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PHYTOPLANKTON FLUCTUATIONS IN THE DES MOINES RIVER, IOWA

by

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A Dissertation Submitted to the
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I. INTRODUCTION

This dissertation is concerned with weekly variation in kinds and numbers of algal plankters occurring in an 80-km section (Figures 1, 2, and 3) of the Des Moines River during 1968. Quantitative and qualitative determinations were made of samples collected weekly at one station and biweekly at four others. The availability of data on physical and chemical analyses of duplicate samples (determined by personnel of Engineering Research Institute's analytical laboratory) make it the most intensive study on a single reach of this river to date. Starrett and Patrick (1952) studied the net plankton and bottom microflora in 1946 and 1947 in a shorter but similar reach upstream to the area of the present study and partly overlapping it. Drum (1964) made an extensive survey of the diatoms of the entire Des Moines River, with 14 different physical and chemical determinations. His major sampling station was the same as Starrett and Patrick's upstream one (Figure 3).

The Des Moines River originates in southern Minnesota as two separate forks which enter Iowa in Emmet County and join to form the main stem in Humboldt County, Iowa (Figure 2). The West Fork's source is Lake Yankton (Williams, R. personal communication, see Appendix), close to Balaton in Lyon County, at 44° 15'N and 95° 52'W, at a mean elevation of 1530 feet above sea level. It is on a high plateau called

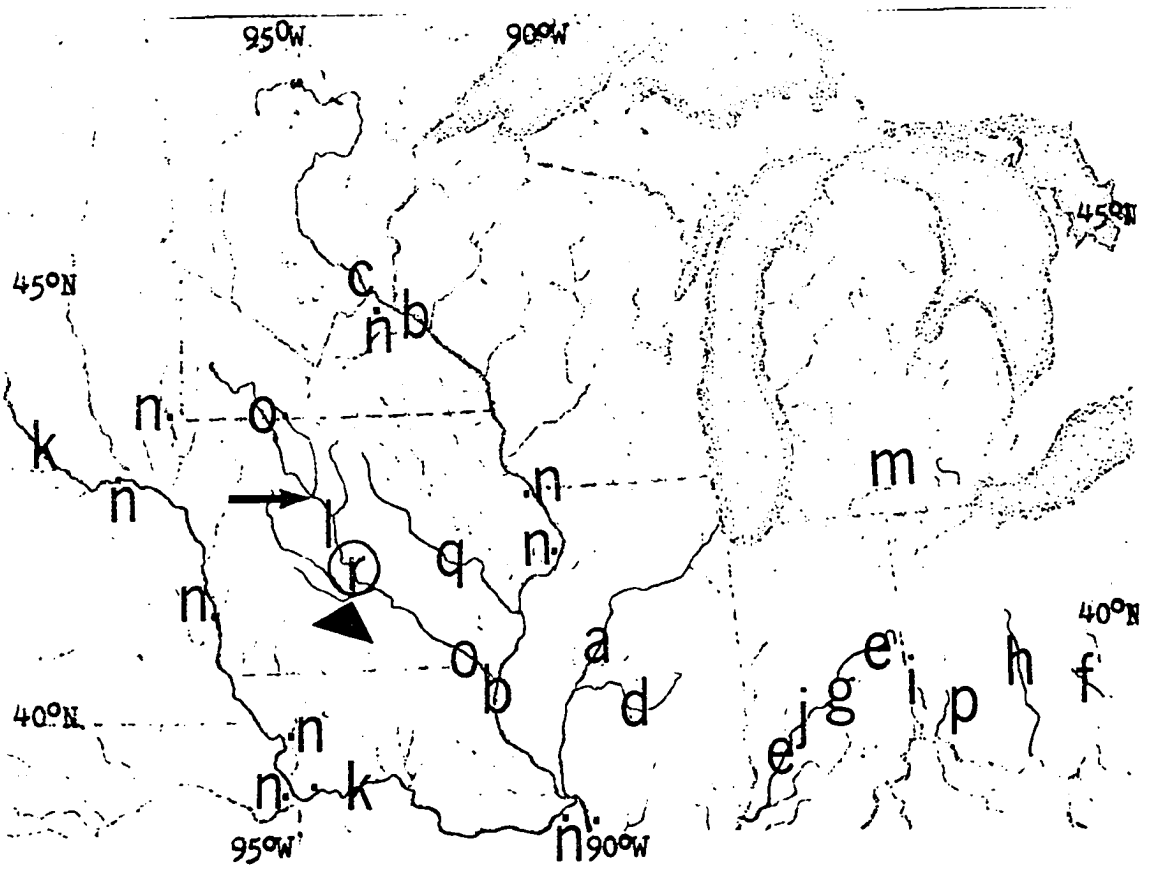

Figure 1. Midwestern United States showing location of present study and phytoplankton studies cited in the literature review

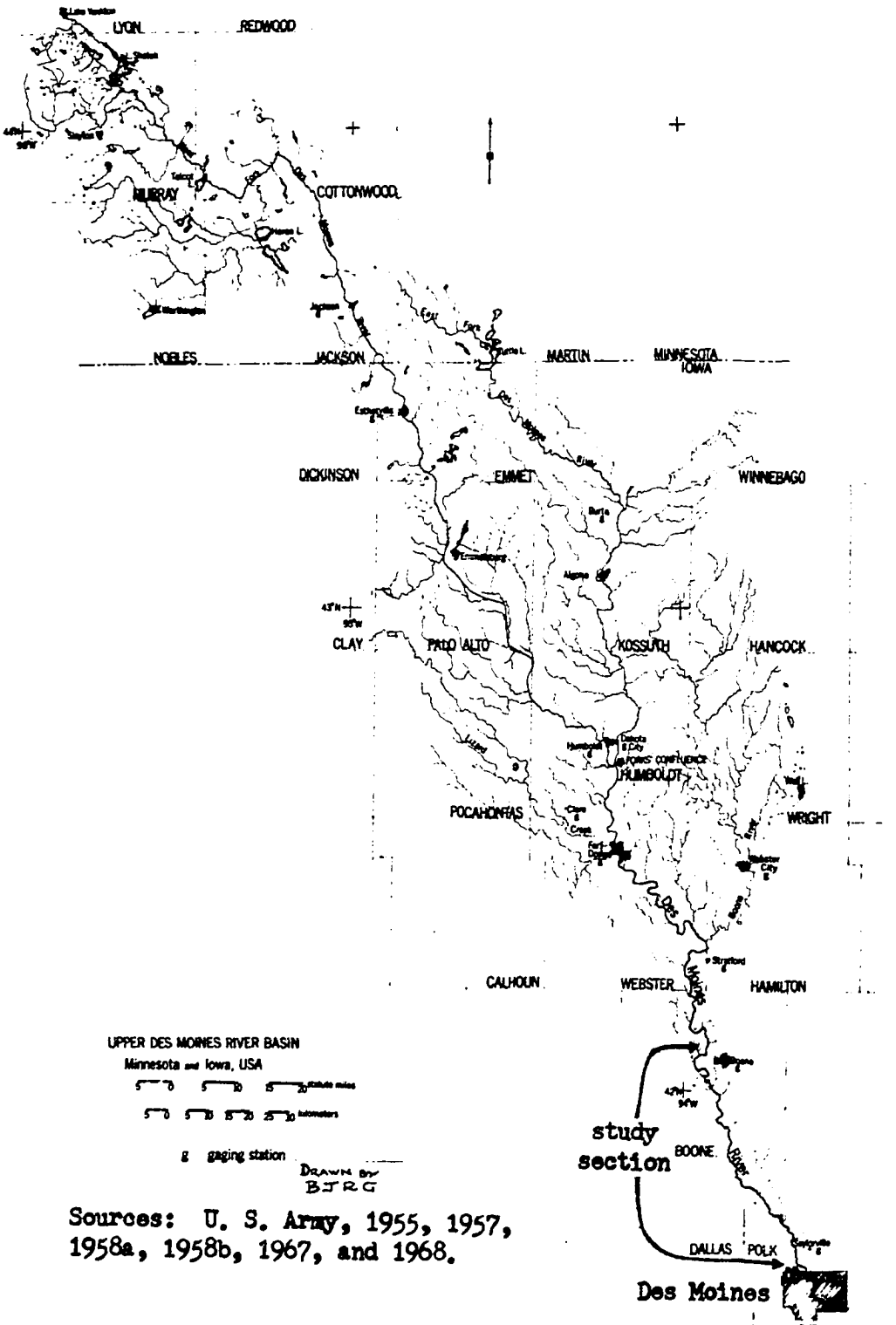

Figure 2. Upper Des Moines River basin showing study section

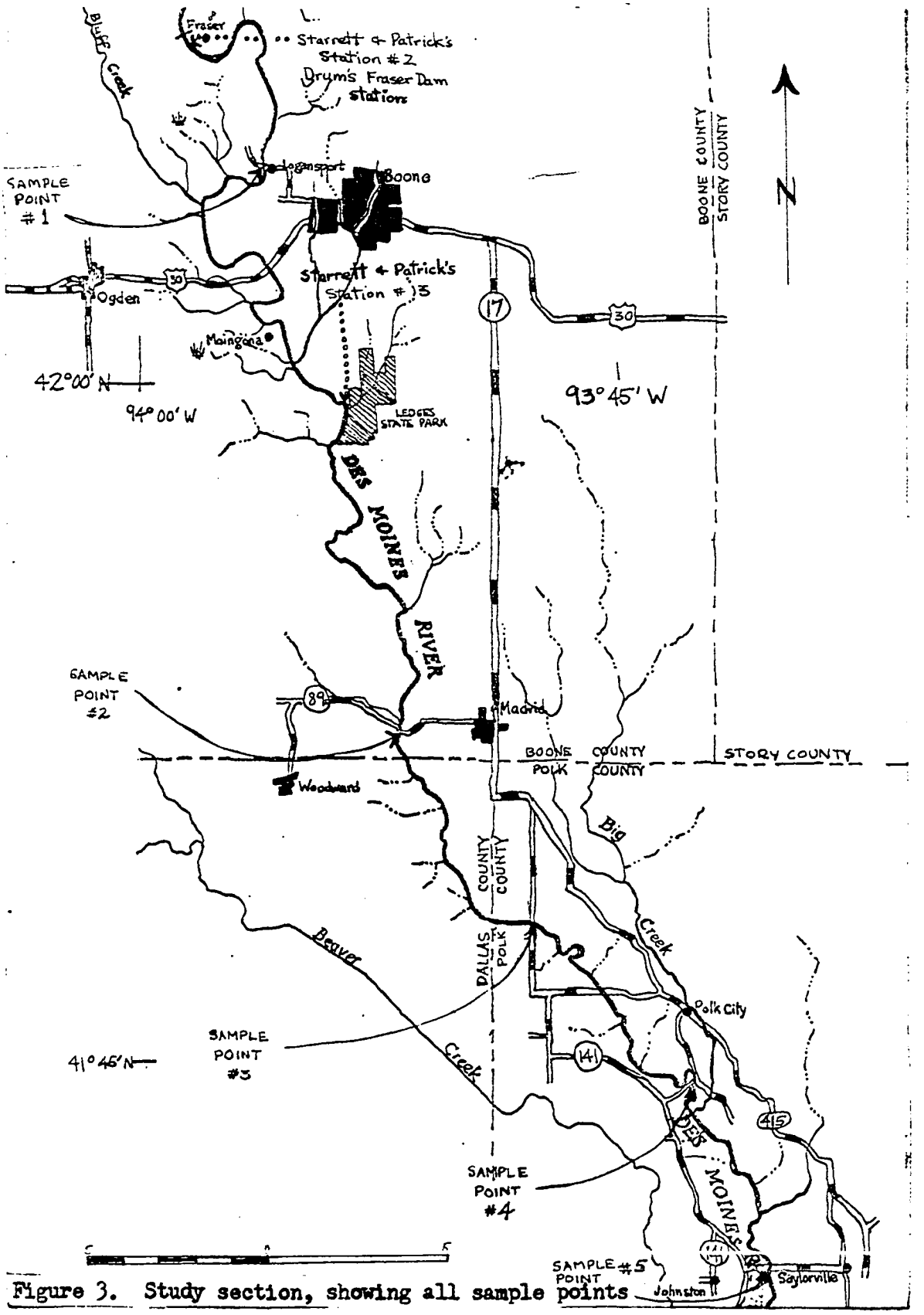

Figure 3. Study section, showing all sample points

the Coteau des Prairies which is dotted with many lakes some of which drain into the Des Moines. The West Fork flows 330 km in a generally southeast direction across glacial till of the Des Moines Lobe of the Mankato subage, Wisconsin glaciation (Schwartz and Thiel, 1963) before it is joined by the East Fork. The East Fork arises on the Coteau also, in relatively flat land on the eastern edge of Jackson County, Minnesota at an elevation of 1350 feet, half a degree south and almost a full degree east of the West Fork's source (U.S. Army, 1967, 1968). Tuttle Lake on the Iowa-Minnesota border is a part of this fork and exerts a major influence on its character. This fork flows southeast and south 177 km over the Des Moines Lobe to its confluence with the West Fork (Figure 1).

The confluence of the two to form the main stem of the Des Moines River is 2.5 km south of Humboldt and Dakota City, Iowa. The average streamflow (discharge) at this point is about 22 m^3/sec (774 cfs). Two fairly large tributaries, Lizard Creek and the Boone River, join the Des Moines between the forks' confluence and the upstream end of my study area. At Station 1 the mean streamflow is 46 cms (1621 cfs), while at the downstream end, it is 62 cms (2173 cfs) (U.S. Department of the Interior, 1969).

The importance of this study is accentuated by the approaching impoundment of Saylorville Reservoir on the river

eight kilometers upstream from the present northern city limits of Des Moines. Effects on algal growth of existing levels of nutrient enrichment are not a matter of public concern at the present time, but water quality problems of various kinds are anticipated following impoundment of water in the new reservoir (Baumann and Dougal, 1968).

II. LITERATURE REVIEW

A few studies of the phytoplankton of Iowa rivers have been made, several rivers of other Midwestern states have been studied, and a considerable body of knowledge has been amassed on the phytoplankton of rivers in the United States and Europe. According to Blum (1956, p. 36):

> Throughout the period of greatest activity of European workers on stream self-purification and indicator organisms (1900-1910), and the period of special interest in the benthic vegetation of streams (1920-), the algal vegetation of American streams has remained relatively unexplored. Following the classical work of Kofoid (1903, 1908) no work even approximately comparable was undertaken on other rivers for many years. Reports on the phytoplankton of several American rivers have since appeared; ... In general, knowledge of our stream algae lags well behind the relatively precise and abundant information which is at hand for European streams, particularly those of Germany and Great Britain. Even in Europe, however, a general overall picture of seasonal changes and geographic changes in plankton and benthos has to date been wanting, due partly to the absence of sufficient observations as well as to the need for synthesis of those observations which have been published. While this is true even for unpolluted streams, it is doubly so for the very heterogeneous polluted ones.

