ACTA HYDROBIOL. | 4 | 3—4 | 229 — 244 | KRAKÓW 1962

KAROL STARMACH

Nowe i rzadkie sinice w planktonie stawu rybnego — New and rare blue-green algae in the plankton of a fish pond

Mémoire présenté le 6 juni 1961 dans la séance de la Commission Biologique de l'Académie Polonaise des Sciences, Cracovie

In 1952 workers of the Laboratory of Water Biology of the Polish Academy of Sciences*) collected plankton during the summer season from fish ponds situated in the basin of the Upper Vistula (Wisła). When looking through the samples collected in the pond „Italiano Duże" in Osiek (Oświęcim district), I became interested in two species of blue-green algae frequently seen in the samples, of which one, as it appeared, had not as yet been described, while the other showed a considerable resemblance to the controversial species of *Anabaenopsis Raciborskii* Wołoszyńska. I shall therefore describe first these two species and then indicate the composition of the plankton and the changeable plankton associations in the period from June to September.

1. *Isocystis planctonica* sp. nova

Specimens of this species appear in the form of curved wavy threads tangled together into loose balls of microscopic size, floating freely in water. The length of separate threads does not exceed 1 mm and is generally within the limits of 0,5—0,8 mm. There are neither cases nor gelatinous covers and a common gelatin uniting the threads of floating balls was not perceived. The cells have an elliptic shape, the threads being rounded and slightly narrower at the top than in the middle. They have a transparent protoplasm with large grains of a darker hue. Their colour is olive or greyish-green, sometimes also yellowish-green. Spores (akinets) are more rarely seen; they are slightly larger than the vegetative cells, and are filled with a dense matter composed of large grains and surrounded by a colourless membrane which is not thickened

*) The Laboratory was at that time called the „Institute for Pond Economy" and belonged to the Ecologic and Agricultural Commission of the Polish Academy of Sciences.

and has no structure. Spores appear in the threads separately, sometimes several spores are situated near each other. Cells in the central parts of the threads were 3,2—3,7 μ broad and 4,0—7,2 μ long. The cells at the summit were 2,3—3,2 μ broad and 3,3—5,5 μ long. When reproducing, the threads divide into single cells or into short sections of a hormogoneous type. It was naturally impossible to state on fixed material whether or not these sections are mobile. During the division of the threads cells often form a zigzag pattern or change their position in regard to each other, disposing themselves irregularly (Fig. 1, D, E).

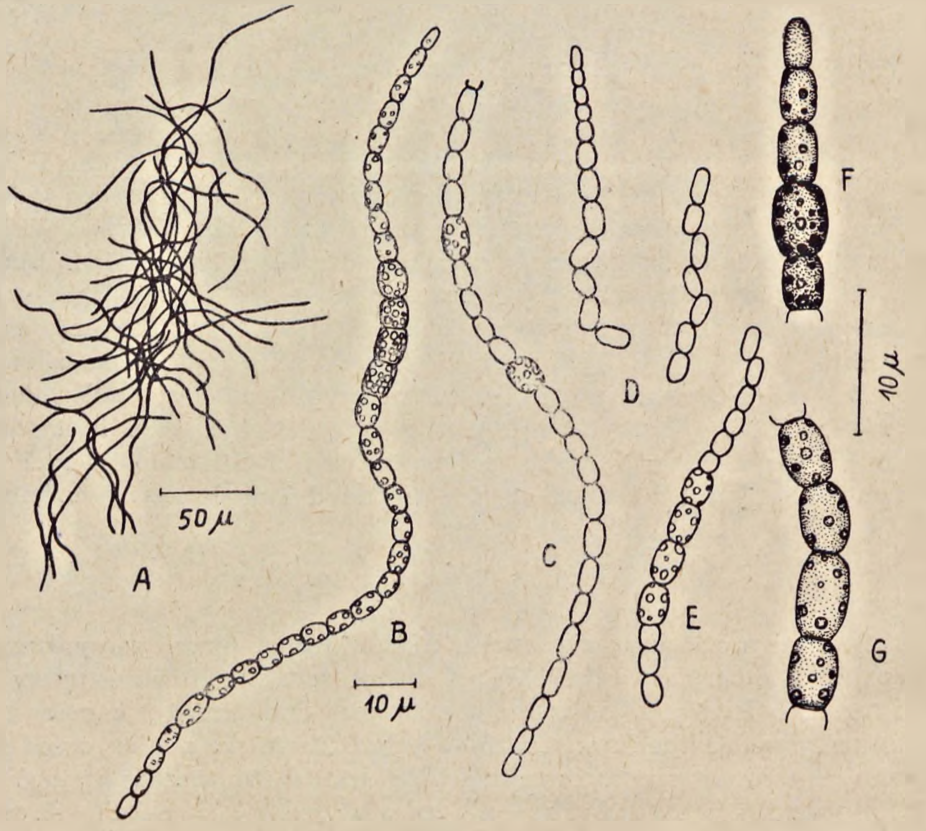

Fig. 1. *Isocystis planctonica* n. sp.: A. appearance of balls of thread most frequently encountered in plankton; B, C, E. single threads with spores; D. loosening of threads into single cells; F, G. fragments of threads under greater magnification

Cells formed by the division of threads divide transversally, forming new threads. Fragments of the threads (hormogony) grow especially in the median parts, but cells on the top extremities are also capable of dividing. The threads usually break off near the spores. There are no heterocysts.

The genus *Isocystis* was described by Borzi (1878 a) on the basis of the species *I. messanensis*, living on the damp wall of a stone wall near Messina (Sicily). This blue-green alga formed there thalli, gelatinous and leather-like in substance vividly bluish-green or olive-green in colour, composed of threads lying closely together in almost parallel bunches. The cells are of an elliptic or round shape, the spores spherical, twice as large as, the vegetative cells, surrounded by a goldenbrown membrane, with a delicately granulated surface. Borzi in his description did not give the dimensions of the cells, but one may suppose from the sketch that the cells are about 4—5 μ broad.

Borzi published in the same year (1878 b) a supplement to his previous work in which he described three new species of *Isocystis*: *I. spermosiroides* with very delicate threads formed growths on the leaves and stems of *Potamogeton crispus* in a pond near Vallombrosa (Italy); *I. moniliformis* with elliptical or spherical cells of a bluish colour (?) growing together with *Schizothrix lateritia* thalli; *I. infusionum* found on aquatic plants in ponds. It was already previously known under the name of *Anabaena infusionum* Kützing or *A. microscopica* Meneghini.

Borzi's descriptions, however, are very inaccurate and for this reason the species *I. spermosiroides* and *I. moniliformis* are almost impossible to identify.

I. infusionum (Kütz.) Borzi, found by me also in Poland in 1930, has round cells, sometimes slightly flattened, 1,0—1,5 μ broad, and spherical spores up to 2 μ broad with a colourless membrane. In Poland it was found in the vicinity of Cracow (Kraków), in the ancient bed of the Vistula called „Koło Tynieckie", on stems of *Potamogeton natans*. A drawing of it appeared in the publication „Rodzaje polskich sinic" (Blue-green algae genus of Poland) (Starmach 1936), on p. 130, fig. 86.

