VARIATIONS IN THE PHYTOPLANKTON OF A NEWLY FORMED RESERVOIR

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ABSTRACT

The phytoplankton of a newly formed reservoir has been studied with respect to composition and component variation as a function of reservoir age. Collections were made from 7 stations in the northern portion of Cedar Creek Reservoir, Jackson County, Illinois over a one year period beginning in February 1974. The study area included approximately one-fifth of the 709 hectare, 6.12×10^7 m^3 lake. Ninety-eight algal taxa representing 6 divisions were identified. An overall increase in species and total cell densities was observed during the period of investigation. Motile forms were dominant at the beginning of the study period. Cyanophytes and chrysophytes were responsible for two large pulses which occurred in early summer 1974 and in mid-winter 1975. It appears that Cedar Creek Reservoir is becoming moderately eutrophic.

INTRODUCTION

Although much work has been done on established bodies of water, a scan of the literature reveals few works which deal with the phytoplankton of newly impounded reservoirs. Investigations which have been done, deal primarily with considerations other than floral composition.

The objective of this study was two fold: first to provide a list of the algae found in Cedar Creek Reservoir through an annual cycle shortly after impoundment and second to examine the changes in the phytoplankton which occurred during this time. Collection began 6 months after impoundment, at which time the pool had reached approximately 50% of its final volume, and continued for a period of one year. Therefore, this study provides a record of the phytoplankton composition and variations over the first year of existance, beginning in early spring.

It is hoped that information gained in this study will provide a foundation upon which future comparative studies can be based.

SITE DESCRIPTION

The study area included the northern fifth of Cedar Creek Reservoir in Jackson County, Illinois. The reservoir has a surface area of 709 ha and a volume of 6.12×10^7 m^3. It has a maximum depth of 14 m which occurs near the saddle dam (Fig. 1). Construction of Cedar Creek Reservoir began in spring 1972; completion and resulting impoundment occurred in August 1973. The lake reached spillway level in fall 1974. A significant portion of the study area is lined by sandstone bluffs which contribute little to the lake's turbidity. Much of the area, however, is lined with mud banks which, in some areas, have eroded badly and account for much of the lake's inorganic turbidity. The soils are fairly old and well leached. Most of the catchment consists of forested and other relatively undisturbed land.

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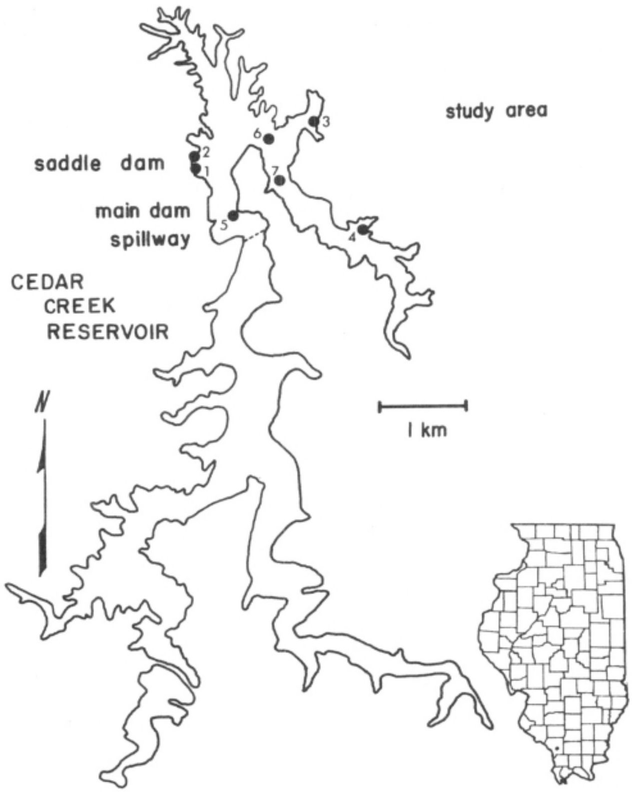

Figure 1. Cedar Creek Reservoir showing study area and sampling stations.

METHODS AND MATERIALS

Net samples, obtained using a very fine (120u) plankton net were used to augment sedimentation samples for floral identification. These samples were taken at irregular intervals from each of the stations shown in Figure 1. Samples were examined while fresh and again after preservation with Lugol's solution (1:100 dilution). For critical examination of diatoms, aliquots of several samples were cleaned in 25% aq H_2SO_4 for three hours at 90 C. A few crystals of $KMnO_4$ were added near the end of the digestion to oxidize any remaining organic material. References used for identification of the phytoplankton are listed in the appended bibliography.

