EFFECT OF THE TURBIDITY OF THE WATER ON THE DEVELOPMENT OF ALGAL ASSOCIATIONS IN THE TISZA

T. KISS KEVE
Municipal Water Works, Debrecen
(Received 10 February 1974)

Abstract

In every year maxima can be observed in summer and early autumn in the plankton algal populations in the Tisza and in the Eastern Main Canal.

The Eastern Main Canal is an irrigation canal built to the east of the Tisza in the eastern half of Hungary. Its water is led off from the river Tisza, dammed up at Tiszalök. The length of the canal is 98 km; its width is 40 m, and its depth 2.3—4.2 m. Its maximum flow rate is 60 m^3/s.

The population maximum is characterized by the dominance of the *Cyclotella* species, *Synedra actinastroides* and the *Chlorococcales* species. It was observed in the present studies that there is a definite correlation between the rapid multiplication of the plankton algae and the photoclimatic conditions of the water. If the Tisza is free from flooding for 2—3 weeks in the summer and early autumn, then the seston settles out of the slowly-flowing water, the transparency of the water increases, the photoclimate becomes more favourable, and the population maximum develops. At such time the number of algae can rise to 5—20 million per litre. The *Cyclotella* species, *Synedra actinastroides* and the *Chlorococcales* species can comprise 80—95% of the total population.

Introduction

The large-scale multiplication of algae can be observed increasingly more often in the surface waters in Hungary. Algal associations rich in numbers of species and individuals may develop not merely in standing waters, but also in slow running rivers (BEHNING 1929, UHERKOVICH 1968a, b, 1969, 1971, FELFÖLDY—TÓTH 1970). In every year in the Tisza it is possible to observe algal population maxima (UHERKOVICH 1971, KISS KEVE 1974a, b), characteristic water-quality states of the river.

At the time of the population maxima it is primarily the true plankton algae which multiply; their numbers often exceed one million individuals per litre.

The development of the *Cyclotella* population maximum to be observed in the Eastern Main Canal and in the Tisza at the end of winter and in early spring is decisively affected by the light conditions prevailing in the water (KISS KEVE 1974a, b). In the present work a study is made of whether a similar correlation can be observed in the case of the mass multiplication of the algae in summer and autumn.

Sampling and examination methods

As regards the water quality, the dammed-up section of the Tisza at Tiszalök was regarded as starting point. From here the changes in the qualitative and quantitative compositions of the algae were followed in the lake-like river section throughout the year, as were the changes in the composition of the algal association in the Eastern Main Canal, proceeding towards Balmazújváros.

Water samples were taken at Tiszalök, Tiszavasvári and Balmazújváros, in all cases from the surface and from the current line. In winter, if the water was frozen, the samples were taken through holes cut in the ice (KISS KEVE 1974b).

The samples from Tiszalök and Tiszavasvári were always taken on one day, one after the other. In the sampling at Balmazújváros an effort was made to ensure that the water samples should be taken from the water mass already examined in the upper canal section. Accordingly, taking into account the momentary water rates in the Tisza and the canal, water samples were taken at Balmazújváros 2—7 days after the sampling at Tiszalök and Tiszavasvári (UHERKOVICH 1968a). Water samples have been taken every week at these three sites since 1968.

Fig. 1. Map of the Eastern Main Canal.

Quality examinations were carried out on settled-out samples and on the simultaneously netted plankton samples. For the quantitative analyses, 100—250 ml (depending on its seston content) of the original, shaken water sample was filtered through a membrane with a pore diameter of 0.45 μ. The material remaining on the membrane was diluted to a few ml and fixed with formalin. The concentrated sample, the volume of which was known exactly, was examined in a Bürker chamber. Since 1971 the quantitative analyses have been performed by the method of UTERMÖHL (1958).

Development of maxima of plankton algal populations in the Tisza and the Eastern Main Canal

The development of a number of population maxima in the Tisza has been described by UHERKOVICH (1968a, b, 1969, 1971). His observations showed that the majority of these occurred in the section of the river below Tiszalök. Data on the occurrence of population maxima in the Eastern Main Canal have not so far been published. In every year since 1968 it has been possible at the three sampling sites to observe rich algal populations each representing a characteristic state of the water quality.

The population maxima observed in our investigations to date can be classified into three types (KISS KEVE 1974a, b):

1. A summer population maximum characterized by the dominance of *Cyclotella—Synedra actinastroides* (UHERKOVICH 1968a, KISS KEVE 1974a).
2. An autumn population maximum characterized by the dominance of *Cyclotella—Chlorococcales* (UHERKOVICH 1968a, KISS KEVE 1974a).
3. An early spring population maximum characterized by *Cyclotella* dominance.

An account of this latter type has already been reported (KISS KEVE 1974 b).

Population maximum characterized by *Cyclotella—Synedra actinastroides* dominance

This rich algal association, which can be observed in almost every year, is typical of the summer plankton of the Tisza and the Eastern Main Canal. It develops in general in July and August. If the river is flood-free for a few weeks, then the algae begin to multiply rapidly. Within 1—2 weeks their number may rise from a few hundred thousand to 5—20 million per litre. The *Cyclotella* species and *Synedra actinastroides* may then comprise 80—90% of the overall population (Tables 1—2).