Two more species are known: *I. salina* Ivanoff (1901) from salt Siberian waters and *I. pallida* Voronichin (1927) from mineral sources of the Caucasus (see Elenkin 1949, p. 1234).

Threads with a structure similar to that of the genus *Anabaena*, having no heterocysts but forming spores (akinets, hypnospores) are characteristic of the *Isocystis genus*. They differ from other species of the *Nostocaceae* family only in that they have no heterocysts and possess a rather specific shape of thalli (aglomerations of threads). For this reason some experts believe that *Isocystis* genera might be considered as threads of the genus *Nostoc* (as for ex. *I. messanensis* or of the genus *Anabaena* (as *I. spermosiroides*, *I. moniliformis* and others) in developmental stages or not yet fully developed.

Material collected in the pond „Italiano Duże" confirms the independence of the genus *Isocystis*, which could easily be discerned

there. Threads of the numerous specimens that were found attain in growth certain determined dimensions, ripen, multiply and form thalli in the shape of irregular spherical aglomerations. They thus present easily recognizable forms (individuals having no heterocysts whatever and therefore differing distinctly from the genera *Anabaena* and *Nostoc*.

The individuals found in the pond did not resemble any of the known species and for this reason I decided to give them the name of *I. planctonica* n. sp. They appeared in plankton samples collected in the months of July, August, and September.

Diagnosis

Isocystis planctonica sp. nova

Filamenta flexuoso-curvata 0,5—1,0 mm longa sine vaginis et integumentis gelatinosis, pauca plurave coniuncta glomerulos libere in aqua natantes solute complicatos, facie et magnitudine irregulares efficiunt. Cellulae ellipticae in mediis filamentis 3,2—3,7 μ latae, 4,0—7,2 μ longae in extremis filamentis 2,6—3,2 μ latae, 4,0—4,5 μ longae, olivovirides vel brunovirides, aliquando ad glaucum accedentes, intus habentes grandes granulos, imprimis in circuitu cellularum inter protoplasmam minute granulosam, tralucidam collocatos. Spori cellulis vegetativis paulo maiores large elliptici, 4,0—4,7 μ lati usque ad 7,2 μ longi, granulosi, circumdati tenui membrana non differentiata. Propagatio efficitur divisione filamentorum in singulas cellulas vel segmenta hormogoniis similia.

Hab. in planctone stagni thallis minutis microscopicis e laxe connexis filamentis compositis. Inventa est in stagno, quod appellatur Italiano Duże, in vico Osiek, districtus Oświęcim, palatinatus Cracoviensis, in Polonia.

Iconotypus: delineatio 1, imagines photographicae fig. 6 A—C.

Diagnosis. Threads of a curved wavy shape, 0,5—1 μ long, with no sheath or any gelatin covering, grouped together in small or large numbers, form loosely tangled balls floating freely in water. The cells are elliptical, 3,2—3,7 μ long and 4,0—7,2 μ broad in the median parts of the threads and 2,6—3,2 μ broad and 4,0—4,5 μ long at their summit. They are olive-green or greyishgreen, sometimes with a yellowish tint, having in their interior large darker grains, mostly situated on the circumference of the cells in the midst of small-grained, transparent protoplasm. The spores are slightly larger than the vegetative cells, broadly elliptical, 4,0—4,7 μ broad and up to 7,2 μ long, with a large grained content, surrounded by a thin undifferentiated membrane. Reproduction takes place by means of the division of threads into separate cells and sections resembling hormogones.

It appears in the plankton of a pond in the form of small, microscopical thalli composed of loosely entangled threads.

Found in the pond of „Italiano Duże" at Osiek, Oświęcim district, province of Kraków in Poland.

Iconotype: Fig. 1 and photographs Fig. 6 A—C.

2. *Anabaenopsis Raciborskii* W o ł o s z. or *Cylindrospermum stagnale*?

In plankton samples of the lake „Italiano Duże", collected in July, August, and September of the year 1952, freely floating small aglomerations of bent threads, sometimes spirally curved and, more rarely, almost straight, with elongated heterocysts occasionally ending sharply at their extremities, were observed. This type of thread is characteristic for the species *Anabaenopsis Raciborskii*, but also resembles that of the *Cylindrospermum* genus. *Anabaenopsis Raciborskii*, the spores of which were not described, especially resembles the *Cylindrospermum*, while other species of *Anabaenopsis* are closer to the genus *Anabaena*.

Initially, I determined the blue-green algae found in the investigated plankton as *Anabaena Raciborskii*, but a great resemblance to *Cylindrospermum* induced me to undertake a detailed analysis of the material.

The threads of the blue-green alga mentioned above appeared in loose aglomerations of microscopic size. In preparations also single threads were seen, but it seems that their normal and characteristic form is that of small bunches or balls. The length of the threads is within the limits of 80—500 μ. They have no gelatin capsule, their breadth and the breadth of cells being 2,8—4,0 μ (3,4 μ on the average). The length of the cells amounts to 3,5—4,8 μ (mean 4,0 μ). The cells were thus of a nearly square shape or twice as long as they were broad. In some of the threads the cells were slightly narrowed near the transversal walls, in others a greater narrowing sometimes gave them a barrel shape. The cells had no gaseous vacuoles and their plasm was composed of fine grains with a few larger grains in the middle. At the time of their most numerous appearance (in samples of Aug. 12) large shiny ectoplasts were visible in the cells. Both ends of the thread terminated in heterocysts of a rather varied shape. Oblong heterocysts were in the majority, sometimes narrowed or sharpened at their ends. Cylindrical or oval heterocysts could also be observed. Their breadth resembled that of the cells and amounted to 2,8—4,0 μ, while their lenght varied between 5,5—10,5 μ (7,3 μ on the average). Intercalaric heterocysts of cylindrical shape were found very occasionally (Fig. 2. Fig. 6 D—F).