Quantitative samples were taken monthly from March 1974 to March 1975 at each station in a 1 nota 1 butan 1 polyethylene bottle. These samples were taken at a depth of 25 cm and preserved with Lugol's solution shortly after collection. The samples were then concentrated to a volume of

10 ml using a sedimentation-decantation regime. Quantitative data were obtained by Lackey's micro transect method (Edmondson, 1969), and were expressed as cells per liter or in the case of species density, species per 5 transects which is equivalent to 0.39 ml of lake water. Palmer's generic index of organic pollution (Palmer, 1969) was used to determine water quality at station 6 and near shore stations. Nygaard's quotients (Nygaard, 1949) were used to determine the lake's tropic level.

Water temperatures were taken with a standard laboratory thermometer (at the collection depth). Hydrogen ion activities were determined with a PORTO-matic pH meter (IL model #175) and narrow range pH paper. Calcium, total hardness, nitrate, tannins and lignins, silica, sulphate, and ammonia analyses were performed using standard photometric techniques with a Hach DR/2 portable spectrophotometer. Chemical tests were run in duplicate on 3-16-74, 9-22-74 and 3-22-75.

Precipitation and other meteorological data were obtained from the University of Illinois, Southern Illinois University co-operative small fruits experiment station located 2 miles north of the research area.

RESULTS

A total of 94 species representing 6 divisions were identified. These are listed in Table 1 following, in general, the classification of Prescott (1962). Although most are euplanktonic forms, some tychoplankters from near shore stations have been included. Palmer's index ratings are shown in Table 2. Nygaard's myxophycean, chlorophycean, diatom, euglenine and compound quotients near the end of the study, were 9/10, 24/10, 11/14, 4/33 and 48/10 respectively. Total cell densities calculated for station 6 collections are shown in Figure 2. Figure 3 shows cell densities by division. Counts made from several station 7 collections, as a check on station 6 results, were similar in all cases. Near shore stations, however, were quite variable due to local factors and for this reason quantitative data for these sites are not presented. The number of species encountered in five transects, equivalent to 0.39 ml of lake water, was calculated for station 6 collections and these values are shown in Figure 4 and Table 3.

No significant differences were found among chemical data obtained from near shore and mid-lake samples except that pH values were slightly higher at the former. All pH values were between 7.3 to 7.8. Representative chemical data are shown in Table 4. Variation from the values given was less than 10% for all sites and sampling times. A water temperature vs. time plot obtained from station 6 data is shown in Figure 5.

Table 1. Algal taxa found in Cedar Creek Reservoir from March 16, 1974 to March 22, 1975

CYANOPHYTA
MYXOPHYCEAE
CHROOCOCCALES

Coelosphaerium sp.
Dactylococcopsis sp.
Gloeocapsa punctata Nägeli
Merismopedia tenuissima Lemmermann
Microcystis aeruginosa Kützing

HORMOGONALES

Anabaena oscillarioides Bory
Anabaena spp. (2)
Oscillatoria sp.

CHLOROPHYTA
CHLOROPHYCEAE
VOLVOCALES

Carteria cordiformis (Carter) Dill.
Chlamydomonas sp.
Pandorina morum (Müller) Bory

TETRASPORALES

Elakatothrix viridus (Snow) Printz.
Sphaerocystis schroeteri Chodat
Tetraspora sp.

ULOTRICHALES

Stigeoclonium tenue (Agardh)

Kützing
Ulothrix sp.

OEDOGONIALES

Oedogonium sp.

CHLOROCCALES

Ankistrodesmus falcatus (Corda) Ralfs
Ankistrodesmus falcatus (Corda) Ralfs var. *mirabilis* (W. & G.S. West) G.S. West
Botryococcus braunii Kützing
Coelastrum microporum Nägeli
Crucigenia rectangularis (Nägeli) Gay
Crucigenia tetrapedia (Kirchner) W. & G.S. West
Dictyosphaerium pulchellum Wood
Franceia droescheri (Lemmermann) G.M. Smith
Kirchneriella obesa (W. West) Schmidle
Lagerheimia subsalas Lemmermann
Micractinium pusillum Fresnius
Micractinium quadrisetum (Lemmermann) G.M. Smith
Oocystis borgei Snow
Pediastrum duplex Meyen
Scenedesmus arcuatus Lemmermann
Scenedesmus bicaudatus (Hansgirg) Chodat
Schroederia ancora G.M. Smith
Schroederia setigera (Schröder) Lemmermann
Selenastrum minutum Nägeli
Tetraedron constrictum G.M. Smith
Tetraedron gracile (Reinsch) Hansgirg
Tetraedron minimum (A. Braun) Hansgirig
Tetraedron regulare Kützing var. *torsum* (Turner) Brunnthaler
Treubaria triappendiculata Bernard

ZYGNEMATALES

Arthrodesmus octocrone Ehrenberg
Closterium gracile Brebisson
Closterium leibleinii Kützing
Cosmarium punctulatum Brebisson
Euastrum binale Ehrenberg
Gonatozygon kinahani (Arch.) Ragenhorst
Hyalotheca mucosa (Dilw.) Ehrenberg
Mougeotia sp.
Spirogyra spp. (3)
Staurastrum gracile Ralfs
Staurastrum leptocladum var. *sinuatum* Wolle
Staurastrum margaritaceum (Ehrenberg) Meneghini
Staurastrum polymorphum Brebisson
Zygnema sp.