A few African rivers have also been studied. The major purpose of this section is to review certain of the European and U.S. studies, and particularly those dealing with Iowa rivers. The European rivers were chosen because their basins are located in climatic areas similar to that of the Des Moines basin (Trewartha, 1957). U.S. studies include those of a few Midwest rivers plus a classic and a modern one from California. Table 1 shows chronological relationships among

Table 1. River phytoplankton studies cited in literature review

Author	Sample year	River and location
Kofoid	1894-9	Illinois (Ill.)
Lemmerman	1904-5	Weser (Germany)
Allen	1913	San Joaquin (Cal.)
Galtsoff	1921	Mississippi (Minn., Wis., Iowa, Ill., Mo.)
Reinhard	1928	Mississippi (Minn., Wis.)
Eddy	1929	Sangamon (Ill.)
Palmer	1930-1	White (Ind.)
Roach	1930-1	Hocking (Ohio)
Coffing	1933-5	White River Canal (Ind.)
Kehr, et al.	1937-9	Scioto (Ohio)
Lackey, et al.	1939-41	Four Mile Creek (Ohio)
Lackey & H	1940	White (Ind.)
Berner	1945	Lower Missouri (Nebr., S.D., Iowa, Mo.)
Fjerdingstad	1946-7	Mølleaa (Denmark)
Starrett & P	1946-7	Des Moines (Iowa)
Blum	1952-3	Saline (Mich.)
Claus & R	1957-8	Danube (Austria)
Swale	1957-9	Lee (England)
Nat WQ Net	1957-62	Numerous U.S. rivers including Iowa and Minn.
Greenberg	1960-1	Sacramento (Cal.)
Drum	1961-4	Des Moines (Minn., Iowa)
Priĭmachenko	1962-3	Upper Dnieper (Russia)
Weber & M	1964-5	Little Miami (Ohio)
McDonald	1964	Iowa (Iowa)

all these studies. Table 1a shows world water quality data.

Kofoid's classic Illinois River study (1903, 1908), which was as intensive as it was extensive, was undertaken before the routing of Chicago's sewage down that river. He sampled several different habitats weekly, making 235 collections in the vicinity of the Havana, Illinois, field station in five years. He sampled plankton from the main channel, tributaries, and backwaters.

Early in his study, he drew the plankton net (No. 20 bolting silk) through the water at a constant speed for a measured amount of time. Later, he used a plankton pump to obtain bottom-to-top vertical samples of measured volumes which were then strained through the net. He used "strong alcohol" to preserve the 1894-97 collections, and 20 percent alcohol plus 2 percent formalin thereafter. He measured plankton volume after centrifuging rather than after settling and used a Sedgewick-Rafter cell to count rediluted plankton, identifying most plankters to species.

His physical data consisted of temperature, turbidity (estimated), current velocity, and discharge. He measured total solids, fixed solids (dissolved and suspended), volatile solids (total and dissolved), chlorides, biochemical oxygen demand (which he denoted as "O_2 consumed"), ammonia nitrogen (free and albuminoid), organic nitrogen, nitrites and nitrates.

Table 1a. Comparison of water quality of the upper Des Moines River with other areas[a]

Location	All units expressed by mg/l				
	Ca	SO_4	Cl	NO_3	SiO_2
Des Moines River					
spring (Drum)	250	90	19	3.0	10
spring (Baumann)	133	nm	5.9	.27	.76
summer (Drum)	230	50	12	5.0	25
summer (Baumann)	180	nm	nm	6.99	14.4
World's average (Livingstone)	15	11.2	7.8	1	13.1
North America "	21	20	8	1	9
Europe "	31.1	24	6.9	3.7	7.5
Japan "	8.8	10.6	5.8	1.15	19.0

[a]Sources: Drum, 1964; Baumann and Dougal, 1968; Livingstone, 1963.

Kofoid noted that changes in plankton and fish populations were usually in the same direction. Some of his other conclusions were that 1) chemical changes did not correlate well with plankton changes; 2) the plankton of the river channel changes greatly, seasonally and annually; 3) hydrologic fluctuations cause great changes; and 4) temperature and light have great effects (positive) on production.

Lemmerman's plankton study of the Weser River (1907) was much smaller in scope. In the lower reaches tides affect this river and the estuary's great turbidity precluded the use of plankton tows. It was more feasible to use five liter samples poured through the net. He did not make other analyses but used data taken earlier for organic matter, calcium, magnesium, dissolved oxygen (DO), chlorine, sodium chloride, and calcium chloride.

The classic study of the San Joaquin plankton by Allen (1921) was influenced by Kofoid's work. It shows the richness of the plankton of a West Coast river and two tributary canals, one of which carries the wastes of Stockton, California to the river. His analyses of weekly net (No. 25) plankton samples included Sedgewick-Rafter counts (of 50 fields) and volumetric data. His other data were of temperature, turbidity and weather conditions.

Reinhard's (1931) less extensive study of upper Mississippi collections taken in 1928 presented a general picture of the plankton fluctuations along a 209 km stretch above and below the outfall of the Twin Cities' sewage effluent. From Minneapolis to Winona, 250 plankton samples were collected from 12 stations. Other data taken were temperature, turbidity, color, total hardness, alkalinity, pH, chlorides, DO, and BOD (biochemical oxygen demand).

The plankton surveys in Illinois, Indiana and Ohio of

the Sangamon, White, and Hocking Rivers and the White River Canal done by Eddy (1932), Palmer (1932), Roach (1932), and Coffing (1937) respectively were similar in methods used. The first three were designed to ascertain the degree of change in the stream plankton due to the influence of industrial waste water.

A very thorough investigation of the Scioto River was made by Kehr, Purdy, Lackey, Placak and Burns (1941). During a 30-month period it was sampled intensively along a 185-km stretch below Columbus, Ohio. During the period three different treatments were given that city's sewage. The weekly and occasional plankton samples totaled 250. Samples were taken in order to determine, pH, DO, BOD, ammonia nitrogen, nitrates, organic nitrogen, alkalinity, and suspended solids.

Lackey, Wattie, Kachman, and Placak (1943) used the smallest stream they could find with a year round flow to try to answer the question: What is a normal stream plankton? From four sampling stations, they made 98 collections between late fall of 1939 and October 1941.

The short and heavily polluted Mølleaa River which Fjerdingstad investigated (1950) proved to be such a degraded habitat that the plankton was almost wiped out in many places, making the use of planktonic species as indicators unsuited to his purposes. Also, the presence of large amounts of detritus in the samples made plankton counts very

difficult. His preference then shifted to the use of benthic forms as indicators.

Blum (1956), in his Saline River (Michigan) survey, also preferred counts of benthic forms. His report included data on temperature, light, turbidity, current velocity, pH, DO, bicarbonates, chlorinity, salinity, inorganic phosphates, nitrates, and chromium (in an industrial waste there).

Lackey and Hupp's plankton study of the White River in Indiana (1956) was initiated because of the river's importance as Indianapolis' water supply, and its consistently high plankton counts. Its source in agricultural lands insures a high inorganic nutrient level, and it is a fertile stream from its source on down. They had a 5-station sampling program but half the samples came from one station and sampling was done irregularly during one summer and autumn. They tried to determine which variables favored increased plankton production and which reduced it.

Claus and Reimer (1961) took monthly phytoplankton samples from the Danube at four differing stations in Vienna, some of which were downstream from Vienna's waste outfalls. They held a Zeppelin-net of No. 25 mesh in the water to obtain qualitative samples, and took two-liter samples from the depth of 3-6 m for the qualitative counts which were made in a haemacytometer.

Greenberg's sampling of the Sacramento River plankton in

California (1964) was done from April 1960 to June 1961. He did quantitative and qualitative analyses of usually monthly samples from 22 stations. Counts were done in a Sedgewick-Rafter cell, and correlations with streamflow, BOD, and temperature were made.

British workers generally ignored quantitative aspects of river phytoplankton studies until 1957 when Swale (1964) began a two-year study of the River Lee. He had six stations on an 11-km stretch and collected samples weekly in the summer and fortnightly in winter. He used a haemacytometer for counts and analyzed for DO, BOD, pH, silica, phosphate phosphorous and nitrate nitrogen. Rainfall, streamflow, and temperature records were also kept.

In Russia, the great interest in hydrobiology of rivers stemming from its well-developed drainage patterns has led to many investigations of river phytoplankton. For instance, Priĭmachenko's 1962-63 sampling on the upper Dnieper (1967) followed studies done on other parts of the river in 1931-32 and 1937. His qualitative determinations were mainly of biomass, and no chemical analyses were made.

Weber and Moore (1967) sampled the Little Miami River in Ohio weekly for a year to find out what contribution phytoplankton made to the total load of organic matter in the river and consequently as a food source for consumer organisms. Amounts of particulate organic matter and dis-

solved organic carbon were determined from simultaneous samples. Sedgewick-Rafter counts of total phytoplankton from preserved samples and proportional counts of diatom species from Hyrax slides were made in the same manner, as described herein.

The Federal Water Pollution Surveillance System, now in the Department of the Interior and once known as the National Water Quality Network, began an extensive plankton sampling program of rivers and the Great Lakes in the U.S. in 1957. By 1963, 128 sampling stations were sending monthly one-liter samples to the laboratory in Cincinnati where total counts are made in Sedgewick-Rafter cells, as well as diatom species counts from permanent slides. Chemical analyses are made at the sampling sites by local technicians. Four of these stations are located on Iowa border rivers: one on the Big Sioux, one on the Missouri, and two on the Mississippi. Data from the latter three are analyzed in "Plankton Population Dynamics" (Williams, 1963).

Galtsoff's quantitative study of the Mississippi River plankton during the summer of 1921 from Hastings, Minnesota to Alexandria, Missouri (1924) was the first such study on an Iowa river. He obtained 673 samples from 171 stations between July 10 and September 24. Fifty-liter samples were pumped into a tank, then filtered through No. 20 silk bolting cloth and preserved in 35 percent formalin. Some vertical

hauls were also made. His quantitative determinations consisted of plankton volumes obtained by hand-centrifugation of the net plankton for two minutes at 1000 rpm and were reported as cc/m^3. The numbers of Copepoda and Cladocera were counted in each sample.

His other determinations were of water temperature, current velocity and transparency. Values from other sources for some chemical constituents, stage, discharge, and sediment flow were included in this paper.

The net plankton of the very turbid lower Missouri was investigated by Berner (1951) during the spring, summer, and fall of 1945. He made 34 collections of plankton at 11 stations during seven months. Special techniques were used to separate the plankters from the large amounts of silt. The plankton was very sparse and almost totally autochthonous. Other data collected with each sample were temperature, pH, DO, total turbidity, acidity, free CO_2, carbonates, and bicarbonates.

The Coralville Reservoir Water Quality Study (McDonald, 1965-) has sampled the Iowa River weekly since October 1964 both upstream and downstream from the reservoir. A plankton centrifuge is used to concentrate the samples which are then counted in a Sedgewick-Rafter cell. Analyses of 16 chemical and physical variables and numbers of coliform bacteria are also made weekly.

The Starrett and Patrick (1952) study of Des Moines River algae samples collected in 1946-47 included semi-weekly net plankton samples from three Boone County stations for the first 6 months, and weekly samples from one of the other stations for another 8 months. The 155 plankton samples were collected by dipping 24.75 liters of surface water with a pail and pouring it through a No. 20 bolting silk plankton net. The samples were preserved immediately in 4 percent formalin. They made Sedgewick-Rafter grid counts on 71 samples but examined all for species composition. They took only temperature and Secchi disc readings at their stations. Chemical data obtained from another source at a station influenced by the large Raccoon River drainage cannot be reliably compared with the chemical conditions of the reach which they studied.

A three-year diatom study covering the entire length of this river was reported by Drum (1964). His numerous collections were used primarily to determine species composition of the diatom flora and he did not try to make counts which could be related to the numbers of other components of the biota. (As will be discussed later, there are great difficulties to be faced in such attempts.) Of 168 plankton samples, 145 were taken at points upstream from my Station 5, 13 of them were taken within my sampling reach, and the rest were taken below Station 5. He took 286 samples for chemical

analysis, making 13-15 different analyses on each. One hundred and fifty-nine samples were from two stations near the midpoint of the river (which is near my study area) at Fraser Dam. One of these was Starrett and Patrick's Station 2, the other at the Ledges State Park. (See Figure 3).

III. MATERIALS AND METHODS

A. Sampling Procedures

All plankton samples were taken from the five sampling stations on the river by the Saylorville Reservoir Preimpoundment Water Quality Study crew.[1] They were composited from midpoint and quarterpoint subsamples, dipped by buckets from depths of less than one meter. When the river was low, the crew was able to wade the river while sampling. Since each station's location was chosen near a bridge, samples taken during periods of high water were obtained by lowering a bucket on a rope. During the periods of ice cover, samples were dipped from a 21 cm hole drilled in the ice near one of the quarterpoints or composited from two or three holes if the river's width justified drilling more. One sample from Station 1 was reserved for microscopic examination of living forms, and was promptly refrigerated until the examination could be made. All others were preserved immediately in 1-liter plastic plankton sample bottles containing 36 ml of the following preservative (Weber, 1966):

1.0 g merthiolate powder (sodium ethyl-mercury thiosulfate)

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[1]Preimpoundment Water Quality Study, Saylorville Reservoir, Des Moines River, Iowa, Project 685 S. U.S. Dept. of the Army, Rock Island District, Corps of Engineers. Contract DACW 25-67-C-0064 with the Sanitary Engineering Section, Engineering Research Institute, Iowa State University.

1.0 ml Lugol's solution (6 g KI + 4 g I_2 dissolved in 100 ml distilled water

1.5 g sodium borate (Borax)

1.0 l distilled water

A schedule for phytoplankton sampling was set up as follows:

Station 1: One 1-liter preserved sample and one 0.5-liter unpreserved sample every week.

Stations 2, 3, 4, and 5: One liter preserved sample every two weeks.

This schedule, adhered to during the sampling year (15 January 1968-15 January 1969) with few exceptions, was designed as a compromise between a complete 5-station weekly sampling, which would have involved too much time, and a complete series from Station 1 only.

I mixed each sample thoroughly by inverting the bottle seven or more times before removing subsamples. One 100 ml portion of the preserved sample was centrifuged for 20 minutes at 1000 G and 30 ml of the concentrate was stored in a screwcap vial as a reserve sample. Another 100 ml sample was centrifuged in the same way and 80 ml of the supernatant fluid was decanted. I divided the remaining 20 ml equally into two 12-ml graduated centrifuge tubes, and centrifuged for an additional 10 minutes at 1000 G, then carefully siphoned off all the liquid down to the 0.25 ml mark in each tube. I carefully transferred all remaining material from one tube to the other by pipette (eyedropper).