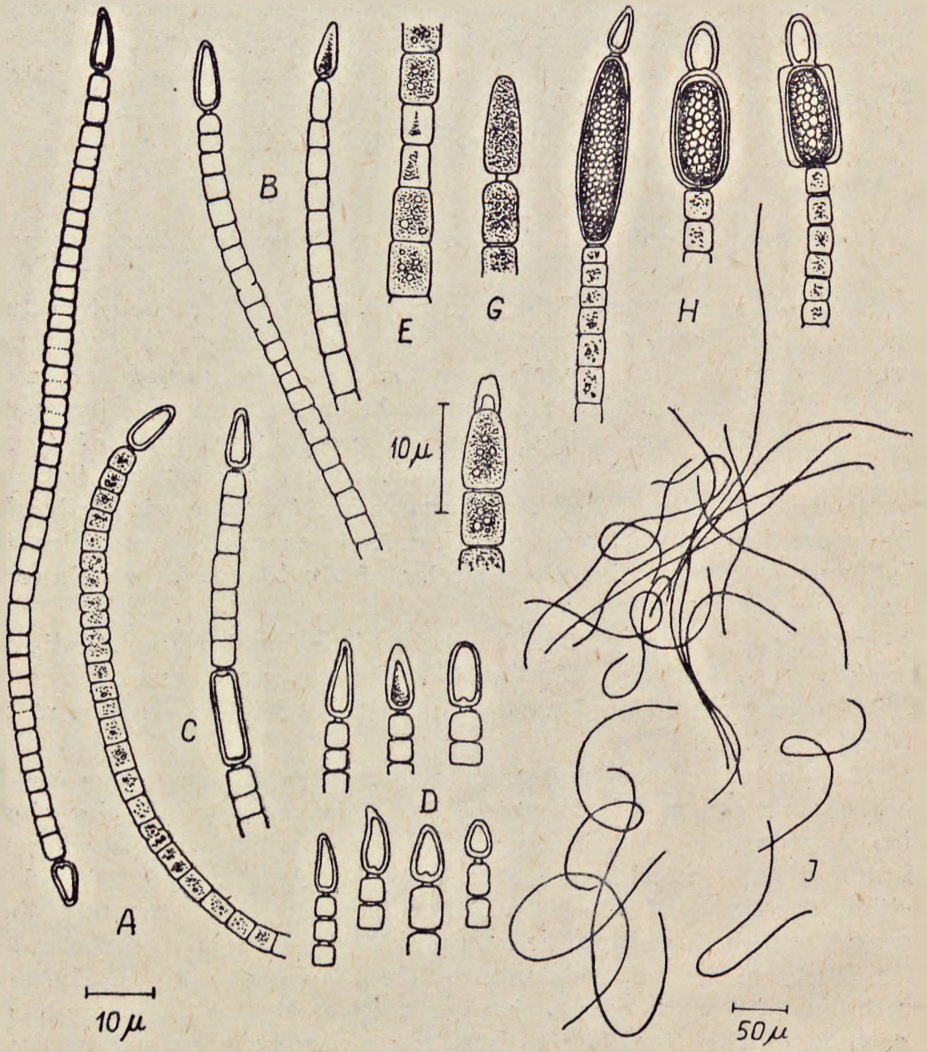

Fig. 2. *Cylindrospermum stagnale* (Kütz.) Born. et Flah.; A, B. threads without spores terminating in heterocysts; C. thread with intercalary heterocyst; D. various shape of heterocysts; E. division of threads; F, G. young heterocysts forming at the ends of the cells of the thread arising from the division of older threads; H. various forms of spores; I. the most frequently encountered arrangement of threads in plankton

The formation of heterocyst and the division of threads in two smaller sections could sometimes be observed. Longer threads usually divide into two parts, more rarely into three. Intercalaric cells, perishing for some unknown reason, are usually the place where division arises. As a rule the two neighbouring cells perish simultaneously. They become thinner, lighter in colour nad their plasma separates from the

membranes, assembling in the middle or at the side of the cell. Finally, the thread breaks in the place where the cells are perishing; their remains still being visible there for a certain time. Simultaneously, the cell near the dead one becomes elongated and narrower at the end and changes into a heterocyst. Therefore the threads formed out of the splitting of the previous one have for a certain time on one of their extremities a typical, think-walled heterocyst, and at the other end a cell which is only just assuming the shape of a heterocyst. All the threads, however, finally metamorphose the cells of their extremities into heterocysts so that, as a rule, each thread two heterocysts. For this reason the growth of threads occurs by way of intercalary divisions of cells. These divisions have in some parts of the thread a more intensive course than in others, with the result that one or two, or, more rarely, three meristic zones are formed. Between the meristic zones a zone of slower growing or stationary cells is formed, in which can be observed perishing (necrotic) cells, which finally cause the division of threads. This division (fragmentation) should therefore be treated as a special manner of reproduction of this blue-green alga. Shorter threads, which could be considered as young threads, have as a rule one zone of rapidly dividing cells. Longer threads possess two or three meristic zones.

The dividing threads become entangled and keep together, forming loose aglomerations and balls. They sometimes have the tendency to twist into a spiral shape, but this happens seldom. The threads are mostly bent irregularly.

In plankton samples from parts of the pond with no vegetation there were no threads forming spores (akinets). These appeared in the of plants near the banks, where algae clumps were concentrated, mostly old yellowish threads of *Spirogyra* and *Zygnema*. In these clumps I encountered several balls of thread also with spores. The threads were of an appearance typical for the genus *Cylindrospermum*. The structure of the threads, shape of the cells and dimensions were similar to those of planktonic forms. On this basis, the loose balls of thread floating freely in the plankton and resembling the species *Anabaena Raciborskii* must be considered as a developmental stage of the genus *Cylindrospermum*. The shape of spores and heterocysts, the dimensions of cells, and the manner of their appearance mostly conform with the species *Cylindrospermum stagnale* (K ü t z.) B o r n. et F l a h. Thus the species *Anabaenopsis Raciborskii* W o ł o s z. would only represent the developmental stage of *Cylindrospermum stagnale*.

The floating threads with no spores have, according to the diagnosis for the species *Anabaenopsis Raciborskii* presented by W o ł o s z y ń s k a (1912) and supplemented by S k u j a (1937), traits conagreeing as to shape, breadth of threads, length of cells, and shape of heterocysts. In the investigated material, besides heterocysts in accordance with

the diagnosis, also some slightly broader ones were found; there existed also slight differences in length. According to Skuja, the length of heterocysts is 12 μ, while in our material the longest heterocysts reached only 10,5 μ. The threads were up to 500 μ long, while the diagnose mentions only threads 200 μ long. These were, however, extreme cases, the majority of threads having dimensions in accordance with those of the diagnosis. As to their form, the threads resembled the drawings given by Wołoszyńska and were on the whole more curved than on those of Skuja.

If, for purposes of determination, we contented ourselves with the fact that in many samples and on numerous preparations no spores adhering to heterocysts are seen, this species could only be identified as *Anabaenopsis Raciborskii*. However, a detailed analysis and investigation of material from different parts of the pond gives different results.

The genus *Anabaenopsis* has for a long time provoked certain doubts and different authors expressed a sceptical view as to the possibility of maintaining it. The history of this genus is rather interesting.

Wołoszyńska described in 1912 the new species *Anabaena Raciborskii* which she had found in the plankton collections brougth to Poland from Java by Professor Raciborski. The material came from central Java, in the years 1899 and 1900, from a locality called Rawa-Demangan, from a large artificial water reservoir with a surface of about 200 ha, resembling a shallow pond. The new species was characterized by straight or curved, more rarely spirally twisted threads 2,4—4,0 μ broad, with a length up to 200 μ. On both ends, or sometimes on only one, heterocysts were fixed, of a cylindrical and cone-like shape, with a breadth resembling that of the thread. No spores were observed. In the work of Wołoszyńska, Fig. 10 on p. 684 contains a series of sketches of the new species, with the subscription *Anabaenopsis Raciborskii* n. sp. In the text, however, the author calls it *Anabaena Raciborskii* sp. nova, belonging to the *Anabaenopsis* section of the genus *Anabaena*. Wołoszyńska, having made the discovery of this species, divided the genus *Anabaena* into two sections: *Eunabaena* and *Anabaenopsis*. This last section should have contained species with heterocysts at both extremities of the threads, in contrast to the typical forms of the genus *Anabaena*, which had intercalaric heterocysts.