EUGLENOPHYTA
EUGLENOPHYCEAE
EUGLENALES

Euglena sp.
Trachelomonas sp.
Trachelomonas stokesiana Palmer
Trachelomonas volvocina Ehrenberg

CHRYSOPHYTA
XANTHOPHYCEAE
HETEROCOCCALES

Ophiocytium sp.

CHRYSOPHYCEAE
CHRYSOMONADALES

Dinobryon divergens Imhof.
Mallomonas caudata Ivanhof.
Synura uvella Ehrenberg

BACILLARIOPHYCEAE
CENTRALES

Attheya zachariasi Brun.
Cyclotella bodanica Eulenstein
Cyclotella glomerata Bachmann
Cyclotella meneghiniana Kützing
Cyclotella stelligera Cl. U. Grun.
Melosira distans Ehrenberg
Melosira granulata (Ehrenberg) Ralfs
Melosira granulata (Ehrenberg) Ralfs var. *angustissima* O. Muller
Melosira varians C.A. Agardh
Rhizosolenia eriensis H.L. Smith
Rhizosolenia longiseta Zachary
Stephanodiscus subtilis Van Goor

PENNALES

Asterionella formosa Hassall
Cymbella prostrata Berkeley
Gomphonema acuminatum Ehrenberg

Gomphonema olivaceum (Lyngby) Kutzing
Gyrosigma acuminatum (Sullivant) Boyer
Hantzschia sp.
Navicula hungarica Grunow var. *capitata* (Ehrenberg) Cleve.
Navicula sp.
Pinnularia sp.
Rhopalodia gibba (Ehrenberg) O. Müller
Surirella linearis Wm. Smith
Synedra acus Kützing
Synedra acus Kützing var. *radians* (Kützing) Hustedt
Synedra ulna (Nitzsch) Ehrenberg var. *aequalis* (Kützing) Hustedt
Synedra sp.

PYRRHOPHYTA
DINOPHYCEAE
PERIDINIALES

Ceratium hirudinella (O.F. Müller) DuJardin
Ceratium hirudinella (O.F. Müller) DuJardin var. *furcoides* (Schröder) Huber-Pestalozzi
Peridinium pusillum (Penard) Lemmermann

CRYPTOPHYTA
CRYPTOPHYCEAE
CRYPTOMONADALES

Chroomonas nordstedtii Hansgirg
Cryptomonas ovata Hansgirg

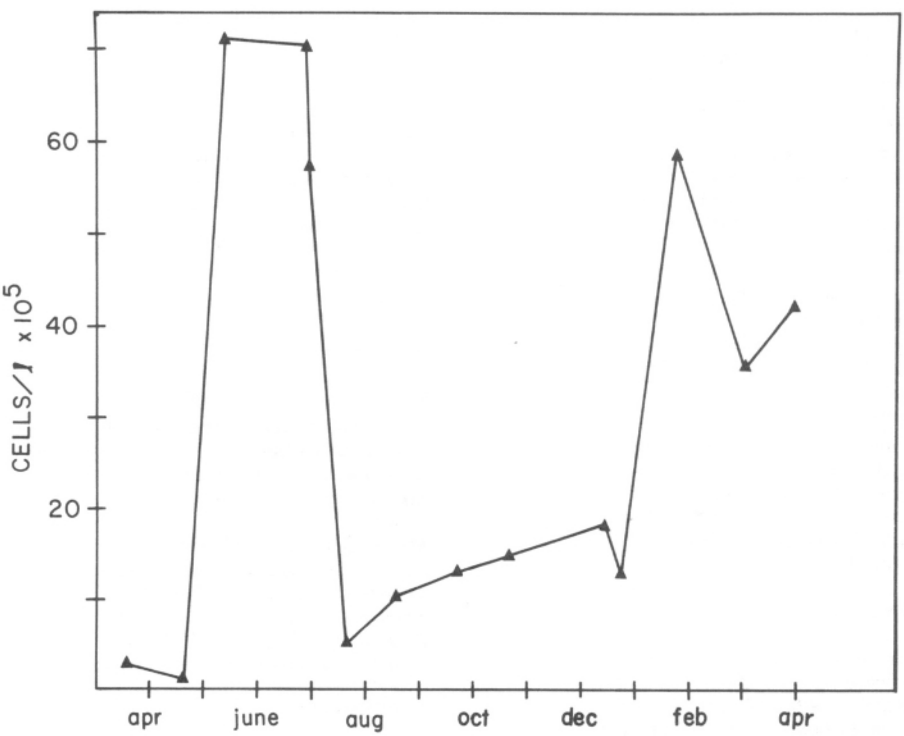

Figure 2. Total cell density observed at station 6 from March 16, 1974 to March 22, 1975