In this manner the phytoplankton in each original 100 ml subsample was concentrated into a 0.5 ml sample.

B. Phytoplankton Analyses

1. Quantitative study of total phytoplankton

a. Microscopic examination and counting procedures

Fresh samples were stored at 5° C and examined at 430X with a Bausch and Lomb binocular microscope as soon as possible in order to become familiar with the live appearance of the species present. Counts were not made from fresh samples.

After preparing permanent slides (see 1b and 2a), I saved the remainder of the concentrated cells in a labeled shell vial. I then made a "wet mount" of each preserved sample by placing a drop of the concentrated cells on a slide and covering it with a 22 x 22 mm coverslip. I recorded each taxon recognizable at 430X in a log book as I observed it, and estimated the relative abundance of each after one traverse of the coverslip at 430X. These voluminous data are not included here because they are not needed to develop the central theme of this dissertation. However, a list of taxa encountered in wet mounts (combined with those from the Sedgewick-Rafter counts) is included in the Appendix (Table 9). Prescott (1954 and 1962) was the primary authority for identifications.

I made quantitative counts (Sedgewick-Rafter counts) of non-concentrated 1-milliliter subsamples of each 1-liter

Quantitative counts were made at a magnification of 210X using the same Sedgewick-Rafter cell for all samples. Prescott 1954 and 1962 were used to identify algae. The microscope I used for the entire series was a Spencer AO binocular microscope with sub-stage illumination and a calibrated Whipple ocular micrometer disc. The Sedgewick-Rafter factor, necessary for calculating the number of plankters per milliliter from the strip count, was determined by the method of Jackson and Williams (1962) and was 28.26 for these pieces of equipment.

My procedures for filling the cell and counting the algae by the strip count method are identical to those described by Weber (1966) who based them on a thorough statistical analysis. Thus, it is possible to compare my data with those from rivers regularly sampled by the Water Pollution Surveillance System (U.S. Department of Health, Education, and Welfare, 1963).

b. Total phytoplankton slides I made slides of the total phytoplankton population mounted in clear corn syrup (Karo, see Patrick, 1936). This was done routinely immediately after making coverslip preparations for diatom proportional counts (see Section 2). With a calibrated dropper I placed one drop of Karo containing a trace of 20 percent formalin into a very small test tube. In a second tube, I placed another drop of Karo tinted with malachite green to increase the cells' contrast. I then introduced one drop

of cell suspension carefully into the bottom of each test tube. Then I mixed the drops of the untinted material with the dropper and placed one drop of the mixture on the center of a 25 x 75 mm slide. I did the same on a separate slide with the malachite green cell mixture. I covered each with a No. 1 22 x 22 mm coverslip slowly enough to allow air bubbles trapped in the viscous material to disperse and escape on the way down. I labelled the slides with the number of milliliters of river water from which the cells on the entire slide had been concentrated. For instance, one drop of pure suspension contained the cells of 6.6 ml of river water. One drop of Karo plus cells contained the cells of 3.3 ml of river water.

2. Diatom analysis

a. Preparation and use of sample slides I prepared two diatom slides with different densities from the final concentrate of each sample. I used a calibrated dropper to measure volumes used. One drop of the concentrate contained the equivalent number of cells to 6.6 ml of the original sample of river water. In preparing the two mounts, one drop of the cell suspension was placed on one coverslip and two drops on another. Coverslips were No. 1 thickness and 22 x 22 mm in area. Distilled water was added to each, five drops to the first and four drops to the second. Thorough mixing in each case was accomplished by alternate suction into and

expulsion from the dropper. However, in many cases this type of mixing was insufficient to provide a uniform density all over the coverslip when heavy particles were contained in the suspension.

While drying, sample identities were maintained by placing the coverslips on a metal plate with numbered squares. This plate was heated until barely warm to the touch and then the hot plate was turned off. After drying slowly for several hours the coverslips were heated to approximately 480° C for 30-60 minutes to accomplish an incineration of the organic matter without destroying the siliceous walls of the diatom frustules. Then I allowed the hot plate to cool off to 120° C, at which temperature the coverslip was inverted on a drop of Hyrax mounting medium (R. I. = 1.65) of a 25 x 75 mm slide. (Note: A drop of viscous Hyrax dropped from a toothpick or applicator stick is always too large, necessitating much scraping away of the hardened material on the edge of the coverslip after heating. A smaller amount of Hyrax can be applied to the clean slide in this way: Invert the bottle with the slide held firmly on the open top. As you turn the bottle upright, scrape about 1/3 of the Hyrax back into the bottle. If the coverslip to be used on it contains much sediment, it is better not to scrape the excess off, since it will be needed to fill in the thicker mount.) The slide was then heated until solvent bubbles no longer formed. Then

I removed the entire mount from the heat, centered the coverslip, pressed on the coverslip with a toothpick to eliminate any remaining air bubbles and excess Hyrax, and set the slide aside to cool and harden.

Counts made from such measured drops are "real" in the sense that, theoretically, they can be converted to actual numbers per milliliter for each species. However, because the distribution of the particles was not uniform, reliable subsampling could not be done and each entire slide would have had to be counted. Since time was a limiting factor and I had not planned to make absolute counts, I proceeded with my original plan by making proportional counts in the following way:

After choosing a random starting point, each slide counted was traversed at 970X. I identified each diatom to species, variety, and form and counted each taxon until I reached a total of 300 diatoms for each sample tallied on laboratory counters and on a "bench sheet" (see Appendix). The count was extended proportionately to the percentage of dead diatoms noted in the original examination of preserved, unconcentrated material. The locations of any previously unidentified diatom taxa (that is, those not already on voucher slides in my collection) were circled with a Leitz diamond object marker, labeled accordingly, and added to a list of taxa to be searched for on slides of cleaned diatoms.

There was some risk that I would not encounter rare forms again on any other slide so, in such cases, the sample slide could double as a voucher slide.

b. Preparation and use of voucher slides A portion of the fresh plankton sample collected nearest the 15th of each month was reserved for making voucher slides. Cleaning the protoplasts from inside diatom frustules was done by a wet oxidation using 30 percent hydrogen peroxide and potassium dichromate (Van der Werff, 1955). Initially, after suspended matter had settled in the sample bottle, I poured off most of the water, decanted the sediment into a 1000 ml beaker and added about 20 ml of 30 percent hydrogen peroxide, waited a few minutes, then added about 0.01 g potassium dichromate. The more or less violent reaction destroys the protoplast but not the cell wall. When it was completely finished, I poured the well-mixed liquid and sediment into a tall 200 ml beaker and allowed the sediment to settle for five hours or more. Then I decanted most of the liquid, stopping when the disturbed sediment reached halfway to the beaker's lip, refilled the beaker with distilled water, allowed the sediment to settle again, and repeated this sequence until the liquid was no longer yellow. After a final settling period of at least five hours, I poured off the clear liquid and decanted the sediment (which included the cleaned diatoms) into a labeled screw-cap vial. I made Hyrax slides in the way described

above but without the high temperature for incineration. Cleaned diatoms are much easier to identify accurately because the markings on the frustules are not obscured by protoplasts within the siliceous cell wall, and the shapes of poorly silicified diatoms are not distorted by high incineration temperatures. I made the greatest number of voucher slides from the first collection (15 Jan 1968) since all species were then "new" to the study. Successively fewer slides were necessary each month because fewer taxa which had not previously been identified were encountered. Before I began the count on the sample slides each month I checked through all voucher slides to look for and identify new taxa. This procedure also helped me become familiar with the dominant diatoms before I made counts on the less easily identified material. Absolute counts cannot be made from slides of diatoms cleaned in this manner, but they may be used for proportional counts.

In preparing voucher slides of diatoms not previously encountered in this study after the taxonomic determination was completed, the coverslip over the specimen was circled with the object marker and that circle was ringed by an India ink ring on the underside of the slide. (This ring was made more permanent by covering it with clear nail polish.) The slide was then labeled with taxonomic and collection information and filed alphabetically in the voucher collection.

C. Environmental Variables

This section contains information gathered from numerous sources. Most of the climatological data came from various U.S. Weather Bureau sources, and hydrological data was furnished by the U.S. Geological Survey and found in several minor sources. The Saylorville Dam Preimpoundment Water Quality Study collected and reported all the data in parts 4 and 5, plus water temperature and turbidity. Besides the variables I chose for this dissertation, they made weekly determinations of the following: pH, CO_2, and organic, ammonia, and nitrite nitrogen. Measured less often but usually at least once a month were: total, volatile and fixed solids; phenolpthalein and total alkalinity; total, inorganic, and organic carbon; chlorides; total and calcium hardness; and iron. All Saylorville data is reported by Baumann and Dougal (1968 and 1969).

1. Climate

The geographical boundaries of the drainage basin section under study are 44° 15' N, 93° 30' W, 41° 30' N, and 96° 0' W (see Figure 2). This area, as well as the remainder of the Des Moines River basin, is well within the North American "Daf" climatic region of Köppen (modified by Trewartha, (1957). A Daf region is defined to be humid, continental (D) with warm summers (a) and constantly moist with precipitation throughout the year (f). In Europe, a smaller Daf area covers

Rumania and a small part of Yugoslavia and the lower Danube flows through it. The Hwang Ho flows through eastern Asia's smaller Daf region. The upper Dnieper, mentioned in the literature review, arises in and flows through a Dbf region, differing only in its cooler summers from Daf areas. No such areas occur on the other continents.

The upper Des Moines basin climate is characterized by warm, moist summers and cold, dry winters (Barger, 1954). Air moisture and, consequently, precipitation decrease northward, as the distance from the Gulf of Mexico increases.

Of the many types of available climatological data, I selected those which have a direct bearing on growth of phytoplankton in flowing water. I chose volume of flow (discharge or streamflow) rather than precipitation, and water temperature, solar radiation, ice cover, and turbidity rather than air temperature and cloudiness. To use one figure which described the summation of energy input upstream from the sampling reach, I devised "mean basin solar radiation", an average of cumulative solar radiation for the seven days prior to each sampling day recorded by pyrheliometers (or "pyranometers") at St. Cloud, Minnesota (near 45° N, 94° W) and Ames. Iowa (near 42° N, 94° W). No other solar radiation stations were close enough to give appropriate data, but these data were checked against cloud cover data from the Sioux Falls, South Dakota (near 44° N, 97° W) weather station (U.S.

Department of Commerce, 1968-69) and similar trends were evident. I assume that this mean reflects the average maximum solar energy available to phytoplankton at the surface of those portions of the river unshaded by gallery forests. As such, it is undoubtedly in excess of the real average per photosynthetic unit in the total river.

In order to correct for losses of light energy due to turbidity, I considered the possibility of using a unit-less quotient of mean basin solar radiation (in langleys, which are gram·calories/cm^2) divided by the turbidity (in Jackson turbidity units, JTU) at Station 3 on the sampling day. However, the fact that the JTU units are on a different scale than the radiation units plus the unknown amount of time each cell or colony would spend in the photic zone make this potentially interesting factor unworkable at present.

Growth of plankters obviously is associated with availability of light energy. The data appear sufficient to be able--with the help of personnel in other disciplines--to develop a special term which can be related to plankton growth. The term would involve consideration of light available (measured in langleys), water turbidity (measured by depth of light penetration), and water turbulence (measured probably by the Reynolds number). This area of study will be pursued as the additional data required becomes available.

Water temperature, ice cover, and turbidity data were

collected by the Saylorville Preimpoundment Survey crew. Solar radiation data were furnished by the Iowa state climatologist, and obtained from the National Climatological Summary (U.S. Department of Commerce, 1968-69) also.

2. Hydrology

The mean annual precipitation of the upper Des Moines basin varies from 59 cm around Lake Yankton, Minnesota to 76 cm at Saylorville, Iowa (Miller, Geraghty, and Collins, 1962). More than half the Minnesota precipitation falls during the four months between May 1 and August 31 (Minn. Cons. Dept., 1962) and more than half of Iowa's between May 1 and September 30. However, large streamflows are normally common in March, with Iowa's spring thaw and breakup followed by that in Minnesota (Twenter and Coble, 1965).

Natural storage of water in lakes and marshes is considerable in the headwaters of the Des Moines, where the more recent glacial depositions have had insufficient time to develop strong drainage patterns (Minn. Cons. Dept., 1962). The valleys of the river and its tributaries are merely depressions of the landscape with shallow trenches carrying the normal streamflow at their lowest elevation. Farther south and downstream, even before the confluence of the two forks, definite valleys carry precipitation away more rapidly and there is less infiltration (Iowa Nat. Res. Coun., 1953). The rate of runoff increases southeastward from a headwaters

annual average of 6.4 cm to approximately 10.2 cm near Des Moines (Linsley and Franzini, 1964).

Evaporation and transpiration (potential) is about 83 cm at the headwaters, increasing slightly toward Des Moines to 90 cm per year (Linsley and Franzini, 1964).

The velocity of the Des Moines varies usually between 1-2 m/sec (personal communication with J. Wehrspann, 1969). The velocity probably varies little from headwaters to mouth but may be slightly greater downstream (Leopold, 1962).

The average gradient in the headwaters area and downstream beyond Estherville is less than 0.285 m/km. For the next 130 km, down to below Fort Dodge, the fall is greatest, about 0.61 m/km. Downstream from there to the mouth, the average fall is 0.42 m/km. Figure 4 shows the slight lessening of the gradient in the 117 km stretch between Fort Dodge and Des Moines (U.S. War Department, 1931).

The character of the bottom depends on the recent conditions of streamflow volume, and on the effects of localized conformations of the riverbed. Within the study area it can be muddy, sandy or stony. There is so much turbulence and variability in the banks and bottom that no rooted aquatic plants are found here, and few in other sections. Probably, deep scouring or gouging during floods occurs also (Leopold, 1962) and contributes to channel instability.

Regular streamflow data are obtained for the U.S.