In our investigations to date it has been found that the total number of individual organisms is less in the Balmazújváros section of the canal than in the Tisza. The decrease is primarily observed for the *Cyclotella* species and *Synedra actinastroides*.

As characteristic species, mention may be made of *Melosira granulata* var. *angustissima, Nitzschia acicularis, Actinastrum hantzschii, Ankistrodesmus acicularis, A. angustus, Crucigenia tetrapedia, Kirchneriella lunaris,* and *Scenedesmus* species. The species-richness of the Chlorococcales group is characteristic of the population maximum.

In the interest of the decrease in size of Table 2, quantitative data are presented for only three typical sampling series. Algal species found during the entire examination period (24 May — 11 August 1972), but omitted from the Table, are as follows: *Attheya zachariasi, Ceratoneis arcus, C. arcus* var. *amphioxys, Cymatopleura solea, Cymbella ventricosa, Melosira granulata* var. *angustissima* f. *spiralis, M. varians, Nitzschia sigmoidea, Rhoicosphenia curvata, Surirella ovata, Ankistrodesmus falcatus, Franceia tenuispina, Lagerheimia wratislaviensis, Pediastrum duplex, Scenedesmus denticulatus* var. *linearis* f. *granulatus, S. ecornis* var. *disciformis, S. intermedius* var. *acaudatus, S. intermedius* var. *balatonicus, S. lefevrii* var. *semiserratus, S. quadricauda* var. *maximus, S. spinosus, Anabaena spiroides, Merismopedia glauca, Phacus longicauda, Ophiocytium capitatum* and *Closterium acutum.*

Table 1. *Quantitative compositions of the phytoplankton of the Tisza and the Eastern Main Canal at Tiszalök (1), Tiszavasvári (2), and Balmazújváros (3) from August 1969*

August 1969	11th	11th	13th	19th	19th	22nd	26th	26th	29th
sampling points	1	2	3	1	2	3	1	2	3
Attheya zachariasi					20				
Cyclotella spp	185	120	60	2400	2500	910	250	50	270
Melosira granulata var. *angustissima*	12,5		15			20			
M. granulata var. angustissima f. *spiralis*		30							
Nitzschia acicularis	12,5		15	60	40		50	50	15
N. longissima var. *reversa*				20					
Synedra actinastroides	125	45	45	3460	3080	560			
S. acus	37,5								
S. ulna	12,5	15		200	300				
other Bacillariophyceae		45	60	60	20	30	175	50	45
total Bacillariophyceae	385	255	195	6200	5960	1520	475	150	330
Actinastrum hantzschii			15	400	40	40			15
Ankistrodesmus acicularis	62,5	15	15		40	20			
A. angustus	175	150	135	20	20	30		50	30
A. arcuatus	12,5	15			40	10		50	
A. longissimus var. *acicularis*		30							
Coelastrum microporum			30	40		20			
Crucigenia apiculata	12,5				20	20			
C. quadrata		15							
C. tetrapedia	50	15		80	80	120			
Dictyosphaerium pulchellum	12,5			20	20	40			
Didymocystis planctonica					40				
Franceia tenuispina				20					
Kirchneriella lunaris	25	30	15	40		10			45

K. obesa	25	45	45			20			
Lagerheimia citriformis					20				
Micractinium pusillum	12,5	60	30	40	40	50			
Oocystis borgei	12,5	30	30	60	40	30			15
Pediastrum boryanum		15							
P. tetras	12,5			20		10			
Scenedesmus acuminatus	12,5	45		80	100	70			15
S. acutus	12,5			80	160		25		15
S. denticulatus var. *linearis*	12,5								
S. ecornis					20				15
S. intermedius						10			
S. opoliensis				20				50	
S. quadricauda	12,5	15		240	60	40	50		30
S. spinosus			30	40	60				
S. spinosus var. *bicaudatus*	12,5			20					
other Scenedesmus spp	50	45		160	40	40	25		75
Tetraëdron minimum					60	10			
T. muticum	12,5								
Tetrastrum glabrum					20				
T. staurogeniaeforme						10			
other Chlorococcales	287,5	195	495	280	200	320	150	100	240
total Chlorococcales	825	720	840	1660	1120	920	250	250	495
Microcystis flos—aquae					40				15
other Cyanophyta			30	40				50	
Euglena spp	15			20					
Chlamydomonas spp	25		10	20		20			
Peridinium spp			10	20		30			
Dinobryon sertularia				20	20	10			
Centritractus belenophorus				20	40				
Staurastrum paradoxum					20	10			
total phytoplankton 1000 ind/1	1250	975	1085	8000	7200	2510	725	450	840

Table 2. *Quantitative compositions of the phytoplankton of the Tisza and the Eastern Main Canal at Tiszalök* (1), *Tiszavasvári* (2), *and Balmazújváros* (3) *from June to July 1972*