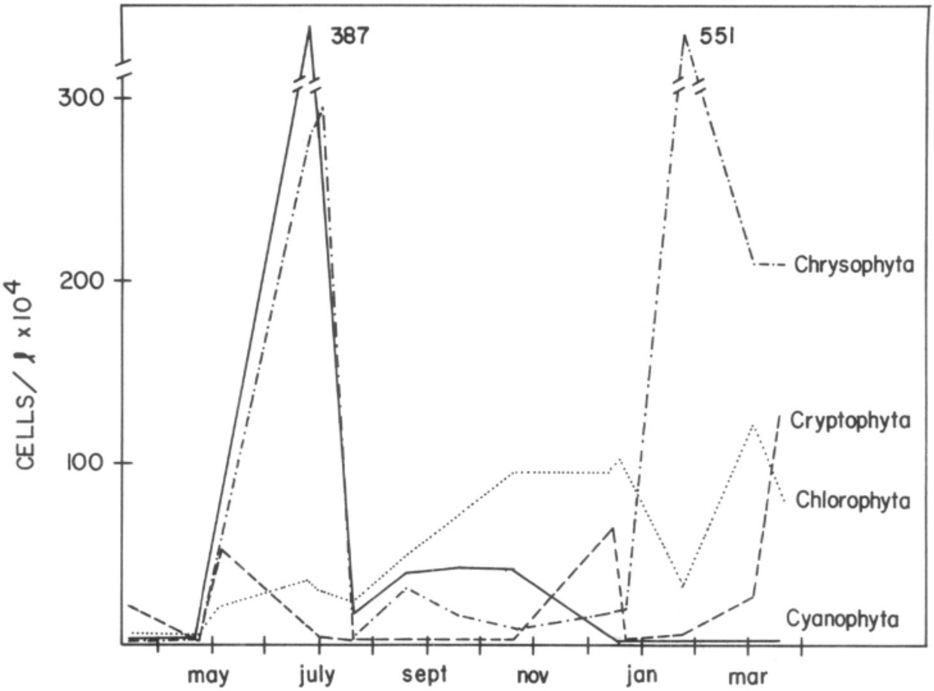

Figure 3. Cell densities by division observed at station 6 from March 16, 1974 to March 22, 1975

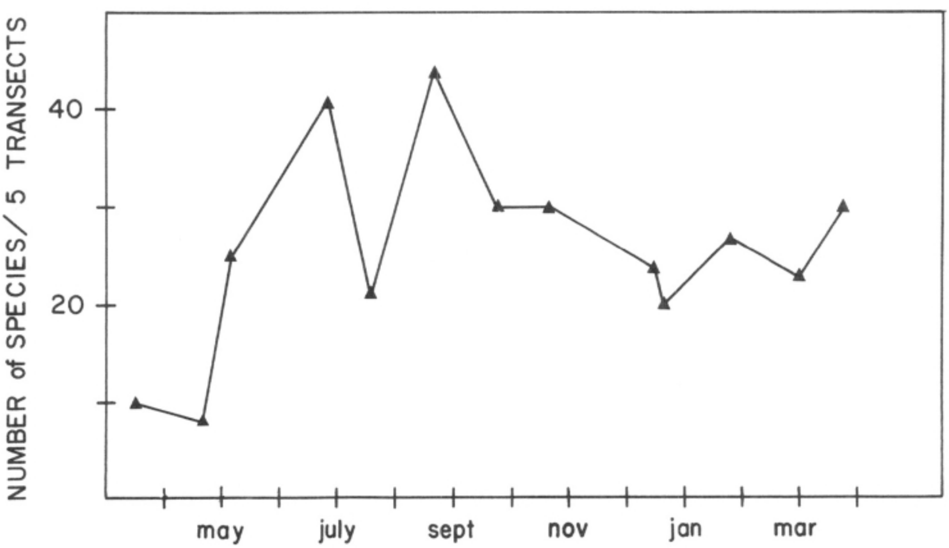

Figure 4. Total species density for station 6 from March 16, 1974 to March 22, 1975