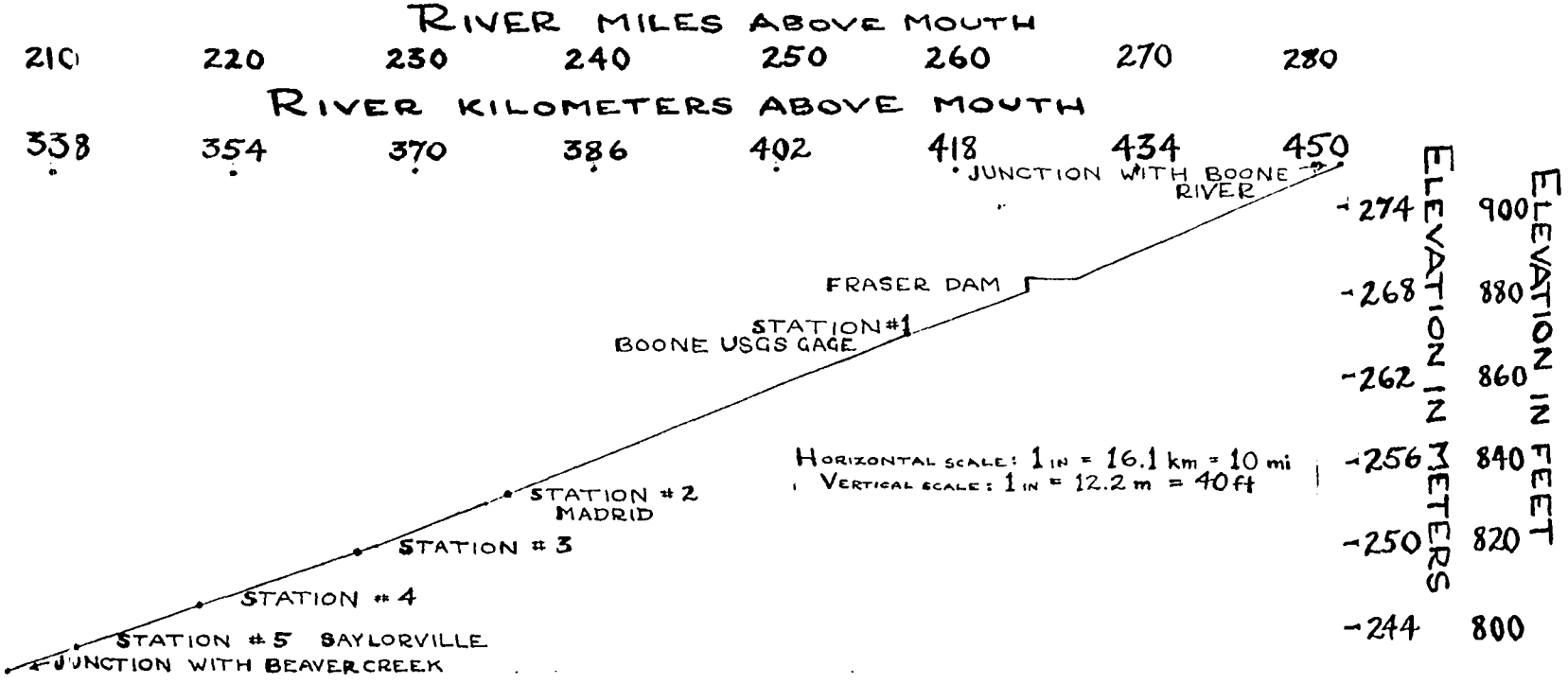

Figure 4. Profile of the Des Moines River from its junction with the Boone River to its junction with Beaver Creek (after U.S. War Department, 1931)

Geological Survey by digital water-stage recording gages on the West Fork at Jackson, Minnesota, and Estherville and Humboldt, Iowa. On the East Fork, recorders are located near Burt and Dakota City, Iowa. Downstream from the forks' confluence, recording gages are near Stratford and Boone, with a wire-weight gage read daily at Saylorville. Recording gages are also located on two tributaries: Lizard Creek near Clare, eight miles northwest of Fort Dodge, and the Boone River near Webster City (U.S. Department of the Interior, 1969). (See Figure 2).

Dams on the main stem of the river are located at Rutland and Humboldt (West Fork), near Humboldt, Fort Dodge (two), Lehigh, Fraser, and Boone. There is also one on the Boone River at Webster City (State of Iowa, 1968). These are the "licensed mill dams" whose purposes now range from recreation to power generation. There are other small dams which maintain levels of tributary lakes.

3. Physical factors

a. Temperature Water temperature was measured by inserting a mercury-filled centigrade thermometer (range: -20° C to 110° C) into one of the 4-liter sample jugs of river water immediately after it was filled from the collecting bucket or "DO dunker" (Amer. Publ. Health Assoc. or APHA, 1965, pp. 311-12).

b. Turbidity Measurements were made by the laboratory staff on well-mixed water samples from the large jugs. A Hach Model 2100 laboratory turbidimeter (Water and wastewater analysis procedures, 1968, pp. 66-7) was used for samples with less than 200 Jackson Turbidity Units (JTU), and a candle turbidimeter for those with more than 200 JTU (APHA, 1965, pp. 313-16).

c. Specific conductance Daily samples are collected for the U.S. Geological Survey from Station 5 (Fisher Bridge on NW 66th Ave) in 1/2-liter glass bottles, picked up once a month, and analyzed in Iowa City with a platinum-electrode recording conductivity meter (Scientific Instruments Co.) and a Wheatstone (Solu) bridge. The cell is the immersion type.

January through September 1968 data were published in "Water resources data for Iowa" (Water year 1968), and data for the remainder of my sampling year were sent to me from Iowa City by the Survey.

d. Solar radiation An Epply pyranometer on top of the Agronomy Building on the campus of Iowa State University which records readings three times an hour is the source of the Ames data. The other station from which data used in calculating mean basin solar radiation were obtained is in St. Cloud, Minnesota. Most of the data were furnished by the state climatologist, and the remainder were copied from Climatological Data, National Summary (Environmental Data

Service, 1968-69).

e. Streamflow River stage (elevation of the water surface) data from the Stevens A-35 electric gage at the Boone Water Works (Station 1) and the wire-weight gage at Fisher Bridge (Station 5) are analyzed by the U.S. Geological Survey at Ft. Dodge and the resulting streamflow (discharge) data are published in "Water Resources Data for Iowa" (Water Year 1968). A recording gage at Jackson, Minnesota takes stage reading for the U.S. Geological Survey in Minnesota (Figure 2). Provisional data for the first four months of Water Year 1969 were furnished by the Fort Dodge office.

4. Chemical factors

a. Dissolved oxygen (DO) Samples were taken at the midpoint and quarterpoints across the river at each station on each sampling day. The DO bottles were filled and overflowed at least three times automatically in the DO dunker (or "sewage sampler"). After bottles were lifted out of the dunker, pointed ground glass stoppers were carefully dropped in the necks to exclude atmospheric oxygen. After their bottle numbers were recorded, sulfuric acid and sodium azide solution were added immediately to preserve them for titration in Ames (APHA, 1965, p. 406). After May 1968 the entire DO analysis was performed in a small laboratory built into the Water Resources Survey panel truck. The azide modification of the Winkler method (APHA, 1965, pp. 406-10) was used for

the entire series.

For each sample taken, I calculated percent saturation of dissolved oxygen. I used 817 feet above sea level as the average altitude of the study reach, so each DO reading was first multiplied by 1.035. Using the temperature readings for each station on each sampling day and the corrected DO readings, I matched them on Rawson's nomogram (Welch, 1948) using a piece of thread, to calculate percent of DO saturation (see Table 3a, page 43b).

b. Chemical oxygen demand (COD) The analytical laboratory used the dichromate reflux method in Standard Methods (1965, pp. 510-14) on subsamples from the 4-liter sample jugs.

c. Nitrate nitrogen This sample was collected in the DO dunker in a DO bottle. It was always set with acid immediately after collection to stop bacterial and algal growth previous to its delayed analysis by the Hach cadmium reduction method, which uses 1-naphthylamine-sulfanilic acid (pp.41-2).

d. Orthophosphate Subsamples from the 4-liter jugs were analyzed in Ames by the stannous chloride method in Standard Methods (pp. 234-36).

e. Silica The method used was the silicomolybdate colorimetric method of Hach Chemical Company (p. 60). Subsamples were taken from the large jugs.

5. Biological factors

a. Biochemical oxygen demand Water samples taken from the large jugs were given a standard five-day BOD test as outlined in Standard Methods (1965, pp. 415-21).

b. Chlorophylls a and b Each one-liter subsample from one of the jugs was filtered through a Millipore (cellulose ester membrane) filter, Type HA (mean pore size 0.45 u $\pm$ 0.02 u), white, plain, and 47 mm in diameter. The cell-bearing filter was then ground for one minute (mechanically) in a tissue grinder tube with 2 ml of 90 percent acetone (aqueous) and 0.1 g of magnesium carbonate. Contents of the grinding tube were washed into a centrifuge tube with 5 ml more of the 90 percent acetone, and centrifuged in a clinical centrifuge at the highest speed (over 1000 G) for 15 minutes. The 7 ml of extract was decanted into a calibrated stoppered cuvette 1 cm thick and absorbance measured at the chlorophyll a and chlorophyll b peaks on a Beckman Model B spectrophotometer (Richards with Thompson, 1952 and Parsons and Strickland, 1963).

6. Combinations of factors

a. DO difference This factor is arrived at by subtracting the dissolved oxygen of Station 5 from that of Station 1 on the same sampling day. Since the sampling of Station 5 was always done around 8 or 9 AM, and Station 1 was sampled early in the afternoon (with rare exceptions),

the dissolved oxygen would be expected to be higher at Station 1 due to photosynthetic activity. The few exceptions to this were during ice cover and on days when Station 1 sampling was late.

In this thesis, the DO difference was between two different stations at two different times. A better measurement (but one not available) would be to take DO measurements simultaneously at both stations, or choose either one of the stations, and sample very early in the morning and at noon.

b. BOD-COD-phytoplankton The graphs of these three variables are arranged so visual comparisons can easily be made by using a string or ruler to connect points on each graph for the same week's data (Figures 14, 15, and 16). (Note: Week numbers are on the abscissa of each of the strip graphs.) Comparisons of these three factors are of particular significance in water quality studies.

IV. RESULTS

A. Environmental Factors

1. Climate

Mean basin solar radiation showed a gradual irregular rise from the 5-11 January 1968 low of 989 to a peak of 4364 langleys (5-11 July) (Figure 5). It subsided to a low of 664 during 28 November-4 December.

Water temperature remained at 0° C from 1 January to 8 March, reached a high of 29.5° C on 23 August and was down to zero again on 26 December. There were some ice cover fluctuations during the 1968 winter with a late January thaw. Ice developed again to an almost 100 percent cover by 9 February (Figure 6).

2. Hydrology

The sample year began with a near-record low streamflow of 1.30 m^3/sec at Station 1 but ended with near normal levels (32.3 m^3/sec). There were no floods (see Figure 7) due to the thaw in January and the very low winter flow. Heavy and constant rains in the northern basin did push the river level up to 231.5 m^3/sec in mid-October even though there was no precipitation around Des Moines. Table 2 compares 1968 upper basin streamflow and groundwater conditions with normal previous years. Mean streamflow at all gaging stations is shown in Table 3.

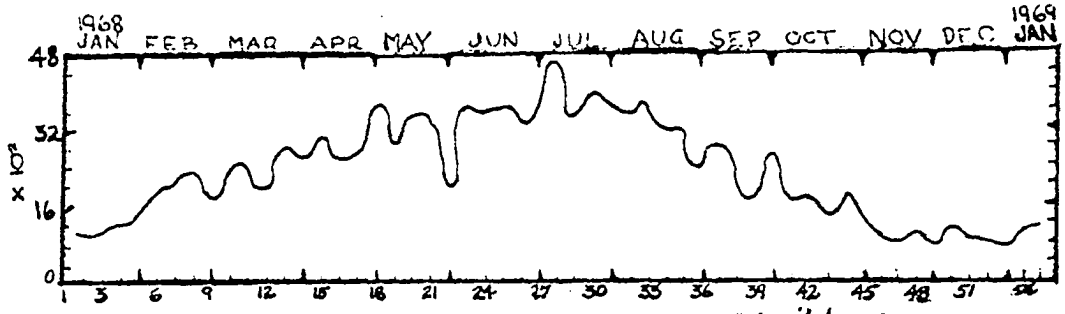

Figure 5. Mean basin solar radiation in g·cal/cm^2/week

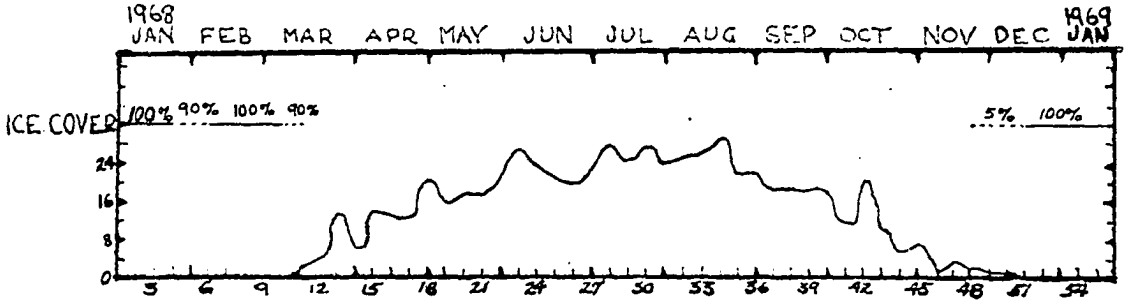

Figure 6. Water temperature in °C. and ice cover at Station 1

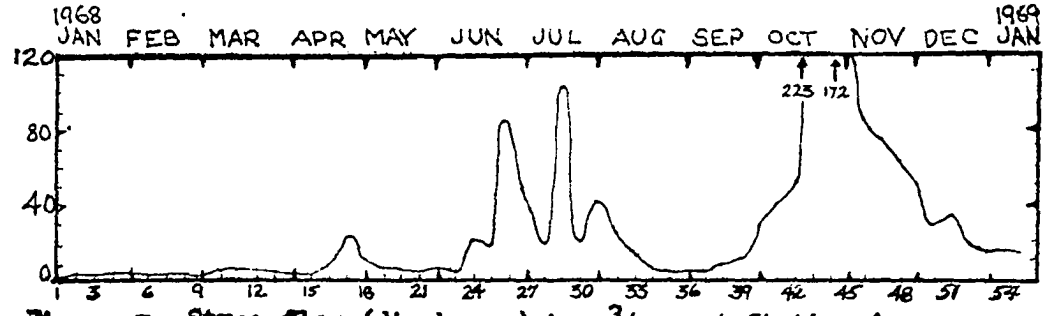

Figure 7. Streamflow (discharge) in m^3/sec at Station 1

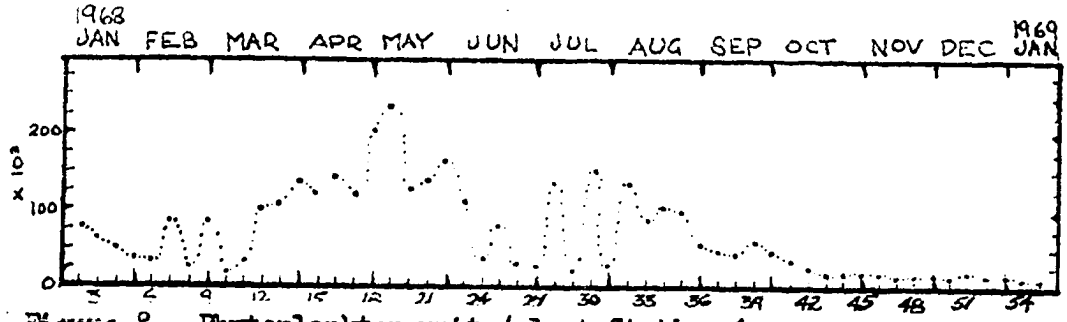

Figure 8. Phytoplankton units/ml at Station 1

Table 2. Iowa hydrological conditions, Jan 1968-Jan 1969[a]

Month	Streamflow	Des Moines R.	Groundwater levels
Jan 1968	much below normal, NW & N central Ia.	near record low flow during first of month	well above average
Feb	normal		above average but less than Jan
Mar	deficient due tc no snowcover early Mar, below average precipitation and above average temps	near Boone, 15% of median Mar flow	generally below average
Apr	deficient N & central		remained constant
May	normal; NW defi cient	deficient for 8th consecutive month	near average
June	near record low	deficient for 9th consecutive month	generally declined
July	normal to defi-cient		above average in most of Ia.
Aug	normal		above average
Sept	normal		well above average
Oct	excessive in N		above average
Nov	excessive; thin ice cover early, disappeared mid-month		above average
Dec	N: excessive		changed little
Jan 1969	excessive; heavy snowcover, N Ia.		changed little

[a]Source: Water Resources Review, Jan 1968-Jan 1969 (U.S. Department of the Interior, 1968-1969).