	June			June			July		
	7 th	7 th	9 th	21 st	21 st	23rd	5 th	5 th	7 th
Sampling points	1	2	3	1	2	3	1	2	3
Cyclotella spp	17700	15300	4000	362,5	212,5	450	875	1250	1550
Melosira granulata var. *angustissima*						12,5			
Nitzschia acicularis	900	550	325	50	37,5	225		200	25
Synedra actinastroides	25	25	75	1225	1200	1200	75	25	300
S. acus			75						
S. ulna					12,5			25	
other Bacillariophyceae		100	125	12,5	62,5	37,5	25	125	175
total Bacillariophyceae	18625	15975	4600	1650	1525	1925	975	1625	2050
Actinastrum hantzschii	75	75	325				600	575	1275
Ankistrodesmus acicularis	100	125	75		12,5		50	125	50
A. angustus	600	500	1025	287,5	237,5	400	225	275	500
A. arcuatus							25	25	50
A. longissimus var. *acicularis*	150	150	175				75	75	
Coelastrum microporum	25	50	100		12,5	37,5	50	75	225
C. sphaericum				12,5	12,5	12,5	75		25
Crucigenia apiculata								75	25
C. tetrapedia					12,5	12,5			25
Dictyosphaerium pulchellum	175	150	125			12,5	150	25	75
Didymocystis planctonica	25	25		25	25	37,5	50	50	125
D. tuberculata		25		12,5	37,5			25	25
Kirchneriella lunaris	25	50	50	37,5	137,5	300	25	25	50
K. obesa	25	25	25	37,5	62,5	87,5		25	125
Lagerheimia quadriseta			25						25
Micractinium pusillum			25						
Oocystis borgei	50			12,5	12,5	12,5	50	25	50
Pediastrum tetras						12,5			

Scenedesmus acuminatus	300	300	50				105	25	
S. acutus	100	50					50		
S. acutus f. *alternans*	100	25					50	25	
S. acutus f. *costulatus*	25		25				25		
S. ecornis								25	25
S. intermedius			25						
S. intermedius var, *bicaudatus*	100			12,5	12,5			25	25
S. opoliensis					12,5				25
S. protuberans								25	25
S. quadricauda	150	225	100	3	75	75	225	200	150
other *Scenedesmus* spp	75	100	25		50	50	75	175	175
Schroederia setigera		75							
Tetraëdron caudatum var. *incisum*		25				12,5			
T. incus		25	50			12,5			
T minimum			50						
T. muticum	25		75		12,5				25
Tetrastrum glabrum		25	50	12,5	12,5	50	75	25	25
T. staurogeniaeforme				12,5				25	
Treubaria triappendiculata	50	25	50	12,5	12,5				50
other Chlorococcales	325	400	275	112,5	150	225	600	475	725
total Chlorococcales	2500	2450	2725	650	900	1350	2575	2425	3900
Microcystis flos-aquae						12,5			
other *Cyanophyta*	75	75				37,5		25	25
Euglena spp				12,5	12,5		50		25
Strombomonas fluviatilis									25
Trachelomonas spp					12,5			25	
Centritractus belenophorus									25
Dinobryon divergens									25
D. sertularia			25						
Peridinium sp					12,5				
Chlamydomonas spp	150	50	25	37,5	12,5				
total phytoplankton 1000 ind/1	21350	18550	7375	2350	2475	3325	3600	4100	6075

Table 3. *Quantitative compositions of the phytoplankton of the Tisza and the Eastern Main Canal at Tiszalök* (1), *Tiszavasvári* (2), *and Balmazújváros* (3) *from August to October 1971*

	August			September			October		
	25 th	25 th	27 th	22 nd	22 nd	24 th	20 th	20 th	22 nd
Sampling points	1	2	3	1	2	3	1	2	3
Asterionella formosa							12,5		25
Cyclotella spp	6960	8500	1625	11100	8200	1440	1875	1900	650
Melosira granulata var. *angustissima*		12,5		50		10	12,5	12,5	50
Nitzschia acicularis	40	25	37,5	50	50	60	25	25	50
N. longissima var. *reversa*		12,5	25	25	25				
Synedra actinastroides	90	75	25		50	20			
S. acus	10					20			
S. ulna var. *oxyrhynchus*		25							
other Bacillariophyceae	10		87,5	75		10		12,5	
total Bacillariophyceae	7110	8650	1800	11300	8325	1550	1955	1950	775
Actinastrum hantzschii	30	12,5		25	50	30			50
Ankistrodesmus acicularis	40	12,5	37,5	50	25	60	37,5		150
A. angustus	90	75	50	250	125	620	100	112,5	525
A. arcuatus	10		25	25	50	20	12,5		75
A. longissimus var. *acicularis*	10	12,5	37,5		50	80	100	75	25
Chodatella balatonica							25		
Coelastrum microporum			37,5	50			12,5	25	
C. sphaericum			12,5						
Crucigenia apiculata	30	25	25		25	20		12,5	
C. fenestrata							12,5		
C. tetrapedia	40	50	75	250	100	110	37,5	50	75
Dictyosphaerium pulchellum	10	12,5	25	25			12,5	25	50
Didymocystis planctonica	10	37,5	87,5	25	25	10		25	50
D. tuberculata				25			12,5	12,5	25
Kirchneriella lunaris	120	75	62,5	50		40		12,5	
K. obesa	10	25	87,5	75	25	110	62,5	50	150
Oocystis borgei	10	25	50	25		30	12,5		25
Pediastrum duplex	10								
Scenedesmus acuminatus		12,5	12,5	150	75	20	37,5	25	50
S. acuminatus var. *bernardii*					25			12,5	
S. acutus					50	10	25	12,5	75