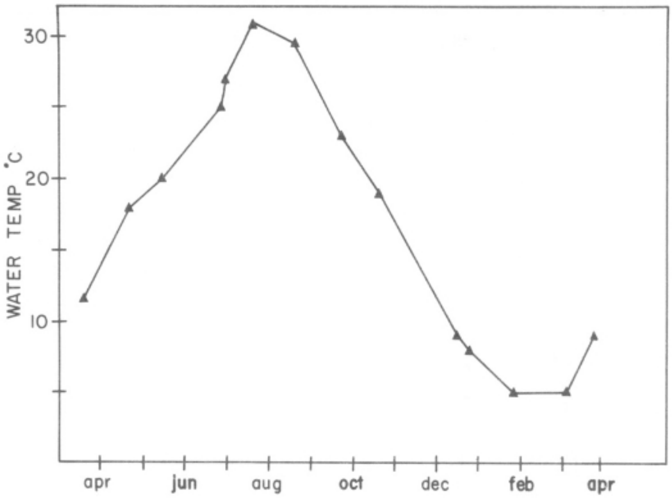

Figure 5. Water temperature, at sampling depth (25 cm), at station 6 from March 16, 1974 to March 22, 1975

Table 2. Palmer's pollution index values for station 6 collections from March 16, 1974 to March 22, 1975. (Values for March 16, 1974, sites 1, 3, and 5, are included for comparison with site 6.)

site	date	index
1	3-16-74	2
3	3-16-74	14
5	3-16-74	9
6	3-16-74	6
6	4-20-74	3
6	5-12-74	11
6	6-26-74	19
6	6-29-74	13
6	7-18-74	11
6	8-20-74	23
6	9-22-74	6
6	10-20-74	11
6	12-15-74	17
6	12-21-74	9
6	1-25-75	14
6	3-02-75	12
6	3-22-75	13

Table 3. Species density (number of species encountered in 5 transects) by division for station 6 from March 16, 1974 to March 22, 1975

Collection Date	Division					
	Pyrrophyta	Cryptophyta	Chlorophyta	Euglenophyta	Chrysophyta	Cyanophyta
3-16-74	0	2	4	1	3	1
4-20-74	0	2	5	1	3	1
5-12-74	0	2	9	2	10	2
6-26-74	0	2	15	2	17	3
6-29-74	1	0	10	1	17	3
7-18-74	1	2	9	1	6	3
8-20-74	0	1	21	3	14	3
9-22-74	0	1	13	1	10	1
10-20-74	0	1	14	2	7	4
12-15-74	0	2	11	2	7	1
12-21-74	0	1	9	1	8	1
1-25-75	1	2	11	1	11	1
3-02-75	0	2	11	1	9	0
3-22-75	0	2	15	1	11	0

Table 4. Representative concentration of select chemical entities in Cedar Creek Reservoir (site 6, March 16, 1974)

Chemical entity	Concentration (ppm)
Total hardness	50.0
Calcium hardness	35.0
Nitrate	0.8
Ammonia	0.3
Silica	2.8
Sulphate	13.0
Tannins and Lignins	0.4

DISCUSSION

A phytoplankton complement of 94 species is somewhat lower than those reported for many oligotrophic lakes. It compares favorably, in number, however, with the 79 species reported for Lake Mead by Staker, et al. (1974) who attribute their low value to eutrophic conditions.

The trend toward higher species density values with age has been observed in other newly formed bodies of water (Hodgkiss, 1974). Minckley and Tindall (1965) reported a "sparse" flora and fauna in Doe Valley Lake during impoundment. Both dilution effects and introduction of species are probably involved in the initial, low species densities and subsequent rise observed in Cedar Creek Reservoir (Fig. 4.). It is likely that certain organisms in the original stream population are suited for growth in a lacustrine environment, but not under environmental conditions that occurred between September, 1973 and February, 1974. These organisms would be diluted by an enormous factor as the pool level rose. It is also likely that species not found in the original stream population have been introduced to the new environment, by birds and other vectors, from similar habitats (Smith, 1924). Both the original and introduced populations would not be detected until environmental conditions favored their rapid reproduction.

The general increase in the total number of species with reservoir age is primarily the result of increases observed in the Chlorophyta and Chrysophyta (Table 3). The increase observed in the Chlorophyta was slightly greater than that observed in the Chrysophyta. The Pyrrophyta, Cryptophyta and Euglenophyta exhibited no overall increase in number of species. These unicellular motile algae are reported to be early successional forms (Eddy, 1925) and would most likely be adapted for early growth in newly formed lakes and ponds. Thus they would reach detectable levels before those organisms which thrive only in mature bodies of water. Cryptomonads were dominant in early samples from all seven stations. The Cyanophyta showed no general increase but this is probably related to the rather strict seasonality of this group (Smith, 1950). An increase in species density was observed until water temperatures cooled at which time the density values fell back to their spring level.