Wołoszyńska inclused in the section *Anabaenopsis* the species: *Anabaena circularis* G. S. West, *A. circularis* var. *javanica* Wołosz., *A. tanganyikae* G. S. West, *A. Raciborskii* Wołosz. Of these species only *A. Raciborskii* had oblong heterocysts and predominantly straight threads, while the others had spherical heterocysts and threads curled in rings. All the species mentioned were found in the plankton of tropical lakes and ponds (Java, the Philippines, Africa), so that the

species of the *Anabaenopsis* section were for a long time considered as characteristic for tropical waters. Miller (1923), though not acquainted with the work of Wołoszyńska, described a blue-green alga from stagnant waters in the neighbourhood of Ivanovo-Vosnesensk (to the north-east of Moscow) which resembled the *Anabaena*, but had heterocysts on both ends of the threads. He considered it as a new species which by chance named *Anabaenopsis*. Miller described the species *Anabaenopsis Elenkinii* and included into the new genus other *Anabaena* species having heterocysts at the extremities of the threads. In this manner *A. Elenkinii* became the leading species of the genus *Anabaenopsis*. Wołoszyńska had already placed, under the sketches representing species of the *Anabaenopsis* section, the names of *Anabaenopsis Raciborskii*, *A. circinnalis* var. *javanica* etc., but these names were not corroborated by a diagnosis and were formally of no importance as „nomina provisoria", though they had been given a long time before Miller.

In later years, a series of new *Anabaenopsis* species from the tropics and from waters of the European part of the USSR were described by: Aptekarj (1926), Taylor (1923), Ramanathan (1938), Gonzales-Guerrero (1928), Prescott (1955), and new localities were cited by Skuja (1937), Cyrus (1952), and others. It became an established opinion that the principal character of the above genus consists in the formation of heterocysts at the extremities. They form intercalarly at first, in threads twisted into rings, from a cell which divides in two. After this, each of the thus formed cells cuts off one smaller cell which transforms itself into a heterocyst. This process was perfectly described by Fritsch (1951) in an article entitled „The Heterocyst, a Botanical Enigma" (p. 204, Fig. 102—108). When the new heterocysts mature, the thread between them breaks off and the intercalaric heterocysts change into terminal ones.

Anabaenopsis Raciborskii does not, however, form threads twisted into rings and for this reason heterocysts are formed in this species by metamorphosis of cells on the summit, after the threads have divided. This species occupies, therefore, a separate place.

After Wołoszyńska, the species *A. Raciborskii* was mentioned for the second time, by Skuja (1937) as coming from the lake Kastoria in Macedonia, the published sketches closely resembling those of Wołoszyńska. He completed the diagnosis, giving, however, a greater length and breadth of the heterocysts. Skuja also noticed no spores.

They are, however, given by Kogan (1956) from material found in Turkmenia; he states that they are elliptic, 7—11 μ long and 3,3—4 μ broad. The cells in this form were 5,4—10,6 μ long and 2,4—3 μ broad, the heterocysts 2,2—3 μ broad and 4—11 μ long. Lately, the *A. Raci-*

borskii was described by Claus (1961) from material originating from salt bogs in Burgerland (Austria). He states that the threads were straight or slightly curved 2,2—2,4 μ broad, the cells 2,4—3,6 μ long, the heterocysts 4,4 μ long and as broad as the cells of the threads. He did not notice any spores. Claus supposes that the specimens he investigated represent a different species with narrow trichomes. He also suggests that the new name of *Anabaena Wołoszynskae* should be given to forms about 4 μ broad, and that of *A. Raciborskii* should remain for narrower threads. Judging from Claus' sketches this species resembles the specimens found in the pond Italiano Duże.

The genus *Anabaenopsis* was not, however, convincingly established, a fact stressed long ago by different authors. Borge (1929) mentions a close resemblance between *A. Raciborskii* and *Cylindrospermum* and is of the opinion that the genus *Anabaenopsis* will not be maintained. Bharadwaya (1933) nad Ramanathan (1938) express a series of critical remarks. The only character which distinguishes the genus *Anabaena* from *Anabaenopsis* is the presence, in the latter, of heterocysts on both extremities of the threads. It differs from the genus *Cylindrospermum* in the lack of spores in the vicinity of the heterocysts. These characteristics are not so constant, however, as to be used for distinguishing the genus. In some other *Anabaena* species (as for instance *A. echinospora)* heterocysts are also seen on both ends of the threads, near the intercalaric heterocysts, and Drew (1930) demonstrated that spores in the *Cylindrospermum* can also separated from the heterocysts by a row of cells. The characteristics of the genus *Anabaenopsis* are therefore artificial and unconvincing. It would be better to consider this genus as a section of the genus *Anabaena* or of the genus *Cylindrospermum*, as proposed originally by Wołoszyńska. The species *A. Raciborskii*, especially, with heterocysts forming from summit cells in the same manner as in *Cylindrospermum*, belongs rather to this genus than to the genus *Anabaena*. Geitler (1942) also notices the separate position occupied by the species *A. Raciborskii* in the *Anabaenopsis* genus. Huber-Pestalozzi (1938) writes that the characteristics of the genus *Anabaenopsis* are not constant and the genus it therefore uncertain. Gonzales-Guererro (1945) considers, after a detailed discussion, that the genus *Anabaenopsis* ought to be abolished, as it represents youthful stages of the genus *Cylindrospermum*. The material of the pond „Italiano Duże", after thorough investigation, entirely confirms this point of view.

Two groups, however, appear distinctly in all species of the genus *Anabaenopsis* known at present. The one resembles in shape species of the genus *Anabaena*, as for instance *Anabaenopsis circularis* (G. S. West) Wołosz., *A. Arnoldii* Aptek., *A. luzonensis* Taylor, *A. Elenkinii* Miller, *A. kolundinensis* Woronichin, *A. Milleri*

Woronichin. *A. Issatschenkoi* Woronichin. The other resembles the genus *Cylindrospermum*, as *Anabaenopsis Cunningtonii* Taylor, *A. tanganyika* (G. S. West) Wołosz., *A. Raciborskii* Wołosz., *A. seriata* Prescott. The spores of this last species are bigger than the vegetative cells; they develop in the neighbourhood of heterocysts, similarly as those of the genus *Cylindrospermum*.

Logically, therefore, the need arises to divide the species of the genus *Anabaenopsis* between the two genera of *Anabaena* and *Cylindrospermum*. The first of the two groups of species mentioned above should form, as was primarily assumed by Wołoszyńska, the section *Anabaenopsis* within the genus *Anabaena*, and the second group should be included in the genus *Cylindrospermum*. It is not quite certain whether in this last genus the section *Cylindrospermopsis* should not be formed, as already suggested by Bharadwaja (1933); this section would be composed of plankton species having no spores. The blue-green algae from the pond „Italiano Duże" are identical with the species *Cylindrospermum stagnale* and resemble *Anabaenopsis Raciborskii*, and their forms, deprived of spores, observed in the plankton, do not require the creation of a separate section.