S. acutus f. *alternans*				25	25				
S. anomalus var. *acaudatus*	10	25							
S. armatus var. *boglariensis*	10								
S. denticulatus var. *linearis* f. *granulatus*		12,5							
S. ecornis						10			
S. ecornit var. *disciformis*						10			
S. intermedius		12,5		25	125			50	100
S. intermedius var. *balatonicus*					25				
S. intermedius var. *bicaudatus*	10		25						
S. opoliensis						10	12,5	37,5	25
S. protuberans		12,5		25					
S. quadricauda	70	50	75	75	125	20	137,5	87,5	325
S. quadricauda var. *maximus*									50
S. quadricauda var. *setosus*								12,5	
S. spinosus			12,5			10	12,5		
S. spinosus var. *bicaudatus*							12,5		
other *Scenedesmus* spp	110	112,5	100	25	100	80	125	37,5	275
Tetraëdron caudatum var. incisum						20			
Tetratsrum glabrum	10		25		50	10	225	150	575
T. punctatum			12,5						
T. staurogeniaeforme	10			25					
Treubaria triappendiculata		12,5		25					
other Chlorococcales	190	250	375	125	225	130	125	100	250
total Chlorococcales	840	875	1250	1375	1300	1460	1150	925	2925
Aphanisomenons flos-aquae				75	25	10			
Microcystis flos-aquae							12,5		
other *Cyanophyta*	30	12,5		25	50	20	12,5	25	75
Euglena spp	30	12,5	62,5						25
Strombomonas fluviatilis				25					
Trachelomonas spp	20	12,5	12,5		25	20	25	12,5	50
Peridinium spp		12,5	37,5						
Centritrctus belenophorus			12,5			10			
Dinobryon spp					25	60	25		25
Chlamydomonas spp	10		25	75	50	10	50	12,5	50
Closterium acutum	10				50				
total phytoplankton 1000 ind/1	8050	9575	3200	12875	9850	3140	3200	2925	3925

The *Cyclotella—Synedra actinastroides* population maximum generally lapses within a few weeks, and then in September, if the river is flood-free, a new rich algal association develops in the Tisza; this is characterized by the dominance of the *Cyclotella* and *Chlorococcales* species.

Population maximum characterized by *Cyclotella—Chlorococcales* dominance

In early autumn, if the end of the summer is not rainy, a species-rich algal association usually develops in the Tisza and the Eastern Main Canal. In addition to the *Cyclotella* species, a considerable number of organisms belonging to the *Chlorococcales* group are then found. Of these one may stress *Ankistrodesmus acicularis, A. angustus, Crucigenia tetrapedia, Tetrastrum glabrum* and *Scenedesmus* species. With high numbers of individuals, these are the main components of the phytoplankton population. On 29 September 1969, for instance, the number of

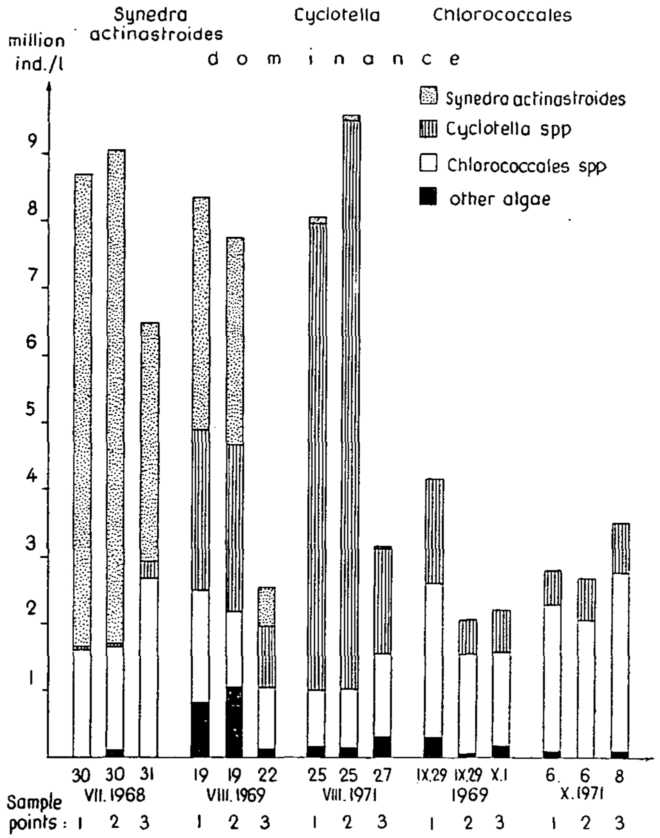

Fig. 2. Quantitative compositions of the phytoplankton of the Tisza and the Eastern Main Canal, based on one characteristic sample each from 1) Tiszalök, 2) Tiszavasvári and 3) Balmazújváros.

individuals from the *Scenedesmus* species reached 990 thousand per litre. They then comprised 23.8% of the total population.