Table 3. Mean streamflow at upper Des Moines River gaging stations in m^3/sec for calendar year 1968 and January 1969[a]

Gaging station	Long-term mean	Years rec	Jan	Feb	Mar	Apr	May
					West Fork		
5-4760 Ja	7.6	31	.03	.05	.46	.56	.29
5-4765 Es	7.2	17	.07	.1	.65	.73	.44
5-4767.5 Hu			.79	1.1	2.2	2.7	2.2
					East Fork		
5-4780 Bu	2.8	17	.07	.09	.26	1.32	.97
5-4790 Da	15.3	28	.64	.62	1.1	3.0	2.6
					Main stem		
5-4805 Fo	36.4	36	1.7	2.1	4.0	6.8	5.9
5-4813 St	45.7	48	2.12	3.0	5.8	10.0	8.4
5-4815 Bo	45.7	48	2.08	3.1	5.7	10.7	9.2
5-4816.5 Sa	61.5	7	2.12	3.4	6.3	12.3	10.3
					Tributaries		
					Lizard Creek		
5-4800 Cl	2.5	28	.02	.05	.23	.35	.20
					Boone River		
5-4810 We	9.7	28	.22	.46	.92	2.1	1.3

[a]All Jackson, Minnesota data (Station 5-4760) from provisional records of the U.S.G.S., St. Paul. October 1968 through January 1969 data of all other stations "Preliminary data, subject to revision", from the Iowa City office of the U.S.G.S. Water resources data for Iowa. All other data from U.S. Department of the Interior, 1969.

Jun	Jul	Aug	Sep	Oct	Nov	Dec	1968	Jan 1969
				West Fork				
.55	3.06	4.16	3.6	35.7	28.7	7.5	7.1	
.74	2.4	4.3	3.7	38.3	31.1	8.6	7.6	4.0
3.74	5.35	6.75	6.35	50.8	48.1	13.8	12.0	7.3
				East Fork				
4.95	3.1	.63	1.7	14.9	8.9	3.1	3.4	1.5
13.2	13.8	3.3	2.7	32.2	21.1	7.7	8.5	3.3
				Main stem				
17.7	20.6	10.3	9.6	89.4	72.8	25.1	22.1	13.0
26.4	42.5	16.5	12.4	118.1	89.3	29.2	30.4	16.7
24.9	41.9	18.2	12.1	114.6	94.5	32.3	30.8	17.8
29.2	49.5	21.0	11.1	113.1	96.4	34.4	32.5	19.6
				Tributaries				
				Lizard Creek				
.25	.86	.36	.36	3.2	1.5	.6	.7	.3
				Boone River				
8.2	17.1	3.0	2.3	22.3	9.1	3.8	5.9	1.8

3. Other physical factors

Turbidity variations (Figure 9) showed similar trends to streamflow except during Week 36 (4 September) sampling when mechanical trouble at the Boone Water Pollution Control Plant caused untreated sewage to be discharged into the river.

Specific conductance ranged from a mid-January (1968) high of 1350 micromhos (at 25° C) to a mid-August low of 510 micromhos (Figure 13). The yearly mean was 800 micromhos.

4. Chemical factors

Dissolved oxygen levels were high all year, never falling below 63 percent of saturation at any station, and usually remaining above 100 percent (see Table 3a and Figures 10 and 11). August 1967 diurnal studies showed a low of 80 percent at 6 AM; December 1967 a low of 100 percent at 8 AM; and February-March 1968 a low of 110 percent at midnight.

The almost constant fluctuations of chemical oxygen demand (range: 4.5 mg/l-168.8 mg/l) paralleled those of biochemical oxygen demand almost perfectly (see Figures 14 and 15).

Nitrate nitrogen, silica and orthophosphate levels dropped when phytoplankton rose to very high levels (Figures 17, 18, 19, and 20).

Table 3a. Dissolved oxygen: percent of saturation

Week	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5
1	150+	150	150	150	150
2	110	134	129	142	151
3	47	71	71	83	110
4	97	122		130	150
5	95	114	121	122	122
6	121	132	129	128	120
7	150+	150	150	150	150
8	150+	150	150	150	150
9	114	150	150	150	150
10	98	75	111	110	109
11	117	130	131	143	144
12	150+	140	146	136	132
13	150+	150	148	135	130
14	150	144	138	122	91
15	101	110	93	98	105
16	94	97	90	91	80
17	150+	144	141	123	98
18	150+	150	150	124	108
19	150+	150	138	119	110
20	118	134	118	88	80
21	115	128	108	95	93
22	150+	150	139	117	114
23	108	122	96	73	94
24	98	53	67	72	67
25	134	96	93	88	88
26	73	67	120	100	100
27	97	95	90	88	90
28	150+	150	150	160	120
29	73	63	65	71	75
30	150+	150	144	111	98
31	116	111	105	100	91
32	150+	148	131	91	70
33	150+	123	97	81	70
34	94	102	92	80	80
35	132	124	114	102	102

Table 3a. (Continued)

Week	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5
36	90	75	80	87	85
37	149	119	110	97	91
38	128	113	112	102	96
39	150+	150	150	150	127
40	133	134	131	115	108
41	108	100	95	91	89
42	91	96	95	95	95
43	88	88	86	90	87
44	98	100	99	98	99
45	103	100	102	100	96
46	104	108	106	103	101
47	113	109	107	110	107
48	105	105	100	102	98
49	108	104	102	101	100
50	107	107	107	106	105
51	106	102	102	104	104
52	94	96	96	97	97
53	86	85	83	84	85
54	78	78	78	77	77
55	74	72	71	71	67

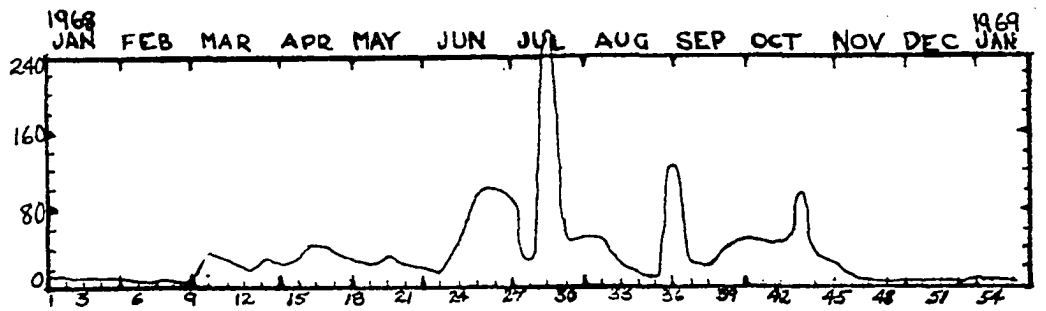

Figure 9. Turbidity in JTU at Station 3

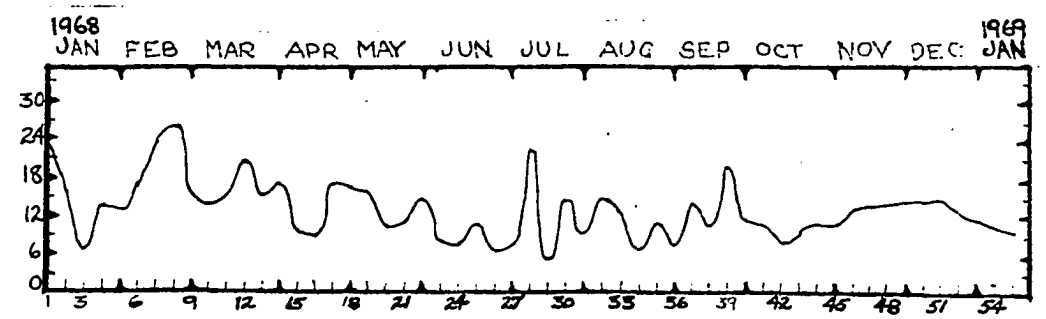

Figure 10. Dissolved oxygen in mg/l, at Station 1

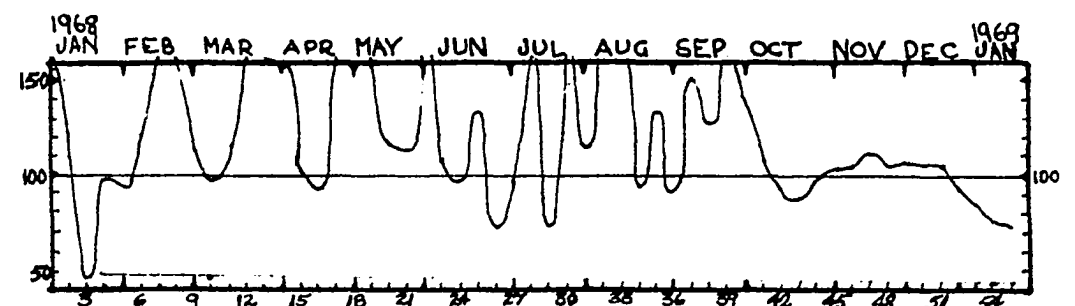

Figure 11. Dissolved oxygen % of saturation at Station 1

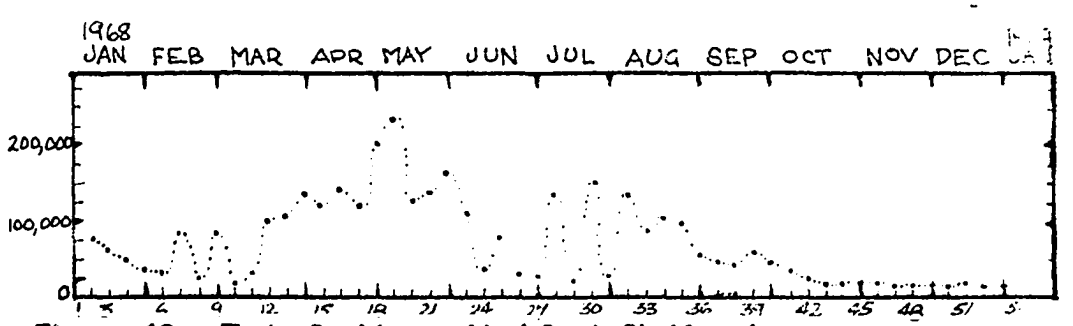

Figure 12. Phytoplankton units/ml at Station 1

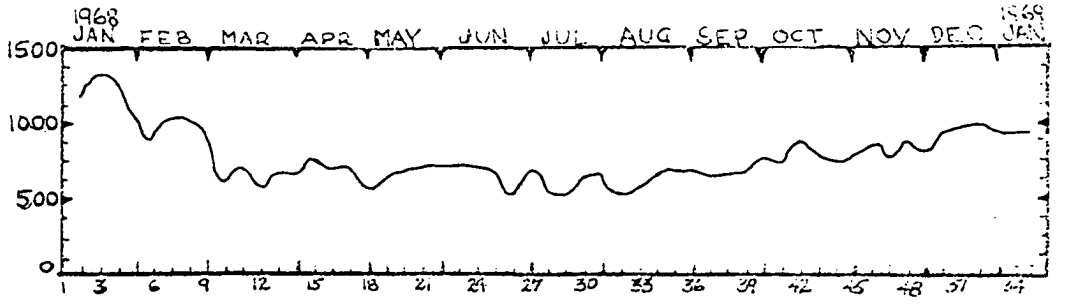

Figure 13. Specific conductance at Station 5 in micromhos at 25°C.

