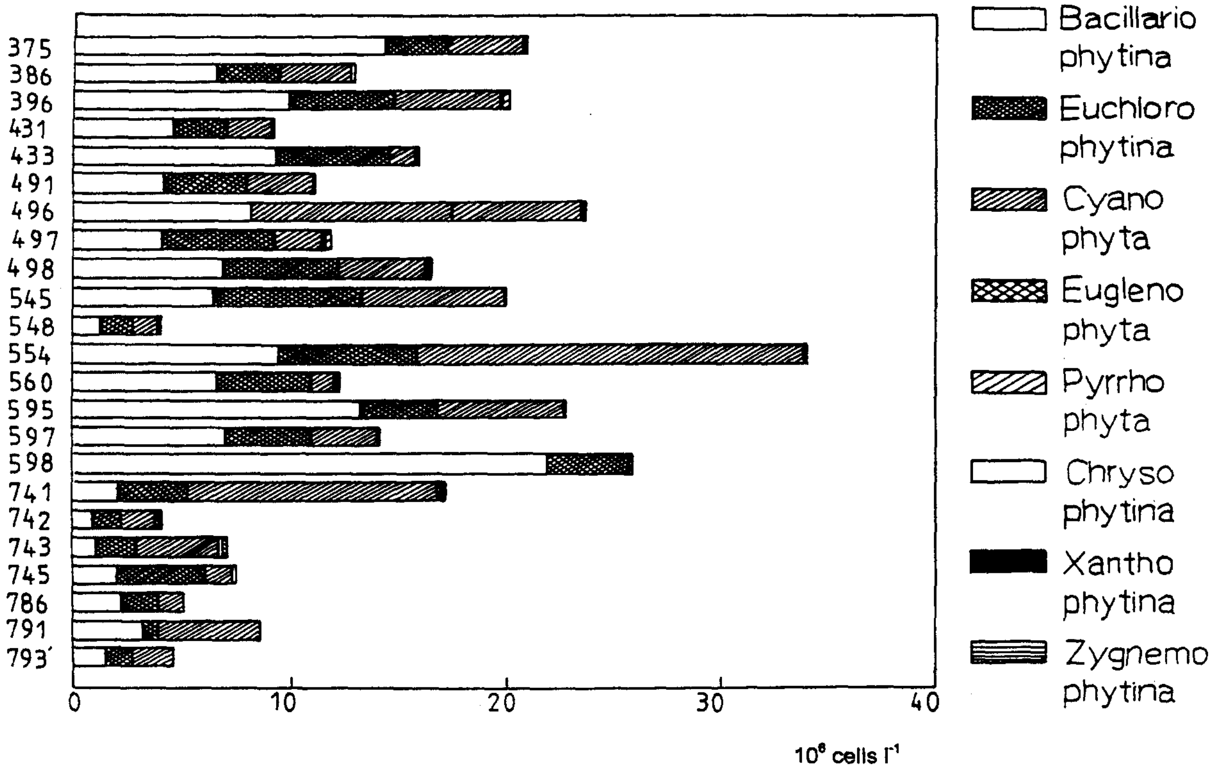

Fig. 7. Phytoplankton abundance (cells numbers l^{-1}) of the Bulgarian Danube section during 1–15th August 1987 (RK – river kilometres).

Conclusion

The data presented above show the existence of a dynamic connection between phytobenthos and phytoplankton. When the waters are low and warm, in the shallows of the river arms alongside the islands and sand strips, as well as in their 'throats' (Fig. 2b), many algal mats develop on the bottom. They are composed mainly by blue-green, green (mostly chlorococcal), diatom and euglenoid algae. Algae produce oxygen and rise to the water surface. At first, they float on the surface as mats and gradually fragment. This process was described by Zhadin (1950) as an additional factor enriching river plankton. However, this event has a mass character in the shallows of the Lower Danube (especially below the island of Tsibar (719–716 km), in the river arms alongside the island groups of Kozlodui (702–687 km), Belene (578–560 km), Vardim (547–541 km) and Brashljan-Vazhitoare (456–443 km), near the island of Kossui (428–242 km), etc. Algal layers of a thickness of 10–15 mm covered large river areas – practically, the whole bottom of the shallow river arms. It is accepted that the process described above is important for two reasons: i) its frequent occurrence in the lower part of the Danube; ii) its relatively long duration – the period of minimum discharge and low waters.

We must also recall that under low water conditions, the connection between the Danube and its lentic adjacent backwaters (mainly marshes and swamps) is interrupted and the influence of the tributaries on the quality and quantity of the Danube phytoplankton and phytobenthos is not always positive (Stoyneva, 1991).

Thus, the role of the shallows alongside the islands and sand strips for the enrichment of the phytoplankton and total river productivity (during the period of low warm waters) is comparable with the role of the adjacent backwaters to which previously priority was given (Naidenow, 1966, 1984).

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