The number of individuals is generally less in the canal than in the Tisza; this is primarily the result of the decrease in the number of individuals in the *Cyclotella* species. In some cases, however, (e.g. 23 September—22 October 1971) it was found that the number of phytoplankton organisms was higher at Balmazújváros. This increase was caused by the enhanced multiplication of the species of the *Chlorococcales* group (Table 3).

The size of Table 3 has been decreased by reporting the quantitative data for only three characteristic sampling series. The algal species found in the course of the full examination period (4 August—29 October 1971), but not reported in the Table, are as follows: *Diatoma vulgare, Gyrosigma scalproides, Melosira granulata, M. varians, Surirella robusta* var. *splendida, Coelastrum cambricum, Crucigenia quadrata, Desmatractum indutum, Franceia tenuispina, Lagerheimia marsonii, L. quadrisete, L. wratislaviensis, L. wratislaviensis* var. *trisetigera, Micractinium pusillum, Pandorina morum, Pediastrum boryanum, P. tetras* var. *tetraodon, Scenedesmus acutus* f. *costulatus, S. armatus, S. carinatus* f. *granulatus, S. gutwinskii* var. *bacsensis, Schroederia setigera, Tetraëdron minimum, T. muticum, Lyngbya limnetica, Merismopedia glauca, M. teniussima, Spirulina maior, Euglena acus, E. proxima, Phacus longicauda, Trachelomonas oblonga, Ceratium hirundinella, Dinobryon divergens, D. sertularia* and *D. sociale.*

Comparison of the *Cyclotella—Synedra actinastroides* and the *Cyclotella—Chlorococcales population* maxima leads to the conclusion that in many respects, they resemble one another. One decisive difference between them is that in the first type the number of *Synedra actinastroides* individuals reaches and exceeds 100,000 per litre, frequently being above one million per litre, whereas in the second type it does not. The former rich algal association develops at the height of the summer, at the earliest in the middle of June. After a few weeks have passed, the *Synedra actinastroides* disappear from the phytoplankton population, which is then characterized by the predominance of the *Cyclotella* and *Chlorococcales* species. This transition is shown in Fig. 2.

Ecological factors affecting the development of the population maximum

Factors of importance in the multiplication of the algae and in the development of the population maxima are the nutrients (Heron 1961, Lund 1964, 1965, Belcher—Swale—Heron 1966, Wang—Evans 1969, Ahlgren 1970, Holland—Beeton 1972), the temperature (Lund 1965, Wang—Evans 1969, Uherkovich 1971). and the light (Swale 1963, Lund 1965, 1967, Unerkovich 1970).

No exact measurements are available as to the nutrient contents of the Tisza and the Eastern Main Canal. It may be assumed that at the end of summer and in early autumn, when there is no flooding, the seston settles out from the slowly-flowing river, and in parallel with this an anaerobic bottom-zone develops and the release of nutrient is increased. Thus, the nutrients do not mean a minimum factor as regards the development of the population maximum. It is desired to clarify this assumption with further measurements.

In his publications on his investigations from the Tisza, Uherkovich (1968a, 1969, 1971) indicates on several occasions that the development of the population maximum, and its character, are affected by whether the river water is warmer or colder. In our examinations to date we have not found a relation between the occurrence of the summer and autumn population maxima and the change of the water temperature.

A third important ecological factor influencing the overmultiplication of the algae is the light (SWALE 1963, LUND 1965). Our own observations so far have revealed that the development of the population maxima is affected considerably by the light conditions. This is also pointed out in the papers of UHERKOVICH (1968a, 1971).

A slight digression must be made here to clarify what factors affect the photoclimate of the waters examined. It is well known that the water of the Tisza is strongly alluvial (UHERKOVICH 1971). At the time of flooding at Tiszalök, suspended-matter contents of even 600—800 mg/l have been measured (KISS KEVE—PINTÉR—MUNKÁCSY 1974). As a result of the shading effect of the large amount of seston, there is a rapid absorption of the light entering the water. Only the uppermost layer of the water is well provided with light, although this undergoes continuous exchange because of the turbulence of the river water. Our observations indicate that the photoclimates of the waters of the Tisza and the Eastern Main Canal are primarily determined by their seston contents. In rainy, overcast weather, if the amount of seston is small the light conditions may still be more favourable than in sunny weather combined with a high seston content.