The number of species detected per division varied seasonally in the Cyanophyta, Chlorophyta, Euglenophyta, and Chrysophyta (Table 3). The number of species of cyanophytes increased during the summer and fall when water temperatures were above 18 C. Optimum growth of these organisms has been observed at these temperatures in other temperate lakes (Fogg, 1965). The number of species of Chlorophyta increased during the summer with a maximum immediately following the highest water temperature. The chrysophytes also exhibited a summer peak but it was skewed toward the spring and lower in amplitude. The Euglenophyta showed higher values at warmer temperatures and the Cryptophyta had larger values during the spring. The highest total species density closely followed the temperature maximum. Meyer and McCormick (1971) also encountered greater numbers of species during the spring and summer in an eight acre lake. Kofoid (1908) had previously observed this type of summer increase in the algae of the Illinois River.

The overall rise in total cell densities during the filling period (Fig. 2) may be characteristic of new reservoirs. Funk and Gaufin (1971) encountered no high densities for an entire year following the impoundment of a 465 ha Wyoming lake. Even the early peaks, recorded during the second summer after impoundment, exhibited relatively low densities (1×10^6 cells/l). Larger densities were encountered (upon filling) during the third summer. Hammer and Hergenrader (1971) observed similar results in Branched Oak Reservoir. In a study of Evergreen lake (near Bloomington, Illinois) Sievert et al. (1975) concluded that normal populations were established soon after filling.

Spring algal blooms are common features of temperate lakes. Such an increase was observed in Cedar Creek Reservoir, but, it occurred somewhat later than might be expected (Fig. 2). The first peak in cell density, occurred from May through June 1974, and was due to large populations of *Merismopedia tenuissima, Melosira distans* and one species of *Anabaena* (Fig. 3). The *Anabaena* species was dominant early in the peak with smaller numbers of *Chroomonas nordstedtii* and *Melosira distans. Merismopedia tenuissima* then became the most abundant form, with *Melosira distans* in only slightly lower densities, and significant densities of the *Anabaena* species and *Microcystis aeruginosa.* Near the end of the peak, *Melosira distans* was dominant with the *Anabaena* species close behind and a small amount of *Asterionella formosa.* This peak is unusual in that the blue-greens usually peak after other organisms such as diatoms or greens. This may be a result of higher water temperatures associated with the delayed nature of this "bloom". Hammar and Hergenrader (1971) noted a similar blue-green "bloom" in Branched Oak Reservoir during June of the second year after impoundment. Funk and Gaufin (1971) noted an early summer peak, with *Pandorina morum* and *Aphanizomenon flos-aquae* as co-dominants, soon after the impoundment of Lake Viva Naughton.

The second peak (Fig. 2) was unusual in that it occurred when the water temperature was at its minimum, about 5 C. A fall peak is a common feature of temperate lakes but winter peaks are rare. This peak, due to *Stephanodiscus subtilis* and *Melosira distans* in a ratio of approximately 3:1 (Fig. 3), could be a result of mixing. However, since ice formed only at the lake edges and the water temperature remained relatively high, conditions were suitable for a rapid increase in cell density of the chrysophytes which are known to prefer cool temperatures (Smith, 1950). Diatoms have even been detected in high concentrations under ice (Funk and Gaufin, 1971: Fogg, 1965).

The sharp drop in cell densities which terminated each peak does not appear to be related to precipitation or other meteorological factors. The rapid drop in chrysophyte populations may have resulted from depletion of dissolved silica since this component was present in low concentrations in all samples tested (Table 4).

Diatoms, except during "blooms", constituted less than 30% of the total cell density. Damann (1945) stated that the phytoplankton of streams and small rivers is composed of at least 90% diatoms. If this was the case with Cedar Creek, impoundment has caused a marked decrease in their relative abundance. Settling is probably a key factor responsible for this difference.

The cell density of chlorophytes increased in general throughout the study (Fig. 3). The chlorophytes were dominant between the two total cell density peaks. Chlorophytes have commonly been observed as dominants after the spring peak in temperate lakes and ponds (Taylor, 1972: Moss, 1972). *Ankistrodesmus falcatus* var. *mirabilis* was the most abundant green alga with cell densities near 5×10^5 cells/l. The warm water increase observed in blue-green cell densities is also typical.