3. Plankton from the pond „Italiano Duże"

As an illustration of the conditions in which appeared the blue-green algae described above: *Isocystis planctonica* n. sp. and *Cylindrospermum (Anabaenopsis) stagnale*, a description is given here of the pond and of the plankton developed in the summer season of 1952.

The pond „Italiano Duże" belongs to the group of ponds of the Fish Farm in Osiek (Oświęcim district, province of Kraków), situated in the basin of the river Soła. This carp pond, not very large and typical for this part of the country, has a surface of 1 ha and is 50—100 cm deep. In the period of investigation it had a relatively small growth of vegetation, composed of macrophytes in which, in the border zone of the pond, *Glyceria aquatica* (L.) Wahlb. and *Typha latifolia* L. prevailed. *Sagittaria sagittifolia* L., *Potamogeton lucens* L. and *Elodea canadensis* Rich. grew in groups in the water. In secluded parts near the banks *Salvinia natans* (L.) All. and *Riccia fluitans* L. floated on the surface. The bottom of the pond was of a loamy clay, covered with greyish mud, with an addition of vegetal detritus.

Plankton was collected from June till September by means of a plankton pail 10 l in capacity. Water was drawn into the pail from a boat at a depth of 0—50 cm and strained through a net of silk gauze No. 25. 5 pails of water, drawn from 5 different places in the pond and then strained furnished one sample. The samples were immediately

fixed in formalin and the plankton was later placed in titrated vessels. After 24 hours of sedimentation the volume of the sediment was noted. The temperature of the water, its pH and alkalinity were noted during the collecting of samples.

The plankton was analysed from the quantitative aspect and the number of species was determined according to a 6 degree scale. Simultaneously, assuming that the most accurate pisture of numerical relations in a mass of plankton, contained in a certain amount of water, is given by combining the number and size of individuals, their size was also approximately determined according to a special scale (S t a r m a ch 1955). This evaluation as well as the numerical evaluation was usually carried out under a 200 × magnification (lens 20 ×, ocular 10 ×). It was established by means of tests that 5—6 preparations must be investigated microscopically under a cover slide of 20 × 20 mm to obtain correct data as to the qualitative and numerical composition of a plankton mass. The size of the individuals multiplied by their number gives an index of the space occupied in a given sample by a certain species. This dimension, conventional of course, does not entirely correspond to the true volume of the organisms, but is in proportion to them. The aim of using such a simple space index lies in the obtaining of comparable data concerning the density of plankton organisms in a determined volume of water and the space occupied by individual species. If a sample of plankton from 50 l of water, stained through a No. 25 net, with a 50—65 μ mesh is considered as the lobe of the association, then the combination of number and size of the species will correspond to the degree of covering applied in plant sociology (according to the Franco-Swiss school).

Numerous attempts carried out previously demonstrated that this method is sufficient for characterizing plankton communities, for the values it furnishes resemble those obtained by the counting and measuring of individuals and the calculation of volume, as applied by some workers. It must be noted that all methods of counting and calculation of volume applied in analysis, are burdened with so great an error, caused by a very heterogenous plankton mass, that the results are somewhat small in relation to the amount of work involved. In practice estimation produces much more rapidly in practice results which are not in accordance numerically, but which present a very similar picture of the plankton mass.

Plankton characteristic

The composition of the plankton is presented in Table. The considerable amount of different species of green algae (*Chlorococcales*) grouped in samples from the first part of the summer is worthy of note,

Plankton of the "Italiano Duze" pond in Osiek

Explanations to the table

1. The quantity of organisms was determined on the basis of the examination at the magnification of 200 x of 3-5 preparations composed of material sedimented in conical test tubes during 24 hours, the sediment being then diluted with distilled water in the proportion 1:4.

Scale: - very rare
1 single
2 few
3 medium
4 many
5 very many

2. The size of individual specimens was determined acoording to the area occupied by the given specimen in the microscopic field of vision, i.e.:

5 - the organism occupies 75-100 % of the field of vision. The index of calculation of size: 16
4 - " " " 50- 75 % " " " " " " " " " " " " 11
3 - " " " 25- 50 % " " " " " " " " " " " " 7
2 - " " " 10- 25 % " " " " " " " " " " " " 3
1 - " " " 1- 10 % " " " " " " " " " " " " 1

3. The numbers in the table represent the spatial index, i.e. the product of multiplying the number of quantity of organisms by the index of calculation of size.

4. The index of frequency represents the sum of the number of individual species multiplied by the degree of constancy.

5. The constancy is calculated according to the scale:

V - indicates that the species occurs in 80-100 % of samples
IV - " " " " " 60- 80 % " "
III - " " " " " 40- 60 % " "
II - " " " " " 20- 40 % " "
I - " " " " " 1- 20 % " "