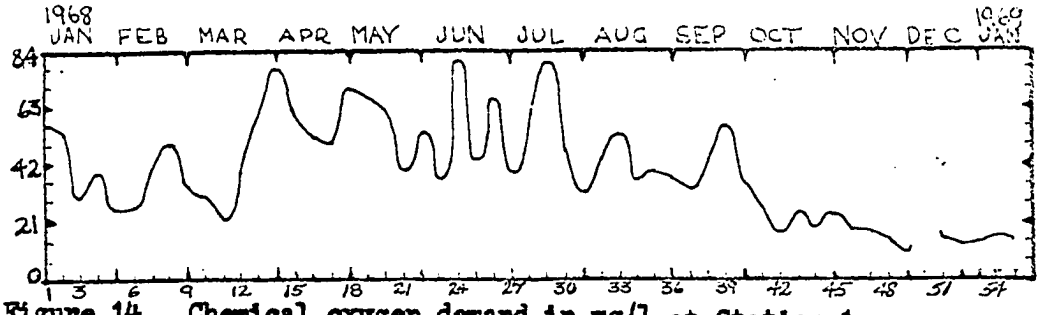

Figure 14. Chemical oxygen demand in mg/l at Station 1

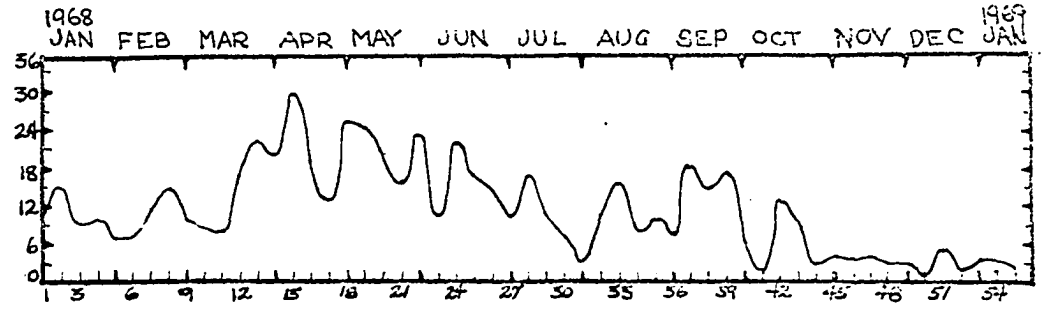

Figure 15. Biochemical oxygen demand in mg/l at Station 1

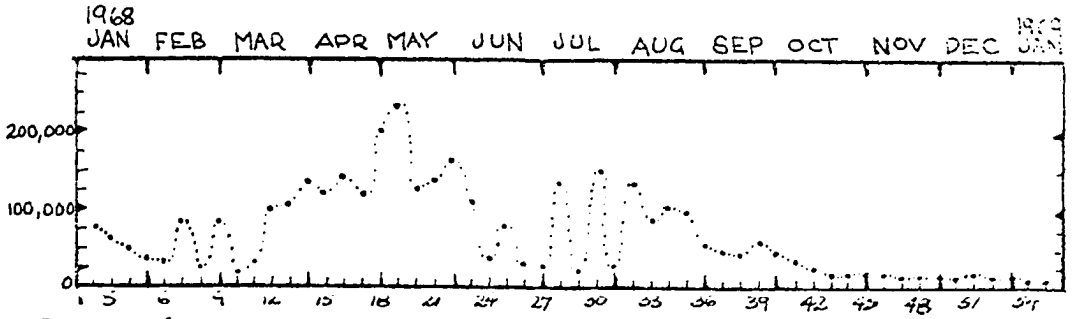

Figure 16. Phytoplankton units/ml at Station 1

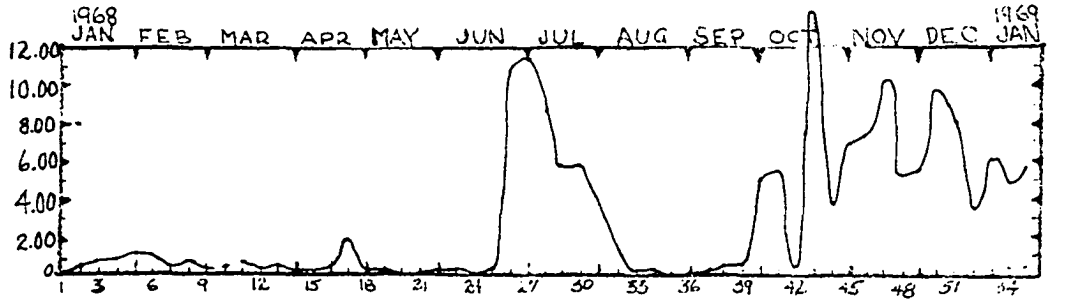

Figure 17. Nitrate nitrogen in mg/l at Station 1

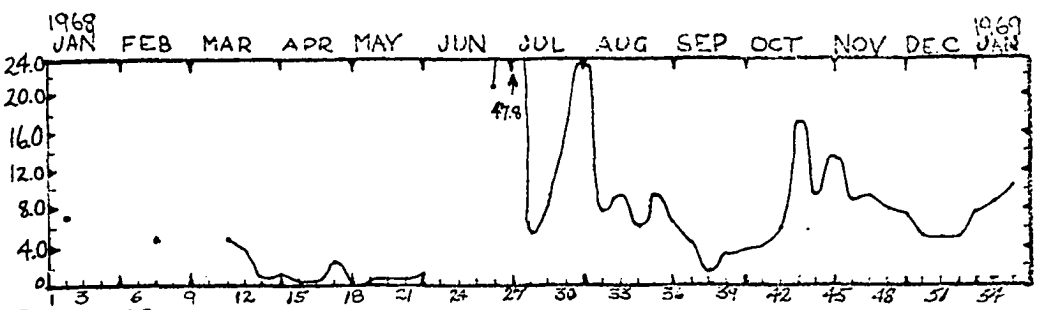

Figure 18. Dissolved silica in mg/l at Station 1

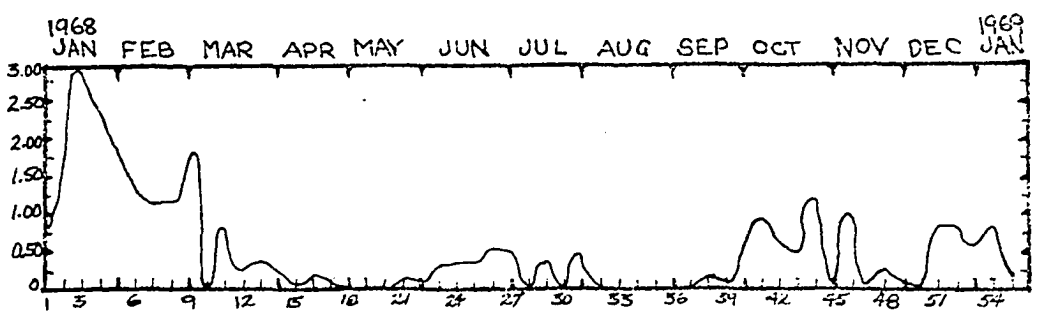

Figure 19. Orthophosphates in mg/l at Station 1

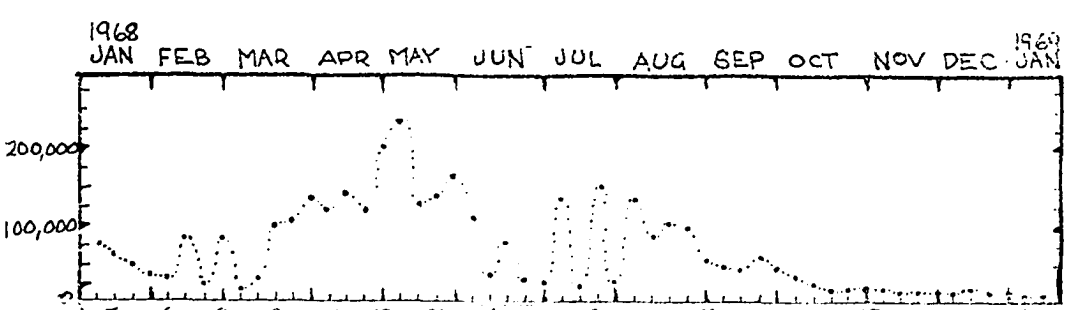

Figure 20. Phytoplankton units/ml at Station 1

5. Biological factors

The 5-day BOD range varied from a low of 1.1 mg/l at Station 5 on 15 January 1969 up to 29.9 mg/l on 12 April 1969 at Station 1 (see Figure 15). Values varied widely from week to week but general trends could be discerned, and they usually paralleled those of COD (Figure 14).

The low for both chlorophylls a and b was zero (Figures 21 and 22). The high for a was 0.86 mg/l on 3 May 1968 at Station 3. The chlorophyll b peak of 0.35 mg/l was determined from the 5 January 1968 sample from Station 4.

Values for chlorophyll a are plotted against total phytoplankton counts in the scatter diagram, Figure 25.

B. Combinations of Factors

DO difference varied from a low of -8.9 mg/l on 26 January 1968 (under ice) to 12.7 mg/l on 12 July (Figure 26). Its variations compared fairly well with the numbers of phytoplankters/ml but not well enough to be used instead of them. Its values under ice cover were erratic.

This factor is plotted against total phytoplankton in Figure 27. A slight similarity of response can be seen.

C. Phytoplankton Fluctuations

The lowest number of phytoplankton units per milliliter (3,363) was found at Station 1 on 9 January 1969 (Table 4).

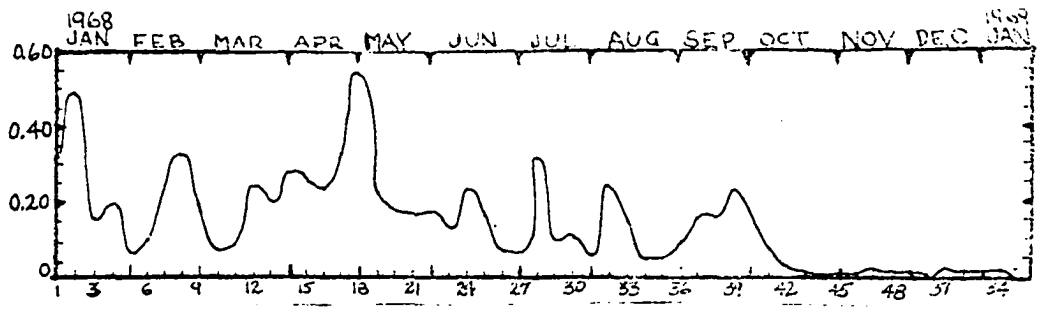

Figure 21. Chlorophyll a in mg/l at Station 1

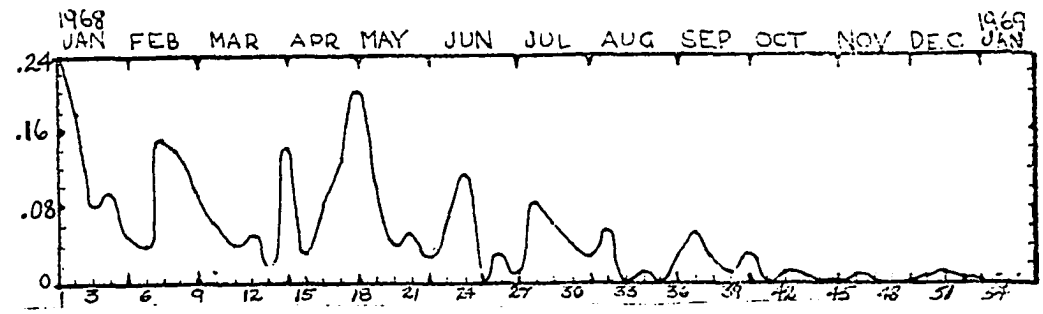

Figure 22. Chlorophyll b in mg/l at Station 1

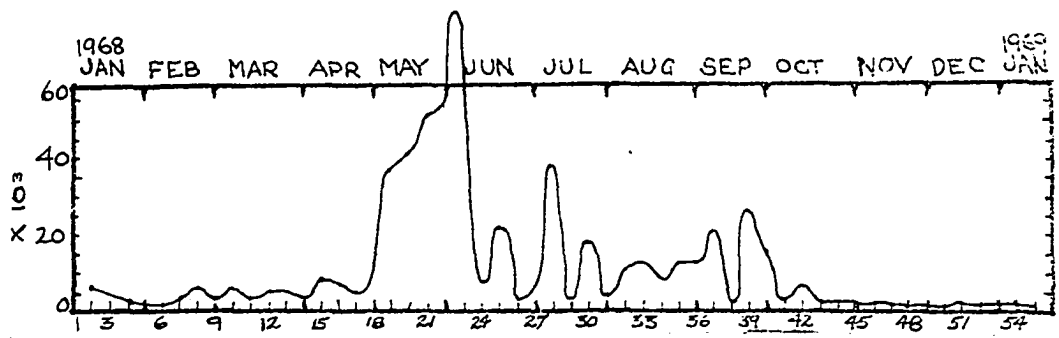

Figure 23. Green algae units/ml at Station 1 (scale different from Figure 24)