Palmer's index values indicated that nearly all samples were free from high organic pollution (Table 2). The August 1974 sample, immediately following the first "bloom" at station 6, was the only sample that positively indicated high organic pollution. Two other samples showed probable signs of high organic pollution. The lake was certainly oligotrophic before the first "bloom" occurred, yet, Nygaard's indices indicated that by March 1975 Cedar Creek Reservoir was moderately eutrophic. These results must be accepted cautiously, however, since Brook (1965) has shown that Nygaard's indices are not always valid indicators of the trophic level of a lake. The relative abundances of chlorophytes ($\approx$ 50%) and specifically desmids ($\approx$ 10%) do not indicate eutrophic conditions (Staker et al., 1974). These vlaues may be a reflection of relatively low calcium concentrations (Table 4) (Fogg, 1965). There does, however, seem to be a trend toward eutrophic conditions when early and late samples are compared. Hammar and Hergenrader (1971) noted that heavy eutrophication occurred in several small reservoirs only a few years after impoundment. In Cedar Creek Reservoir, however, the nutrient levels are lower and water residence times are shorter. It seems logical to conclude then from our observations and comparisons with similar studies, that Cedar Creek Reservoir will be moderately eutrophic when mature.

In summary, this study has resulted in a fairly complete floral listing of those organisms appearing in the phytoplankton over one complete seasonal cycle. Comparison with similar listings obtained in later years should reveal valuable information about long range trends in phytoplankton composition as a function of reservoir maturity. The interpretation of variations in phytoplankton composition observed during and shortly after filling must remain tentative because of the paucity of work on newly formed reservoirs with which to compare our observations, and the wide latitude of yearly variations observed in established bodies of water. Additional studies on the phytoplankton of forming and newly formed reservoirs similar to Cedar Creek Reservoir should allow workers in this area to distinguish between those trends which can be attributed to the development of the flora and those which can be attributed to normal variations observed in established lakes.

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LITERATURE CITED

BROOK, A.J. 1965. Planktonic algae as indicators of lake types, with special reference to the Desmidiaceae. Limnol. & Oceon. 10(3):403-411.

DAMANN, K.E. 1945. Plankton studies of Lake Michigan. I. Seventeen years of plankton data collected at Chicago, Illinois. Am. Midl. Nat. 34:769-796.

EDDY, D. 1925. Freshwater algal succession. Trans. Am. Microsc. Soc. 44:138-147.

EDMONDSON, W.T. 1969. A simplified method for counting phytoplankton. Pp. 14-15. *In* R.A. Vollenweider, ed. A manual on methods for measuring primary production in aquatic environments. IBP Handbook no. 12. Blackwell Sci. Publ., Oxford.

FOGG, G.E. 1965. Algal cultures and phytoplankton ecology. Univ. Wisconsin Press, Madison, Wisconsin.

FUNK, W.H. and A.R. Gaufin. 1971. Phytoplankton productivity in a Wyoming cooling water reser voir. Pp. 167-178. *In* G.E. Hall, ed. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8.

HAMMAR, M.J. and G.L. Hergenrader. 1971. Eutrophication of small reservoirs in the great plains. Nebr. Engineer, June (1971):1-5.

HODGKISS, I.J. 1974. Studies on Plover Cove Reservoir, Hong Kong: Composition and distribution of phytoplankton and its relationship to environmental factors. Freshwater Biol. 4:111-126.

KOFOID, C.A. 1908. Plankton Studies. V. The plankton of the Illinois River, 1894-1899. II. Constituent organisms and their seasonal distribution. Ill. Lab. Nat. Hist. Bull. 8 (1):2-361.

MEYER, K.A. and J.F. McCormick. 1971. Seasonal fluctuation of phytoplankton composition, diversity and production in a freshwater lake. J. Elisha Mitchell Sci. Soc. 87:128-135.

MINCKLEY, W.L. and D.R. Tindall. 1965. Limnological observation of Doe Valley Lake, Meade County, Kentucky during impoundment. Am. Midl. Nat. 73:248-250.

MOSS, B. 1972. Studies on Gull Lake, Michigan: I. Seasonal and depth distribution of phytoplankton. Freshwater Biol. 2:289-307.

NYGAARD, G. 1949. Hydrobiological studies on some Danish ponds and lakes. D. Kgl. Danske Vidensk. Selskab., Biol. Skrifter 7:1-18.

PALMER, C.M. 1969. A composite rating of algae tolerating organic pollution. J. Phycol. 5:78-82.

PRESCOTT, G.S. 1962. Algae of the western Great Lakes area. Wm. C. Brown Co. Dubuque, Iowa.

SIEVERT, A.C., T.A. Nelson, J.M. Fioramonti, D.J. Gillard, G.L. Hortin, L.S. Johnston, S.W. O'Neal, S.J. Rakow, J.M. Simkins, D. Birkenholz and M.E. Kurz. 1975. The effects of agricultural run-off and siltation on a new recreational lake. Trans. Ill. State Acad. Sci. 63:369-379.

SMITH, G.M. 1924. Ecology of the plankton algae in the Palisades Interstate Park, including the relation of control methods to fish culture. Roosevelt Wildl. Bull. 2:95-121.