6. Dominant : species having a degree of constancy IV-V
Subdominant: " " " " " II-III
Adominant : " " " " " I

No of sample	1	2	3	4	5	6	7	Constancy	Index of frequency
Date of collection	7.VI.	20.VI.	2.VII.	15.VII.	29.VII.	12.VIII.	23.IX.		
Sediment from 50 l water after 24 hrs in ml	0,1	0,2	0,3	0,1	0,3	0,2	0,1		
Temperature of water °C	19,5	20,5	21,0	19,0	19,7	20,2	17,5		
pH	7,2	7,5	8,0	7,25	7,25	7,6	7,5		
Alkalinity (cm^3 n/10 HCl in 100 cm^3 of water)	1,5	1,5	1,2	1,2	1,5	1,5	1,4		
A. Phytoplankton									
1. Dominant									
Dinobryon divergens Imh.	1,5	-	-	6	3	9	3	IV	30
Volvox aureus Ehrb.	9	45	18	9	9	4,5	-	V	52,5
Coenedesmus quadricauda /Turp./Menegh.	-	-	-	0,5	0,5	0,5	0,5	IV	8
2. Subdominant									
Marssoniella elegans Lemm.	-	-	-	-	0,5	0,5	-	II	2
Cylindrospermum stagnale /Kutz./Born.et Flab.	-	-	-	1,0	2	8	1	III	18
Gloeotrichia natans /Hedw./Rabenh.	-	-	-	-	0,5	0,5	-	II	2
Nodularia Harveyana /Thwait./Thur.	-	-	-	-	0,5	0,5	-	II	2
Isocystis planctonica sp.nov.	-	-	-	-	1,5	3	1,5	III	6
Trachelomonas granulosa var.subglobosa Playf.	0,5	0,5	-	-	-	0,5	-	III	4,5
Phacus monilatus Stokes	-	-	-	-	-	0,5	0,5	II	2
Dinobryon divergens var.angulatum /Sel./Brunth.	-	-	-	-	1,5	1,5	-	II	2
- sertularia Ehrb.	-	-	-	-	2,5	2,5	-	II	2
- bavaricum var.medium /Lemm./Krieg.	-	-	-	-	1,5	1,5	1,5	III	4,5
Synura uvella Ehrb.emend.Korsch.	1,5	-	-	-	-	1,5	-	II	2
Fragilaria virescens Ralfs	2,5	2,5	-	-	-	-	2,5	III	4,5
Synedra acus Kutz.	0,5	0,5	0,5	0,5	-	-	-	III	6
Botryococcus Braunii Kutz.	-	-	-	2,5	2,5	2,5	-	III	4,5
Pandorina morum Bory	1,5	1,5	1,5	-	-	-	-	III	4,5
Eudorina elegans Ehrb.	-	-	1,5	1,5	1,5	1,5	-	III	6
Volvox globator /L./Ehrb.	4,5	9	4,5	-	-	-	-	II	4
Sphaerocystis Schroteri Chod.	0,5	0,5	-	-	0,5	0,5	-	III	6
Pediastrum Boryanum /Turp./Menegh.	-	-	0,5	0,5	0,5	0,5	-	III	6
- tetras /Ehrb./Ralfs.	0,5	0,5	-	-	-	-	-	II	2
- duplex Meyen	-	0,5	0,5	-	-	0,5	-	III	4,5
Dictyosphaerium Ehrenbergianum Näg.	-	0,5	0,5	0,5	-	-	-	III	4,5
Crucigenia apiculata Schmidle	-	-	-	-	-	0,5	0,5	II	2
- rectangularis /A.Br./Gay.	0,5	0,5	-	-	-	-	-	II	2
Scenedesmus arcuatus Lemm.	-	-	-	-	0,5	0,5	0,5	III	4,5
Xanthidium antilopaeum /Bréb./Kutz.	0,5	0,5	0,5	-	-	-	-	III	4,5
Cosmarium depressum /Nag./Lund.	-	0,5	0,5	0,5	-	-	-	III	4,5
- circulare Reinsch.	-	-	0,5	0,5	-	-	-	II	2
Closterium moniliferum /Bory/Ehrb.	-	0,5	0,5	0,5	-	-	-	III	4,5
3. Adominant									
Aphanothece stagnina preng./P.Peters.et Geitl.emend.	-	-	-	-	-	1,5	-	I	0,5
Anabaena spiroides Kleb.	-	-	-	-	-	-	0,5	I	0,5
Tolypothrix distorta Kutz.f.penicillata /Ag./Kossinskaja	-	-	-	-	-	1,5	-	I	0,5
Oscillatoria lacustris /Kleb./Geitl.	-	-	-	-	-	1,5	-	I	0,5
Trachelomonas Lemmermannii var.verrucosa /Skuja/Popova	-	-	-	-	0,5	0,5	-	I	1
- Steinii Lemm.	-	-	-	-	-	0,5	-	I	0,5
Kirchneriella lunaris /Kirchn./Mob.	-	-	-	-	-	0,5	-	I	0,5
Sorastrum spinulosum Näg.	-	-	-	-	-	0,5	-	I	0,5
Spirogyra calospora Cleve	-	-	-	-	-	0,5	-	I	0,5
Staurastrum anatinum Cook et Wills.	-	-	0,5	-	-	-	-	I	0,5
B. Zooplankton									
1. Dominant									
Asplanchna priodonta Gosse	3,5	7	3,5	3,5	7	3,5	7	V	25
Keratella cochlearis /Gosse/	3	1,5	6	6	6	3	3	V	47,5
- quadrata /Müll./	-	-	1,5	1,5	1,5	3	1,5	IV	12
Polyarthra vulgaris Carlin	1,5	1,5	-	3	1,5	1,5	-	IV	12
Diaphanosoma brachyurum /Liévin/	4,5	9	36	18	36	9	4,5	V	26,5
Alonella nana /Baird/	1,5	3	-	1,5	-	1,5	1,5	IV	12
Diaptomus sp.	6,5	6,5	13	13	6,5	6,5	6,5	V	22,5
Cyclops sp.	22	11	33	22	22	11	11	V	60
Nauplii	7	7	21	21	21	7	7	V	65
2. Subdominant									
Conochilus unicornis Rousselet	28	7	-	-	-	-	-	II	10
Synchaeta oblonga Ehrb.	-	-	-	-	-	1,5	1,5	I	2
Brachionus plicatilis Müll.	-	-	1,5	1,5	-	1,5	-	III	4,5
Leoane hamata /Stockes/	-	-	-	-	1,5	1,5	1,5	III	4,5
Euchlanis dilatata Ehrb.		-	-	0,5	0,5	-	-	II	2
Epiphanes senta /Müll./	-	0,5	-	-	-	0,5	-	II	2
Pompholyx complanata Gosse	-	-	-	-	1,5	1,5	1,5	III	4,5
Daphnia longispina /O.F.Müll./	9	18	3	-	-	4,5	-	III	13,5
Moina rectirostris Leydig	3,5	3,5	-	-	-	-	-	II	2
Bosmina longirostris /O.F.Müll./	-	-	-	3,5	7	14	7	III	13,5
Camptocercus rectirostris Schoedler	-	-	-	1,5	1,5	-	-	II	2
Pleuroxus striatus Schoedler	-	-	1,5	-	1,5	-	-	II	2
Difflugia limnetica Levander	-	-	1,5	1,5	-	3	1,5	III	7,5
- gramen Pen.	-	-	-	-	1,5	1,5	-	II	2
Arcella vulgaris Ehrb.	1,5	-	1,5	1,5	-	-	-	III	4,5
3. Adominant									
Brachionus calyciflorus Pallas	-	-	-	-	-	1,5	-	I	0,5
Arcella discoides Ehrb.	-	-	-	-	-	1,5	-	I	0,5

as well as that of blue-green algae (*Cyanophyta*) in its latter half. As to animals, there were many *Rotatoria*, *Cladocera* and *Copepoda*. Among the rotifers, *Asplanchna priodonta* and *Keratella kochlearis* were species appearing throughout the year, thus bearing the character of seasonally undifferentiated ubiquaries. *Conochilus unicornis* belongs to the species which end their development during the first half of the summer. In its second half, *Lecane hamata*, *Pompholyx complanata*, and *Keratella quadrata* were seen, the latter, however, did not appear in any great quantity.

Daphnia longispina and *Moina rectirostris* are characteristic for the early summer period. In late summer *Bosmina longirostris* develops especially, and *Camptocercus rectirostris* in lesser quantities. *Copepoda* do not show any considerable seasonal differentiation. The more frequently noted of their species are the *Cycplops*, the *Diaptomus* species appearing in smaller numbers. Of the protozoa, the genus *Difflugia* had more representatives in the second half the summer.

In the plankton mass of the pond „Italiano Duże" the following species could therefore be found:

a) species noted throughout the summer season, appearing in all samples, though not in equal amounts,

b) species appearing in the first half of summer,

c) species appearing in the second half of summer.

In connection with this two distinct aspects showed clearly early summer, from June 7 to July 15, and late summer from July 29 to September 23.