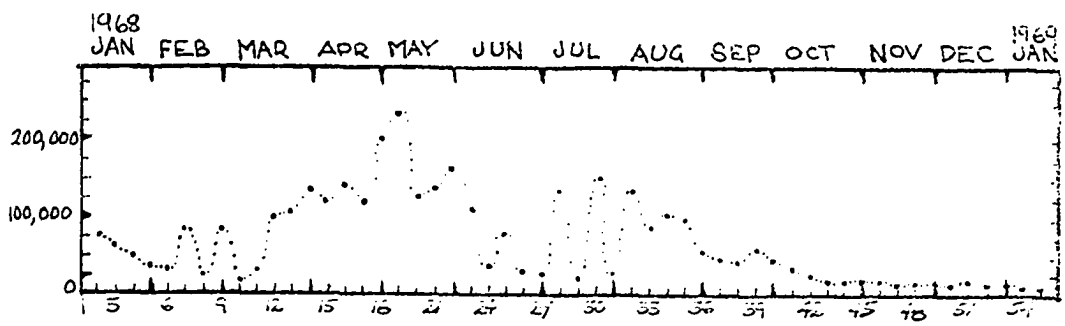

Figure 24. Phytoplankton units/ml at Station 1

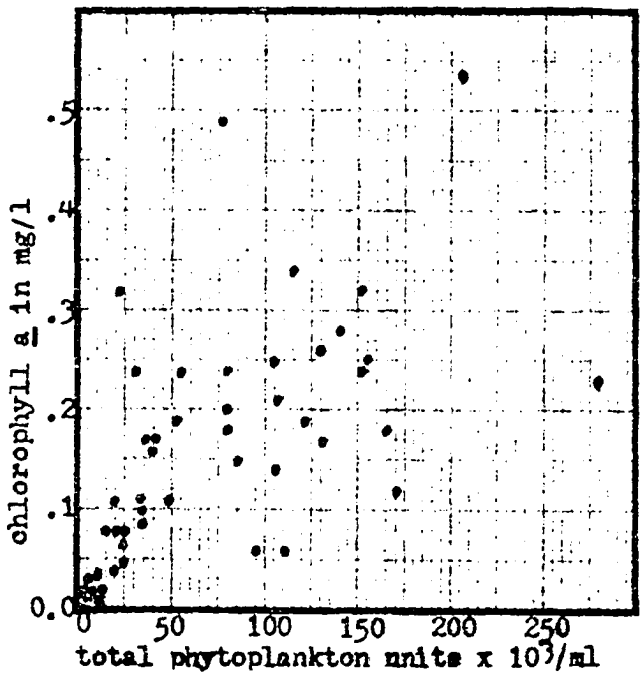

Figure 25. Scatter diagram of chlorophyll a and total phytoplankton at Station 1

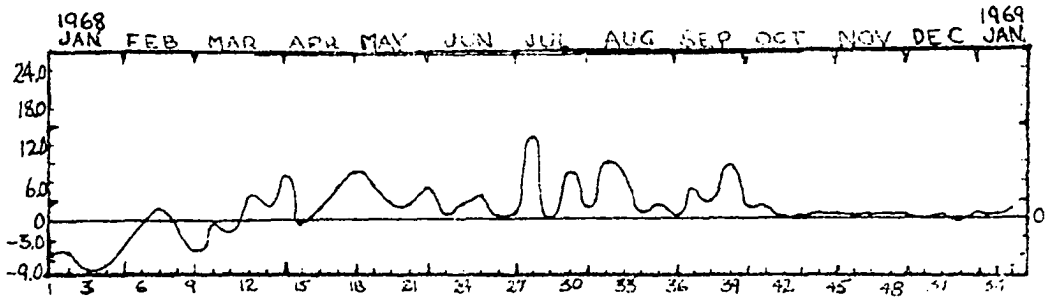

Figure 26. DO difference in mg/l between stations 1 and 5

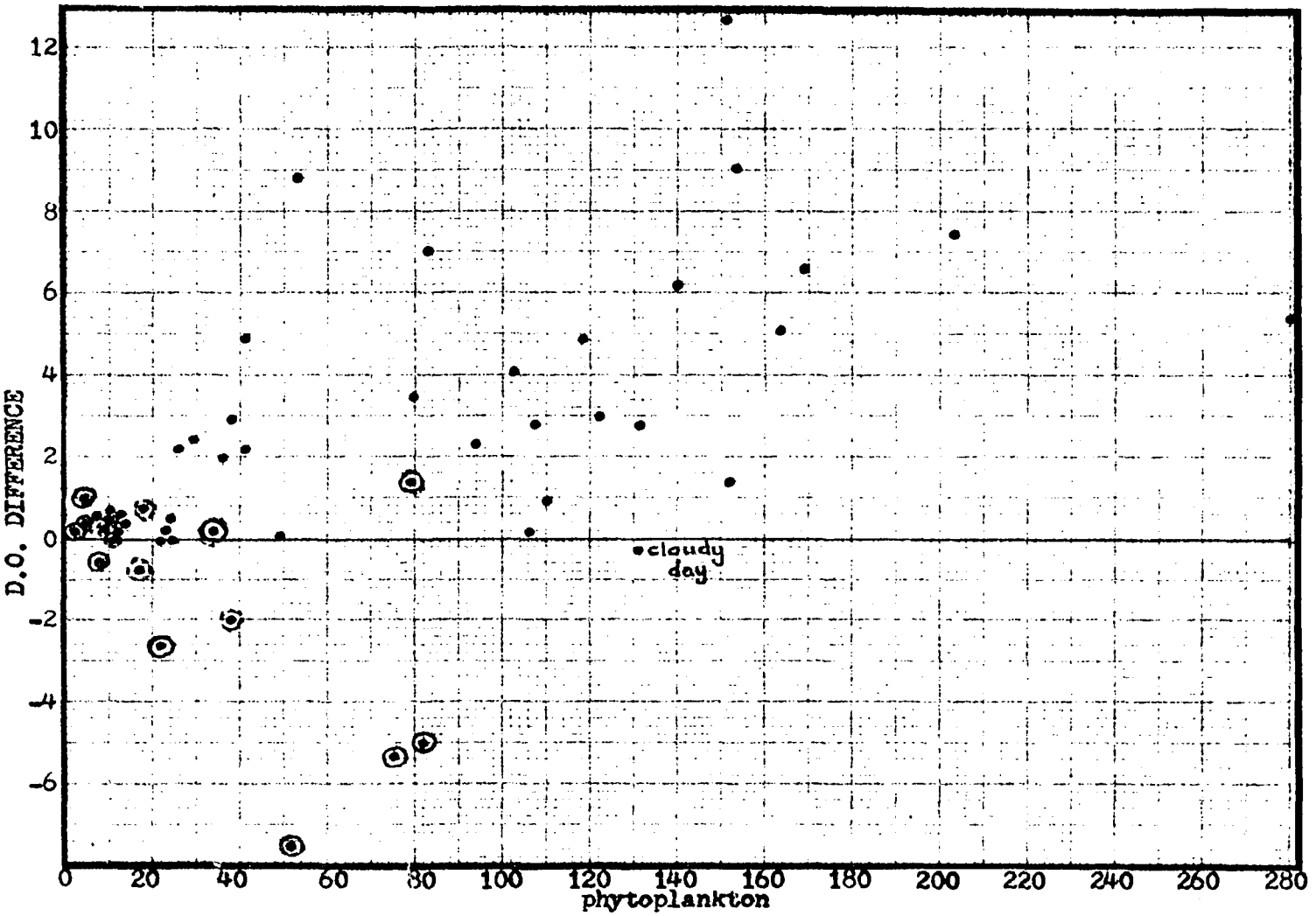

Figure 27. Scatter diagram of DO difference and total phytoplankton units/ml at Station 1

They were divided almost equally among coccoid greens, green flagellates, centric diatoms, and pennate diatoms (see Week 53, Table 4), a rare distribution. The highest number of units/ml (281,074) was found at Station 1 on 10 May.

The species list in the Appendix is divided into the same categories used in Table 4, which are those used by the Water Pollution Surveillance System. A categorized list of genera of common plankton algae, and a list of the 96 commonest species of diatoms (U.S. Department of Health, Education, and Welfare, 1963) are also in the Appendix.

Coccoid and filamentous green algae increased greatly from winter lows in January, February, and March to peak numbers in May and June, then back to low numbers again after mid-October (see Figure 30). Green flagellate data is included in the graph of Figure 23, but change the curve very slightly.

Blue-green algae (Figure 29) were never very numerous except in October.

Green flagellates outnumbered other pigmented flagellates at all times (Figure 31), peaking during early March.

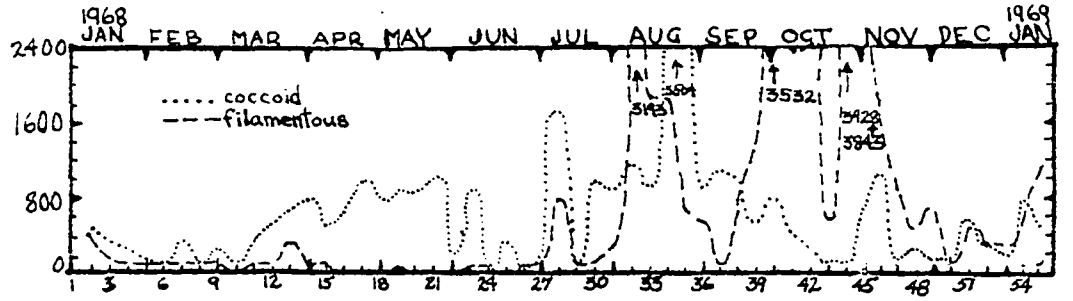

Figure 29. Blue-green algae in units/ml at Station 1

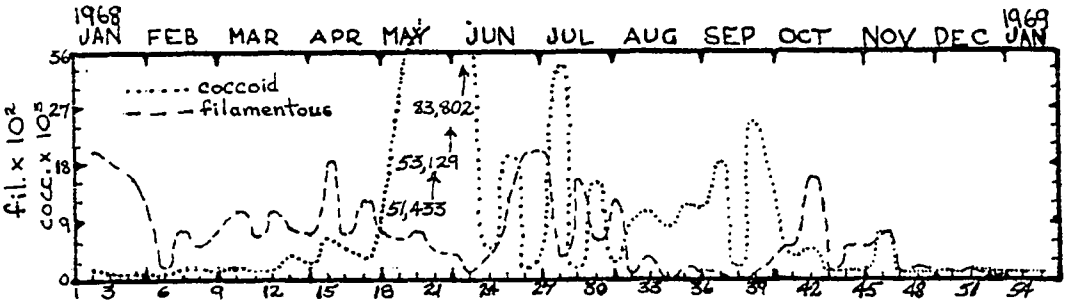

Figure 30. Green algae in units/ml at Station 1

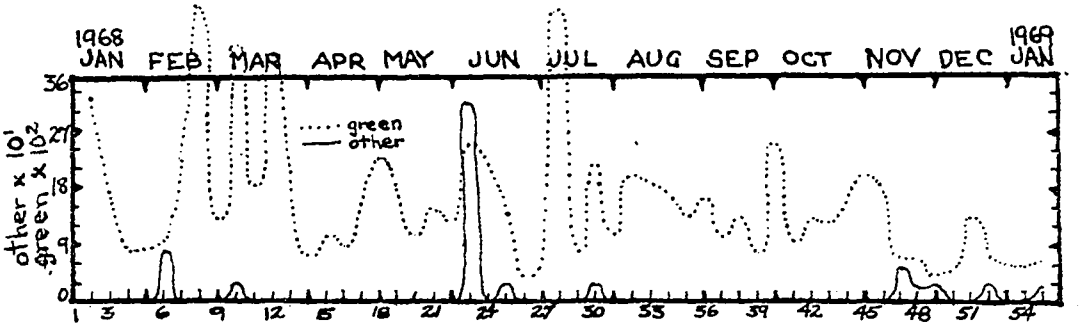

Figure 31. Pigmented flagellates in units/ml at Station 1

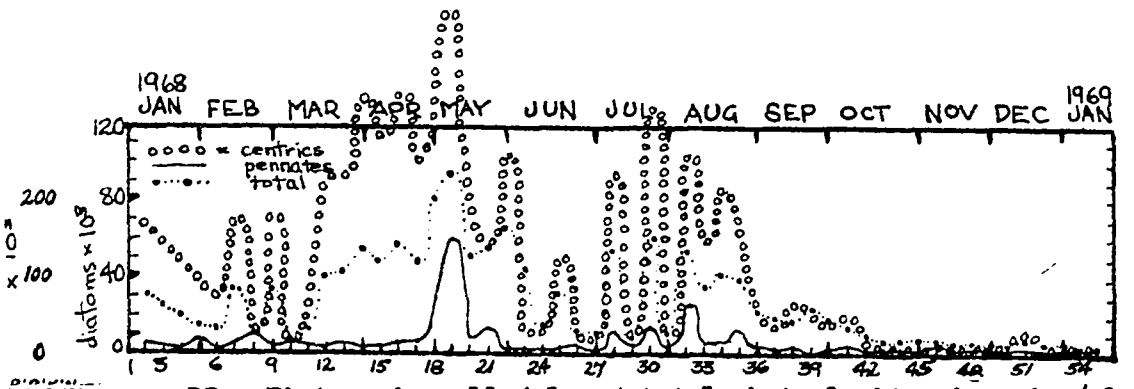

Figure 32. Diatoms in cells/ml and total phytoplankton in units/ml at Station 1

Table 4. Phytoplankton populations, Des Moines River at Station 1 in units/ml

Week	Sample	Total	Blue-green	
			Coccoid	Filamentous
	1968			
2	1/15	74,794	424	398
4	1/26	51,999	254	57
5	2/2	(no phytoplankton sample taken)		
6	2/9	33,673	113	57
7	2/16	79,242	339	85
8	2/23	22,352	141	28
9	3/1	81,078	226	85
10	3/8	17,211	170	0
11	3/15	37,812	339	28
12	3/22	103,037	480	57
13	3/29	107,106	622	339
14	4/5	140,084	735	28
15	4/12	130,928	452	85
16	4/20	152,435	707	0
17	4/27	117,900	961	0
18	5/3	203,057	791	0
19	5/10	281,074	820	28
20	5/17	122,536	820	0
21	5/24	130,984	989	0
22	6/1	164,389	226	0
23	6/7	105,779	820	28
24	6/14	28,628	85	57
25	6/21	79,664	339	0
26	6/28	23,399	28	57
27	7/5	23,683	198	170
28	7/12	152,039	1,696	763
29	7/19	22,045	57	170
30	7/26	168,882	933	57

Green		Flagellates (pigmented)		Diatoms	
Coccoid	Filamentous	Green	Other	Centric	Pennate
1,639	2,035	3,193	0	66,794	311
254	1,639	848	0	48,890	57
		(no phytoplankton sample taken)			
367	254	976	85	31,651	170
1,351	820	2,289	0	73,759	594
1,441	565	4,832	0	14,130	1,215
1,752	820	1,328	0	76,019	848
2,148	1,102	4,126	28	8,761	876
1,611	678	1,837	0	32,810	509
1,272	1,159	3,787	0	93,541	2,741
3,589	848	1,724	0	94,671	5,313
3,024	763	706	0	133,274	1,554
6,302	1,893	1,130	0	117,986	3,080
5,765	735	904	0	135,450	8,874
3,532	1,215	1,554	0	104,703	5,935
12,717	800	2,346	0	155,317	31,086
34,477	622	1,893	0	181,627	61,607
38,716	735	1,017	0	70,933	10,315
51,433	480	1,470	0	59,939	16,673
53,129	509	1,272	0	105,777	3,476
82,802	57	2,487	311	14,526	4,748
5,369	537	2,148	0	18,086	2,346
19,499	1,271	1,554	28	51,264	5,709
1,356	2,035	367	0	10,908	8,648
5,652	2,063	1,046	0	10,513	4,041
33,912	339	4,691	0	97,271	13,367
1,159	1,583	820	0	11,304	6,952
15,402	622	2,204	28	132,822	16,814

Table 4. (Continued)

Week	Sample	Total	Blue-green	
			Coccoid	Filamentous
31	8/2	25,548	820	254
32	8/9	153,677	1,074	3,193
33	8/16	83,453	848	1,837
34	8/23	109,565	2,430	1,809
35	8/29	94,444	3,504	622
36	9/4	48,692	848	537
37	9/12	41,316	1,017	85
38	9/18	37,643	933	735
39	9/25	53,215	509	1,470
40	10/2	41,456	763	3,532
41	10/10	36,174	396	2,346
42	10/16	23,541	226	2,402
43	10/23	6,078	85	565
44	10/30	10,147	170	3,928
45	11/7	12,235	706	3,843
46	11/13	12,407	989	1,413
47	11/21	6,642	170	820
48	11/28	10,739	254	452
49	12/5	10,936	141	622
50	12/11	11,304	141	170
51	12/19	17,775	565	452
52	12/26	7,630	311	339
	1969			
53	1/2	6,132	198	254
54	1/9	3,363	735	678
55	1/15	3,787	509	1,102

Green		Flagellates (pigmented)		Diatoms	
Coccoid	Filamentous	Green	Other	Centric	Pennate
3,109	1,272	1,074	0	12,971	6,048
9,608	113	1,978	0	109,451	28,260
10,824	339	1,837	0	59,855	7,913
8,535	0	1,696	0	87,889	7,206
12,321	170	1,356	0	63,387	13,084
11,869	141	1,667	0	26,282	7,348
19,641	28	1,074	0	15,882	3,589
2,006	0	1,300	0	26,847	5,822
25,010	57	876	0	23,484	1,809
14,271	424	2,543	0	16,956	2,967
3,448	509	932	0	21,704	6,839
4,804	1,583	1,300	0	8,478	4,748
678	85	1,243	0	2,148	1,272
1,357	537	1,526	0	1,583	1,046
1,243	537	2,006	0	2,798	1,102
848	735	1,809	0	5,850	763
396	28	706	57	4,069	396
283	198	622	28	8,252	650
763	141	396	28	7,828	1,017
735	141	509	0	9,467	141
1,526	57	1,328	0	13,084	763
678	57	791	28	5,426	198
452	57	593	0	4,013	565
339	0	565	0	650	396
424	0	650	28	820	254

D. Diatom Analyses

Table 5 lists the 184 taxa of diatoms encountered in this study. A symbol is used to indicate when a given taxon has been reported previously from the Des Moines River. The taxa encountered were distributed among 34 genera. Eighty-five had not been previously reported from the Des Moines River. Two genera, Peronia and Biddulphia, have not been reported from Iowa heretofore.

Reference numbers of voucher slides are recorded for each diatom identification. Sample slide voucher specimens had to be used instead of bona fide voucher slides when no other specimen could be found. Thus, it may be safely assumed that those taxa vouched for by sample slides were probably rare in this river's plankton.