In our investigations there was no possibility of carrying out on-the-spot,

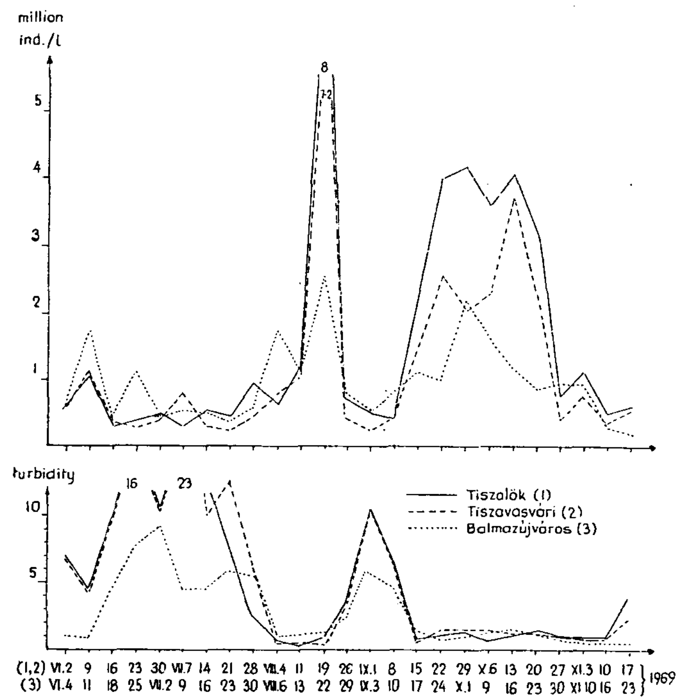

Fig. 3. Quantitative conditions of the phytoplankton of the Tisza and the Eastern Main Canal, and the change in the turbidity of the water between 2 June and 23 November 1969.

instrumental, underwater photomeasurements. Instead of this, photometric turbidity measurements were made at 442 mμ. The values of the turbidity were expressed in units of mg mastix/l. Since the turbidity of the water depends on the seston content, while the amount of seston also decisively affects the photoclimate of the water, in the knowledge of the turbidity it is possible to draw conclusions on the light conditions prevailing in the Tisza and the Eastern Main Canal. Of course, this can be done only to the extent of saying whether these are favourable or unfavourable for the multiplication of the algae.

From Figures 3—6 it can be stated that if the turbidity of the water of the river or the canal decreases (to be less than a turbidity value of ca. 3), i.e. if the photoclimate becomes favourable, then the rapid multiplication of the algae will begin and the population maxima will develop. With the increase of the turbidity, however, there is a parallel decrease in the number of algae, and the population maximum declines. At a turbidity of 3 the seston content of the water varies in the range 20—40 mg/l, while the Secchi transparency is 100—150 cm.

The dependence of the total number of algae on the turbidity was studied by carrying out correlation calculations (THEISS 1958). (The data of Figs. 3—6 were utilized. The data for the numbers of algae referring to the same turbidity values were averaged.) The result was:

Correlation index I=0.583

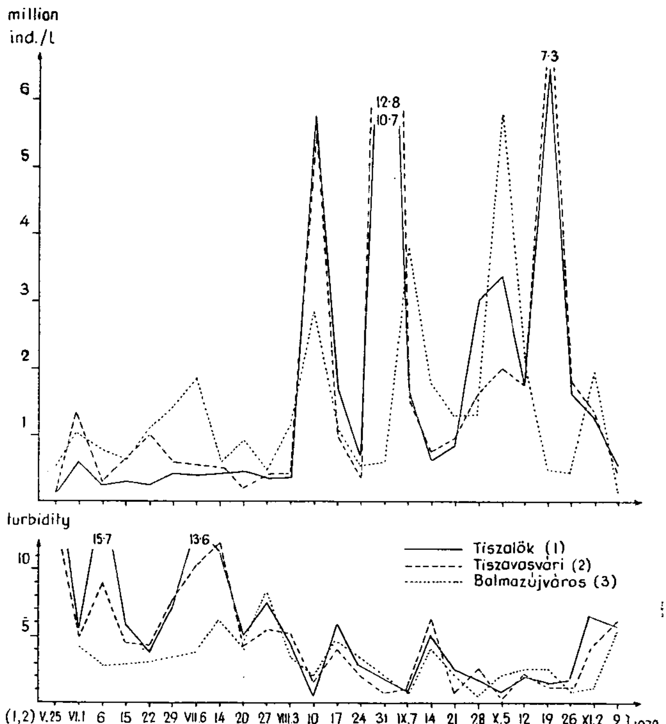

Fig. 4. Quantitative conditions of the phytoplankton of the Tisza and the Eastern Main Canal, and the change in the turbidity of the water between 25 May and 11 November 1970.