In the first period, the characteristic species are *Volvox aureus* — *Daphnia longispina* prevails, and in the second one *Dinobryon divergens* — *Bosmina longirostris*. The most decided developmental periods of these species are in the summer season. Each group has

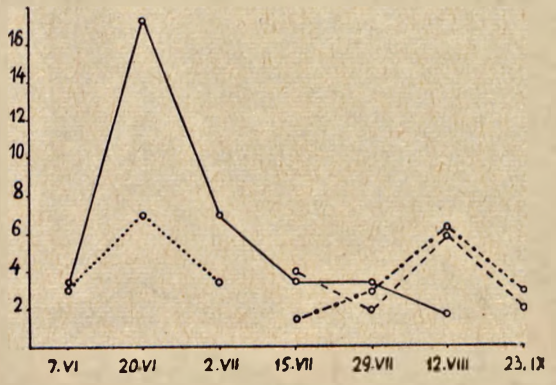

Fig. 3. The development of different species in the plankton of the pond „Italiano Duże". ——— *Volvox aureus*; .... *Daphnia longispina*; — — — — *Dinobryon divergens*; —.—.—.— *Bosmina longirostris*.

a distinct maximum at a different time: the first on June 20, the second on August 12. The development of the species characterizing the two communities is presented on the diagram in Fig. 3.

Both species of the previously described blue-green algae developed in the second half of summer, thus they therefore belong to the association *Dinobryon divergens — Bosmina longirostris*. *Cylindrospermum (Anabaenopsis) stagnale* had in sum a higher space index than *Isocystis planctonica* (Fig. 4). Both species were found in the greatest number in the samples of Aug. 12.

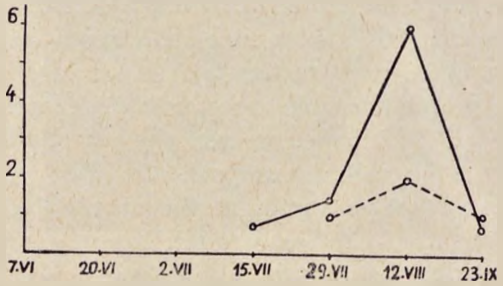

Fig. 4. The development of the species *Cylindrospermum stagnale* and *Isocystis planctonica* in the pond „Italiano Duże"; ——— *Cylindrospermum stagnale*; — — — *Isocystis planctonica*

Plankton can also be characterized in a general manner on the basis of a summing up of the space index for plants and animals. In this case attention is paid to the fact that plankton animals, although less numerous than plants, prevail where space is concerned since they occupy in water a greater space than plants. In the development of both groups, phyto- and zooplankton, two maxima are formed, corresponding to the two associations mentioned previously. The maximum for plants occurred in the middle of June and for animals at the beginning of July Fig. 5. The second maximum for plants was

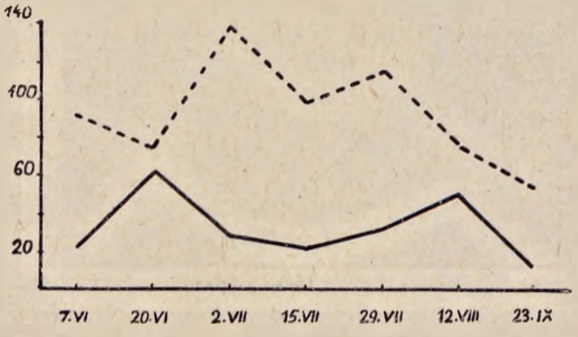

Fig. 5. ——— Phytoplankton; — — — — Zooplankton.

attained by the middle of August, while for animals it was already at the end of July. In September a decrease in the amount of both animals and plants is visible. The maxima for animal and plant appearance do not agree and are in opposition to each other. This may be connected with the feeding of zooplankton on phytoplankton, but these relations are not clear when only net plankton are taken into consideration and nannoplankton are omitted. Animals usually feed on the smallest specimens of plant plankton and consume larger forms only dead.

STRESZCZENIE

W planktonie stawu „Italiano Duże" w Osieku (powiat Oświęcim, wojew. krakowskie) znaleziono dwie ciekawe sinice. Jedna z nich była nowym gatunkiem, który nazwano *Isocystis planctonica* n. sp., druga, na pozór podobna do gatunku *Anabaenopsis Raciborskii* Woł o s z., zaliczona została po szczegółowej analizie do gatunku *Cylindrospermum stagnale* (K ü t z.) B o r n. et F l a h. Po zestawieniu odnośnych danych z literatury i na podstawie analizowanego materiału proponuje autor zlikwidowanie rodzaju *Anabaenopsis* i włączenie mieszczących się tam gatunków bądź do rodzaju *Anabaena*, bądź też do rodzaju *Cylindrospermum*. Gatunki o niciach zwiniętych w pierścienie lub spirale, posiadające kuliste heterocysty, tworzące się najpierw interkalarnie po dwie obok siebie, następnie po rozpadnięciu się nici osadzone na ich końcach, powinny być umieszczone w sekcji *Anabaenopsis* rodzaju *Anabaena*. Gatunki pokrojowo podobne do *Cylindrospermum*, tworzące heterocysty z komórek szczytowych nici, oraz posiadające spory przy heterocystach, powinny być włączone do rodzaju *Cylindrospermum*. Szczegóły budowy nici u obu gatunków przedstawione są na rysunkach i fotografiach.

Podano również bliższą charakterystykę planktonu, w którym zostały znalezione powyższe sinice. Przy spisie planktonu zastosowano oryginalną próbę określania zespołów planktonowych.

Zbiorowisko planktonu w stawie „Italiano Duże" było w ciągu lata niejednorodne. Wczesnym latem dominował zespół *Volvox aureus* — *Daphnia longispina*, późnym latem zaś zespół *Dinobryon divergens* — *Bosmina longirostris*. Opisane szczegółowo sinice wchodziły w skład tego ostatniego zespołu.

REFERENCES

A p t e k a r j E. M., 1926. De nova specie: *Anabaenopsis Arnoldii* mihi. Not. Syst. ex Inst. Crypt. Horti Bot. Principalis USSR. 4, 41—56.

B a c h m a n n H., 1939. Mission scientifique de l'Omo. Zeitschr. f. Hydrobiol. 8, 119—139.

B h a r a d w a y a Y., 1933. Contributions to our knowledge of the *Myxophyceae* of India. Ann. of Botany, 47, 117—143.

B o r g e O., 1929. Susswasseralgen. (Zellpflanzen Ostafrikas.) Hedwigia, 68.

B o r z i A., 1878. Note alla Morphologia e Biologia delle Alghe *Ficcocromaceae*. Nuovo Giorn. Botan. Italiano, 10, 278.

B o r z i A., 1878. Nachträge zur Morphologie und Biologie der Nostocaceen. Flora, 61, 465—471.

C l a u s G., 1961. Contributions to the knowledge of the Blue-Green Algae of the Salzlackengebiet in Austria. Int. Revue ges. Hydrobiol. 46. 514—541.