SMITH, G.M. 1950. The fresh-water algae of the United States. 2nd edition. McGraw-Hill Book Co., New York.

STAKER, R.D., R.W. Hoshaw, and L.G. Everett. 1974. Phytoplankton distribution and water quality indices for Lake Mead (Colorado River). J. Phycol. 10:323-331.

TAYLOR, M.P. 1972. Seasonal plankton changes in primary productivity in Beech Reservoir. J. Tenn. Acad. Sci. 47:103-111.

WHITFORD, L.A. and G.J. Schumacher. 1973. A manual of fresh-water algae. Sparks Press, Raleight, N.C.

BIBLIOGRAPHY

BOURRELLY, P. 1966. Les algues d'eau douce. Tome I: Les algues vertes. Editions N. Boubee' and Cie, Paris.

BOURRELLY, P. 1968. Les algues d'eau douce. Tome II: Les algues jaunes et brunes. Editions N. Boubee' and Cie., Paris.

BOURRELLY, P. 1970. Les algues d'eau douce. Tome III: Les algues deues et rouges, les Eugleniens, Peridiniens et Cryptomonadines. Editions N. Boubee' and Cie., Paris.
HUBER-PESTALOZZI, G. 1938. Das Phytoplankton des Süsswassers. Teil 1: Blaualgen, Bakterien, Pilze. *In* Die Binnengewasser, ed. by A. Thienemann, Bd. XVI. E. Schweizbart'sche Verlagsbuchhandlung, Stuttgart.
HUBER–PESTALOZZI, G. 1941. Das Phytoplankton des Süsswassers. Teil 2: 1-Hälfte: Chrysophyceae, Farblose Flagellaten, Heterokonten. *In* Die Binnengewässer, ed. by A. Thienemann, Band XVI. E. Schweizbart'sche. Verlagsbuchhandlung, Stuttgart.
HUBER-PESTALOZZI, G. 1950, Das Phytoplankton des Süsswassers. Teil 3: Crypotophyceen, Chloromonadinen, Peridinee. *In* Die Binnengewässer, ed. by A. Thienemann, Bd. XVI. E. Schweizbart'sche Verlagsbuchhandlung, Stuttgart.
HUBER-PESTALOZZI, G. 1955. Das Phytoplankton des Süsswassers. Teil 4: Euglenophyceen. *In* Die Binnengewässer, ed. by A. Thienemann, Bd. XVI. E. Schweizbart'sche Verlagsbuchhandlung, Stuttgart.
PASCHER, A., ed. 1927. Die Süsswasser-Flora Deutschlands, Österreichs und der Schweiz. Heft 4. Volvocales. Gustav Fischer, Jena.
PASCHER, A., ed. 1930. Die Süsswasser-Flora Mitteleuropas. Heft 10. Bacillariophyta. Gustav Fuscher, Jena.
PATRICK, R. and C.W. Reimer. 1966. The diatoms of the United States. Vol. 1. Philadelphia Acad. Nat. Sci., Philadelphia.
PRESCOTT, G.A. 1962. Algae of the western Great Lakes area. Wm. C. Brown Co. Dubuque, Iowa.
PRESCOTT, G.A. 1970. How to know the freshwater algae. Wm. C. Brown Co. Dubuque, Iowa.
SMITH, G.M. 1920. Phytoplankton of the inland lakes of Wisconsin. Pt. I. Wis. Geol. and Nat. Hist. Survey, Sci. Serv. 12, Bulletin 57(1):1-243.
SMITH, G.M. 1924. Phytoplankton of the inland lakes of Wisconsin. Pt. II. Wis. Geol. and Nat. Hist. Survey, Sci. Ser. 12, Bulletin 57(2)1:227.
TIFFANY, L.H. and M.E. Britton. 1971. The algae of Illinois. Hafner Publ. Co. New York.
UHERKOVICH, G. 1966. Die *Scenedesmus*—arten Ungarns. Ungaischen Akademie der Wissenschaften, Budapest.
WEBER, C.I. 1971 (1966). A guide to the common diatoms at Water Pollution Surveillance System Stations. U.S.E.P.A. Natl. Environ. Res. Center. Cincinnati, Ohio.
WEIK, K.L. and R.H. Mohlenbrock. 1963. Notes on the algal flora of Illinois. II. The genus *Trachelomonas* Ehrenberg of the Pine Hills, Union County, Illinois. Trans. Am. Microsc. Soc. 82(4):381-390.
WEST, W. and G.S. West. 1904-1912. A monograph of the British Desmidiaceae. Vols. I-IV. The Ray Society, London.
WEST, G.S. and N. Carter. 1923. A monograph of the British Desmidiaceae. Vol. V. The Ray Society, London.