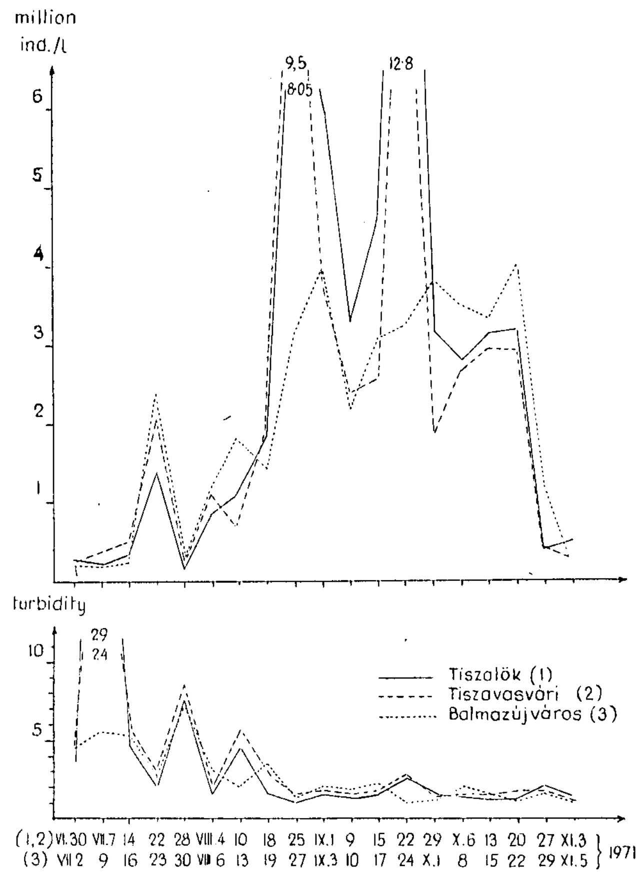

Fig. 5. Quantitative conditions of the phytoplankton of the Tisza and the Eastern Main Canal, and the change in the turbidity of the water between 30 June and 5 November 1971.

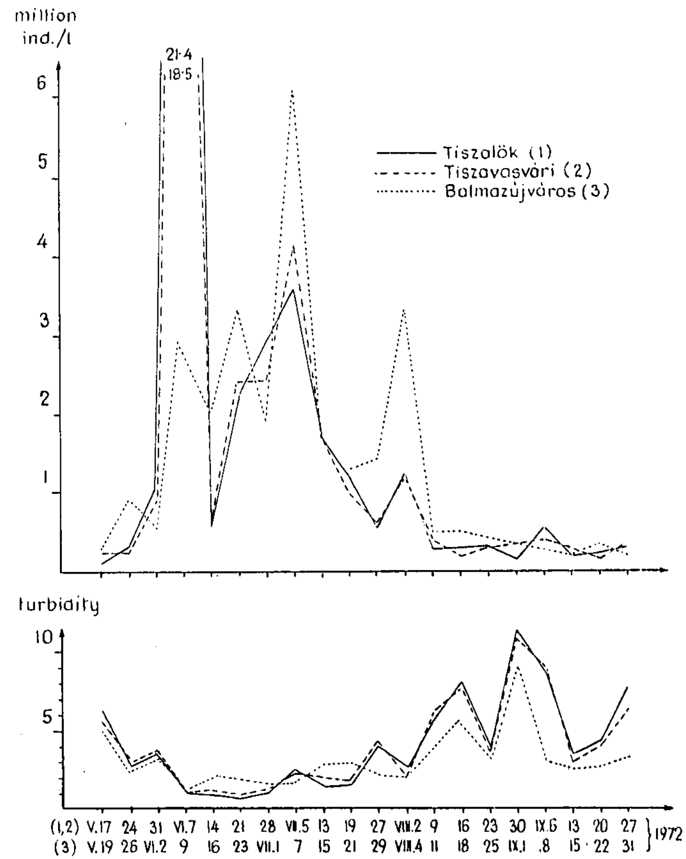

Fig. 6. Quantitative conditions of the phytoplankton of the Tisza and the Eastern Main Canal, and the change in the turbidity of the water between 17 May and 31 September 1972.

The correlation can be described by a hyperbolic function (see Fig. 7):

$$Y' = 317.3 + 3075.4 \cdot \frac{1}{X}$$

From a comparison of the turbidity values from Figures 3—7, it may be stated that plankton algal population maxima can develop in the Tisza and in the Eastern Main Canal if the turbidity of the water decreases below 3. At such time the light conditions are favourable for the overmultiplication of the algae.

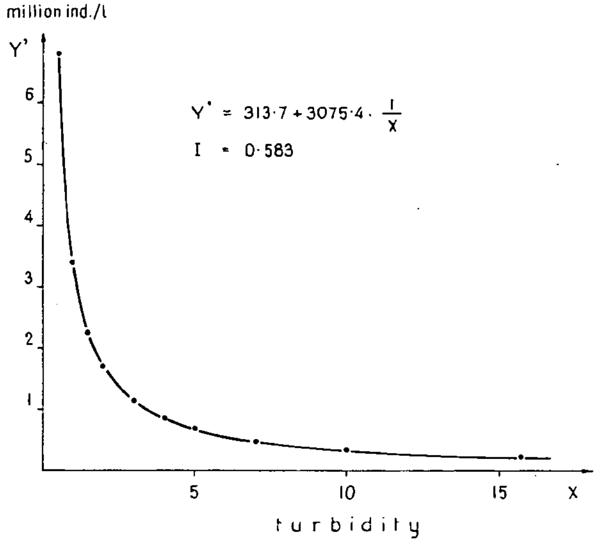

Fig. 7. Hyperbolic relation between the overall number of algae and the turbidity.