Cyrus Z., 1952. Nova pozoruhodna sinice našich vod. Preslia, 24, 59—64.
Drew K. M., 1930. The occurence of heterocyst and spores at both ends of the filament in the genus *Cylindrospermum*. Rev. Algol., 5, 143—145
Elenkin A. A., 1949. Monographia algarum cyanophycearum aqui dulcium et terrestrium in finibus URSS inventarum, Fasc. II., Acad. Scient. URSS, Moskva.
Fritsch F. E., 1951. The Heterocyst a Botanical Enigma. Proc. of the Linnean Soc. of London, Session 162, 2. 31. III. 1951, 194—211.
Geitler L., 1942. Schizophyta in Engler und Prantl. Die natürl. Pflanzenfamilien, 1, Leipzig, W. Egelmann.
Gonzales-Guerrero P., 1928. El genero *Anabaenopsis* (Wolosz.) V. Miller en Espana. Bol. R. Socc. Esp. Hist. Nat., 28, 357—359, Madrid.
Gonzales-Guerrero P., 1944. Revision critica de la Cianoficeas espanolas de aqua dulce. Ann. del Jardin Bot. de Madrid, 4, 205.
Gonzales-Guerrero P., 1945. El genero *Anabaenopsis* estado infantil de *Cylindrospermum*. Ann. Jard. Bot. Madrid, 5, 299—303.
Huber-Pestalozzi G., 1938. Das Phytoplankton des Süsswassers, 1. Teil, Die Binnengewässer, 16, Teil 1, E. Schweizerbart, Stuttgart.
Kogan S. I., 1956. Species algarum curiose e Turkmenia. Not. Syst. Sect. Crypt. Inst. Bot. Acad. Sci. URSS. 11, 33—35.
Miller V., 1923. Zur Systematik der Gattung *Anabaena* Bory. Arch. Soc. Russ. Protistol., 2, 116—126.
Prescott G. W., Andrews F., 1955. A new Species of *Anabaenopsis* in a Kansas Lake with notes on Limnology. Hydrobiologia, 7, 60—63.
Ramanathan K. R., 1938. On a Form of *Anabaenopsis* from Madras. Journ. Ind. Bot. Soc., 17, 325—339.
Skuja H., 1937. Süsswasseralgen aus Griechenland und Kleinasien. Hedwigia, 77, 15—70.
Starmach K., 1936. Rodzaje polskich sinic. Kosmos, Ser. B, 611, 77—143.
Starmach K., 1955. Metody badania planktonu. PWRiL, Warszawa.
Taylor W. R., 1932. Notes on the Genus *Anabaenopsis*. Amer. Journ. Botany, 19, 454—463.
Wołoszyńska J., 1912. Das Phytoplankton einiger jawanischer Seen, mit Berücksichtigung des Sawa Plankton. Bull. l'Acad. des Scien., Cracovie, Sér. B, Sc. Nat., 649—709.

Adres autora — Author's address

prof. dr Karol Starmach

Zakład Biologii Wód, Polska Akademia Nauk, Kraków, ul. Sławkowska 17
albo — or
Katedra Hydrobiologii, Uniwersytet Jagielloński, Kraków, Olcandry.

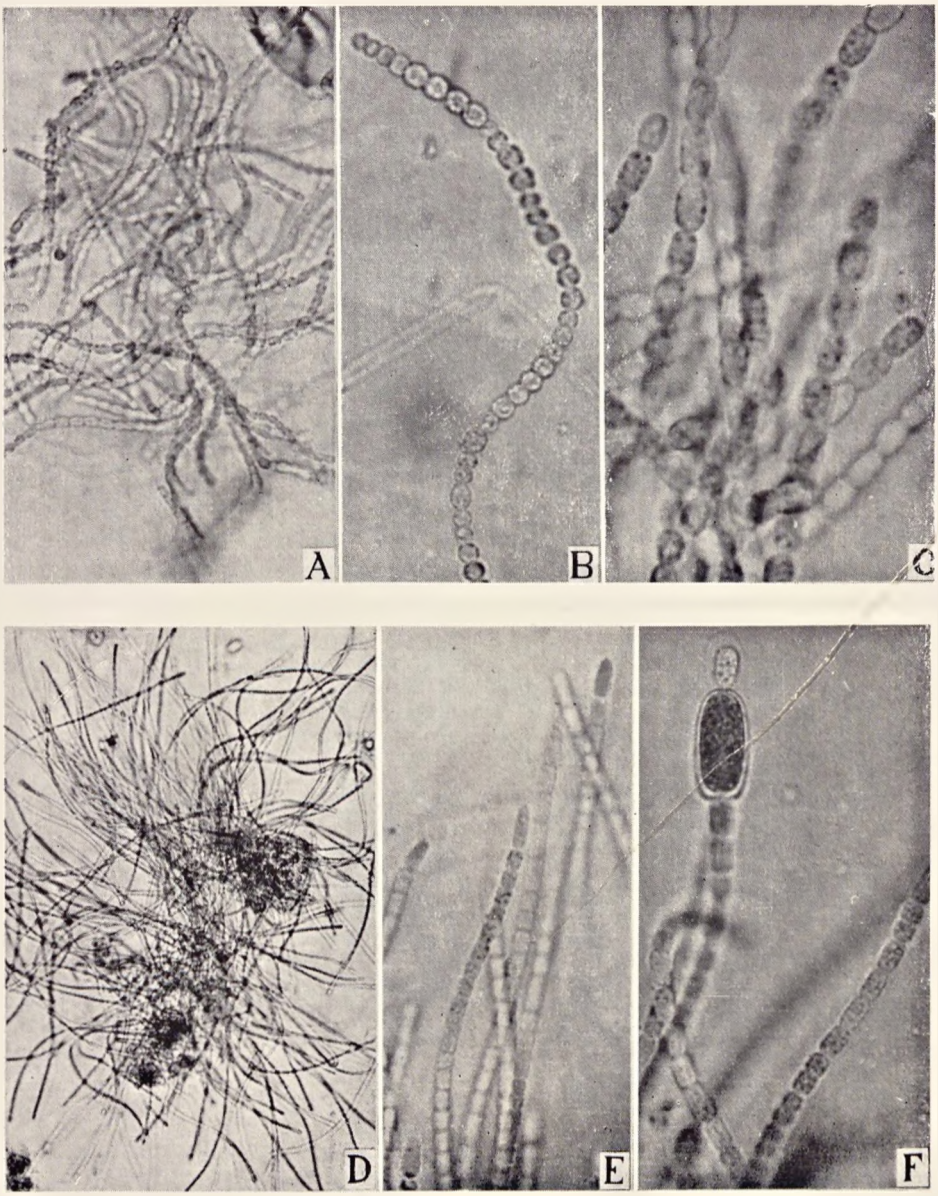

Fig. 6. A—C. *Isocystis planctonica* n. sp.: A. Balls of threads under the low magnification; B. single threads; C. threads strongly magnified; D—F. *Cylindrospermum stagnale* (Kütz.) Born. et Flah.; D. Ball of thread under the low magnification; E. threads terminating in heterocysts; F. thread terminating in heterocysts and spore.