There may be significant differences between the total numbers of algae at the three sampling points at any time. The reason for this is in part that in summer and early autumn the rate of flow of the Tisza section dammed up at Tiszalök is small because of the low water-level, whereas the water flow in the canal may be rapid because of the intensive irrigation (UHERKOVICH 1964, 1966, 1971, KISS KEVE—PINTÉR—MUNKÁCSY 1974) and the increased turbulence is not favourable for the multiplication of the algae. The rich algal association of the Tisza becomes poorer in the Canal, and the numbers of algae decrease. It can be observed in Figures 3—6 that if a population maximum develops in the Tisza, then the turbidity there is less than in the Balmazújváros section of the Canal. Naturally, the reverse situation also occurs in several cases. It is beyond doubt, however, that, besides the flow conditions, the light and the turbidity, other unexamined ecological factors (such as the nutrient supply) also affect the development of the number of algae. Nevertheless, it can be seen from the results of the investigations that if the value of the turbidity is high and if the photoclimate of the water is unfavourable, then the population maxima can not develop in the Tisza and in the Eastern Main Canal.

Our observations lead to the conclusion that if the Tisza is flood-free for 2—3 weeks after May—June and its water becomes clearer, then the possibility exists for the population maxima of the plankton algae to develop in it.

References

AHLGREN, G. (1970): Limnological studies of Lake Norrviken, a eutrophicated Swedish lake. — Schweizerische Zeit. für Hydrologie *32*, 353—396.

BEHNING, A. (1928): Das Leben der Wolga. — Stuttgart.

BELCHER, J. H.—SWALE, E. M. F.—HERON, J. (1966): Ecological and morphological observations on a population of *Cyclotella pseudostelligera* HUSTEDT. — J. Ecol. *54*, 335—340.

HERON, J. (1961): The seasonal variation of phosphate, silicate and nitrate in waters of the English lake district. — Limnol. and Ocean. *6*, 338—346.

HOLLAND, R.—BEETON, A. M. (1972): Significance to eutrophication of spatial differences in nutrients and diatoms in Lake Michigan. — Limnol. and Ocean. *17*, 88—96.

FELFÖLDY, L.—TÓTH, L. (1970): A mezőgazdaság kemizálásának hatása a vízgazdálkodásra. II. Műtrágyahatás és mesterséges eutrofizálódás (The effect of applying chemicals in agriculture on the management of water supplies. II. Fertilizer-effect and artificial eutrophication). — Vízügyi Műszaki Gazdasági Tájékoztató *25*, 1—196.

KISS KEVE, T. (1974a): Vízvizsgálatok a Keleti Főcsatornán. II. A planktonalgák mennyiségi változásai (Water examinations in the Eastern Main Canal. II. Quantitative changes of the plankton algae). — Hidrol Közlöny *54*, (in press).

KISS KEVE, T. (1974b): Ecological factors of formation of *Cyclotella* population maxima in the Eastern Main Canal and in the river Tisza (Hungary). — Acta Biol. Debrecina (in press).

KISS KEVE, T.—PINTÉR, CSNÉ—MUNKÁCSY, T. (1974): Vízviszgálatok a Keleti Főcsatornán. I. Hidrográfiai viszonyok, a vízminőség kémiai jellemzői (Water examinations in the Eastern Main Canal. I. Hydrographic conditions, and chemical characteristics of the water quality). Hidrol. Közlöny *54*, 32—40.

LUND, J. W. G. (1964): Primary production and periodicity of phytoplankton. — Verh. Internat. Verein. Limnol. *15*, 37—56.

LUND, J. W. G. (1965): The ecology of the freshwater phytoplankton. — Biol. Rev. *40*, 231—293.

LUND, J. W. G. (1967): Planktonic algae and the ecology of lakes. — Sci. Prog. Oxford *55*, 401—419.

SWALE, E. M. F. (1963): Notes on Stephanodiscus hantzschii Grun in culture. — Arch. Microbiologie *45*, 210—216.

THEISS, E. (1958): Korreláció és trendszámítás (Correlation and trend calculation). — Közgazd. és Jogi Kiadó, Budapest.

UHERKOVICH, G. (1968a): Adatok a Tisza potamofitoplanktonja ismeretéhez. VI. A népességmaximumok kialakulásának kérdéséhez (Data on the potamophytoplankton of the Tisza. VI. The development of population maxima). — Hidrol. Közlöny *48*, 315—322.

UHERKOVICH, G. (1968b): Über verschiedene Typen der Algenmassenvermehrung in der Tisza (Theiss). — Tiscia (Szeged) *4*, 11—20.

UHERKOVICH, G. (1969): Adatok a Tisza potamofitoplanktonja ismeretéhez. VII. A népességmaximumok formáiról (Data on the potamophytoplankton of the Tisza. VII. Forms of the population maxima). — Hidrol. Közlöny *49*, 31—36.

UHERKOVICH, G. (1970): Seston Wysly od Krakowa po Tczew. Über das Wisla-Phytoseston zwischen Krakow und Tczew. — Acta Hydrobiol. Kraków *12*, 161—190.

UHERKOVICH, G. (1971): A Tisza lebegő paránynövényei (A Tisza fitoszesztonja) (Phytoseston of the Tisza). — Damjanich Museum, Szolnok.

UTERMÖHL, H. (1958): Zur Vervollkommung der quantitativen Phytoplankton Methodik. — Verh. Internat. Verein. Limnol. *9*, 1—38.

WANG, WUN-CHENG—EVANS, R. L. (1969): Variation of silica and diatoms in a stream. — Limnol. and Ocean. *14*, 941—944.