Ten of the more important diatoms encountered in this study were selected on the basis of their relative numerical abundance. They are listed in Table 6 which gives their proportional number (out of 300) for each week.

In a further consideration of these data, the proportions of the three main genera of centric diatoms (Stephanodiscus, Cyclotella, and Melosira) are compared with the total for all pennate diatoms (Figure 33).

Table 5. Diatom taxa found in the upper Des Moines River plankton

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Achnanthes lanceolata var. dubia Grun.	6/14/68-1H	PR 66	D
Amphiprora ornata Bailey	1/15/68-1EE	Hu 30	B
Amphora delicatissima Krasske	3/8/68-1C	Hu 30	
Amphora Normani Rabh.	10/16/68-1A	Hu 30	
Amphora ovalis Kütz.	10/6/68-1B	Hu 30	AB
Asterionella formosa Hass.	5/3/68-1[c]	PR 66	AB
Biddulphia laevis Ehr.	11/14/68-1A	VH 80	
Caloneis amphisbaena (Bory) Cl.	1/15/68-1F	PR 66	B
Caloneis bacillaris var. thermalis (Grun.) A. Cl.	1/15/68-1UU	PR 66	
Caloneis bacillum (Grun.) Cl.	3/8/68-1DD	PR 66	BD
Caloneis lewisii Patr.	4/20/68-1I	PR 66	ABC
Caloneis limosa (Kütz.) Patr.	10/16/68-1G	PR 66	

[a]Identification source symbols: DS 62 = Dodd and Stoermer, 1962; Hu 30 = Hustedt, 1930; Hu 49 = Hustedt, 1949; PR = Patrick and Reimer, 1966; Sc 77 = Schmidts Atlas, 1877-1944; St 64 = Stoermer, 1964; US 66 = U.S. Department of the Interior. FWPCA, 1966; VH 80 = Van Heurck, 1880-1881.

[b]Symbols for "also reported by": A = Starrett and Patrick, 1952; B = Drum dissertation, 1964; C = Stoermer, 1964; D = Fee and Drum, 1965.

[c]Sample slides have no letters following the date and station number.

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Caloneis ventricosa var. alpina (Cl.) Patr.	11/13/68-1E	PR 66	
Caloneis ventricosa var. minuta (Grun.) Patr.	5/17/68-1G	PR 66	
Caloneis ventricosa var. truncatula (Grun.) Meist.	5/17/68-1C	PR 66	
Cocconeis placentula var. lineata (Ehr.) V. H.	1/15/68-1V	PR 66	
Cocconeis rugosa Sov.	1/15/68-1C	PR 66	
Coscinodiscus rothii (Ehr.) Grun.	6/14/68-1D	Hu 30	
Cyclotella atomus Hust.	4/20/68-1M	US 66	BD
Cyclotella comta (Ehr.) Kütz.	2/9/68-1D	Hu 30	
Cyclotella kutzingiana var. planetophora Fricke	7/18/68-1B	Hu 30	
Cyclotella meneghiniana Kütz.	1/15/68-1D	Hu 30	AB
Cyclotella meneghiniana var. laevissima (van Goor) Hust.	1/15/68-1R	Hu 30	
Cyclotella michiganiana Skvortzow	4/20/68-1A	US 66	
Cyclotella ocellata Pant.	3/8/68-2	Hu 30	
Cyclotella pseudostelligera Hust.	3/29/68-2	US 66	B
Cymatopleura elliptica var. constricta Grun.	11/13/68-1H	Hu 30	
Cymatopleura elliptica var. nobilis (Hantzsch) Hust.	10/16/68-1C	Hu 30	

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Cymatopleura solea (Brébisson) W. Smith	2/9/68-1B	Hu 30	AB
Cymatopleura solea var. regula (Ehr.) Grun.	1/15/68-1X	Hu 30	
Cymbella aequalis W. Smith	11/13/68-1C	Hu 30	
Cymbella aspera (Ehr.) Cleve	1/15/68-1AA	Hu 30	
Cymbella sinuata Gregory	9/18/68-1H	Hu 30	B
Cymbella tumida (Brébisson) Van Heurck	4/20/68-1K	Hu 30	BD
Cymbella turgida (Gregory) Cleve	3/8/68-1G	Hu 30	
Cymbella ventricosa Kütz.	4/20/68-1E	Hu 30	BD
Diatoma tenue var. elongatum Lyngbe	4/26/68-1A	PR 66	
Diatoma vulgare Bory	3/8/68-1B	PR 66	AB
Diatoma vulgare var. breve Grun.	1/15/68-1JJ	PR 66	
Diploneis sp.	10/6/68-1A		
Epithemia sorex Kütz.	1/15/68-1E	Hu 30	B
Epithemia turgida (Ehr.) Kütz.	1/15/68-1BB	Hu 30	AB
Epithemia turgida var. granulata (Ehr.) Grun.	10/16/68-1F	Hu 30	
Epithemia zebra var. saxonica (Kütz.) Grun.	11/13/68-1B	Hu 30	B

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Fragilaria brevistriata var. capitata Herib.	3/8/68-1K	PR 66	
Fragilaria capucina var. mesolepta Rabh.	8/16/68-5A	PR 66	B
Fragilaria crotonensis Kitton	7/12/68-1B	PR 66	B
Fragilaria leptostauron var. dubia (Grun.) Hust.	1/15/68-1RR	PR 66	
Fragilaria vaucheriae (Kütz.) Peters	3/8/68-1J	PR 66	B
Frustulia vulgaris (Thwaites) Det.	3/8/68-1S	PR 66	AB
Frustulia weinholdii Hust.	5/10/68-2	PR 66	
Gomphonema angustatum (Kütz.) Rabh.	10/16/68-1E	Hu 30	
Gomphonema angustatum var. producta Grun.	3/8/68-1P	Hu 30	
Gomphonema constrictum Ehr.	6/14/68-1A	Hu 30	B
Gomphonema lanceolatum Ehr.	7/12/68-1M	Hu 30	B
Gomphonema longiceps var. subclavata fo. gracilis Hust.	11/13/68-1G	Hu 30	B
Gomphonema olivaceum (Lyngbye) Kütz.	5/17/68-1R	Hu 30	AB
Gomphonema parvulum var. lagenula (Kütz. ? Grun.) Hust.	9/18/69-1F	Hu 30	
Gomphonema parvulum var. micropus (Kütz.) Cleve	10/16/68-1E	Hu 30	AB

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Gyrosigma acuminatum (Kütz.) Rabh.	1/15/68-1G	PR 66	AB
Gyrosigma scalproides (Rabh.) Cl.	4/20/68-1I	PR 66	ABD
Gyrosigma spencerii (Quck.) Griff. and Henfr.	4/20/68-1F	PR 66	
Gyrosigma spencerii var. curvula (Grun.) Reim.	1/15/68-1NN	PR 66	
Hantzschia amphioxys (Ehr.) Grun.	5/17/68-1J	Hu 30	AB
Hantzschia amphioxys fo. capitata O. Müll.	12/19/68-1A	Hu 30	
Melosira ambigua (Grun.) O. Müll.	5/17/68-1K	Hu 30	AB
Melosira binderana Kütz	5/10/68-4	Hu 30	
Melosira granulata (Ehr.) Ralfs	4/20/68-1J	Hu 30	ABD
Melosira granulata var. angustissima Müll.	1/15/68-1Y	Hu 30	ABD
Melosira granulata var. muzzanensis Meister	5/10/68-2B	Hu 30	B
Melosira italica (Ehr.) Kütz.	4/20/68-1D	Hu 30	
Melosira italica var. tenuissima (Grun.) O. Müll.	1/15/68-1E	Hu 30	B
Meridion circulare var. constrictum (Ralfs) V.H.	3/8/68-1C	PR 66	

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Navicula arvensis Hust.	3/15/68-1	PR 66	
Navicula canalis Patr.	5/17/68-1L	PR 66	B
Navicula capitata Ehr.	3/8/68-1Z	PR 66	
Navicula capitata var. hungarica (Grun.) Ross	1/15/68-1Q	PR 66	
Navicula cincta (Ehr.) Kütz.	3/8/68-1F	Hu 30	B
Navicula circumtexta Meist. ex Hust.	4/26/68-4	PR 66	BC
Navicula cryptocephala var. veneta (Kütz.) Rabh.	6/14/68-1B	PR 66	B
Navicula cuspidata (Kütz.) Kütz.	10/6/68-1D	PR 66	AB
Navicula cuspidata var. major Meist.	10/2/68-1	PR 66	
Navicula decussis Østr.	3/8/68-1M	PR 66	BC
Navicula elginensis (Greg.) Ralfs	8/16/68-1D	PR 66	
Navicula exigua var. capitata Patr.	5/17/68-1E	PR 66	AC
Navicula gibbula Cleve	3/8/68-1D	Hu 30	
Navicula gottlandica Grun.	4/20/68-1B	PR 66	
Navicula heufleri var. leptocephala (Bréb. ex Grun.) Patr.	3/8/68-1T	PR 66	

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Navicula lanceolata var. cymbula (Donk.) Cleve	9/18/68-1E	St 64	C
Navicula minima Grun.	3/8/68-1BB	Hu 30	B
Navicula mournei Patr.	1/15/68-1A	PR 66	
Navicula mutica Kütz.	5/17/68-1D	DS 62	
Navicula pupula Kütz.	6/14/68-1M	PR 66	AB
Navicula pupula var. elliptica Hust.	3/8/68-1J	PR 66	
Navicula pupula var. rectangularis (Greg.) Grun.	10/16/68-1C	PR 66	
Navicula pygmaea Kütz.	5/17/68-1H	PR 66	AB
Navicula rhynchocephala var. amphiceros (Kütz.) Grun.	2/9/68-1C	PR 66	
Navicula rhynchocephala var. germainii (Wallace) Patr.	1/15/68-1J	PR 66	
Navicula salinarum Grun.	1/15/68-1A	PR 66	
Navicula salinarum var. intermedia (Grun.) Cleve	3/8/68-1U	PR 66	
Navicula tripunctata (O. F. Müll.) Bory	6/14/68-1E	PR 66	BD
Navicula tripunctata var. schizonemoides (V.H.) Patr.	1/15/68-1VV	PR 66	B
Navicula viridula var. avenacea (Bréb. ex Grun.) V. H.	1/15/68-1QQ	PR 66	

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Navicula viridula var. rostellata (Kütz ?) Cl.	10/16/68-1D	PR 66	
Neidium affine var. amphirhynchus (Ehr.) Cl.	5/17/68-1I	PR 66	A
Neidium affine var. hankense (Skv.) Reim.	10/6/68-1E	PR 66	
Neidium dubium (Ehr.) Cl.	6/14/68-1M	PR 66	AB
Neidium iridis (Ehr.) Cl.	5/17/68-1F	PR 66	AB
Neidium ladogense var. densestriatum (Østr.) Foged	6/14/68-1I	PR 66	
Nitzschia accomodata Hust.	3/8/68-1R	Hu 49	B
Nitzschia acicularis W. Sm.	1/26/68-1A	Hu 30	BD
Nitzschia amphibia Grun.	3/8/68-1I	Hu 30	ABD
Nitzschia angustata (W. Smith) Grun.	1/15/68-1N	Hu 30	
Nitzschia apiculata (Gregory) Grun.	3/8/68-1N	Hu 30	ABD
Nitzschia capitellata Hust.	1/15/68-1SS	Hu 30	
Nitzschia closterium var.	9/18/68-1A	Hu 30	A
Nitzschia commutata Grun.	3/8/68-1AA	Hu 30	B
Nitzschia dissipata (Kütz.) Grun.	1/15/68-1M	Hu 30	ABD
Nitzschia epiphitica O. Müll.	10/6/68-1G	Hu 49	
Nitzschia filiformis (W. Smith) Hust.	3/8/68-1V	Hu 30	B

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Nitzschia fonticola Grun.	7/12/68-1L	Hu 30	B
Nitzschia gracilis Hantzsch	1/15/68-1DD	Hu 30	B
Nitzschia hantzschiana Rabh.	9/18/68-1G	Hu 30	
Nitzschia holsatica Hust.	1/15/68-1P	Hu 49	
Nitzschia hungarica Grun.	1/15/68-1CC	Sc 77	AB
Nitzschia ignorata Krasske	3/8/68-1X	Hu 30	B
Nitzschia intermedia Hantzsch	3/8/68-1EE	Hu 49	
Nitzschia intermissa Hust.	2/9/68-1A	Hu 49	
Nitzschia linearis W. Smith	4/20/68-1Q	Hu 30	ABD
Nitzschia obtusa W. Smith	1/15/68-1PP	Hu 30	
Nitzschia palea (Kütz.) W. Smith	1/15/68-1O	Hu 30	ABD
Nitzschia palea var. tropica Hust.	8/16/68-1A	Hu 49	
Nitzschia recta Hantzsch	1/15/68-1K	Hu 30	BD
Nitzschia robusta Hust.	8/16/68-1C	Hu 49	
Nitzschia sigma (Kütz.) W. Smith	1/15/68-1S	Hu 30	AB
Nitzschia sigmoidea (Ehr.) W. Smith	4/20/68-1R	Hu 30	AB
Nitzschia spiculoides Hust.	2/23/68-1	Hu 49	B
Nitzschia sublinearis Hust.	1/15/68-1I	Hu 30	

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Nitzschia tarda Hust.	7/12/68-1A	Hu 49	B
Nitzschia thermalis Kütz.	4/20/68-1G	Hu 30	B
Nitzschia tropica Hust.	3/8/68-1A	Hu 49	
Nitzschia tryblionella var. debilis (Arnott) A. Mayer	10/16/68-1C	Hu 30	BD
Nitzschia tryblionella var. levidensis (W. Sm.) Grun.	8/16/68-1B	Hu 30	B
Peronia fibula (Bréb. ex Kütz.) Ross	6/14/68-1J	PR 66	
Pinnularia abaujensis var. linearis (Hust.) Patr.	11/13/68-1I	PR 66	
Pinnularia borealis Ehr.	11/7/68-1	PR 66	B
Pinnularia brebissonii (Kütz.) Rabh.	1/15/68-1II	PR 66	A
Pinnularia microstauron (Ehr.) Cleve	3/8/68-1Q	PR 66	B
Pinnularia rupestris Hantz.	10/16/68-1A	PR 66	
Pleurosigma salinarum Grun.	9/18/68-1D	PR 66	
Rhoicosphenia curvata (Kütz.) Grun. ex Rabh.	6/14/68-1C	PR 66	
Rhopalodia gibba (Ehr.) O. Müll.	3/8/68-3	Hu 30	AB
Rhopalodia gibberula var. van heurckii O. Müll	6/14/68-1G	Hu 30	B
Stauroneis anceps Ehr.	5/17/68-1Q	PR 66	B
Stauroneis smithii Grun.	10/6/68-1F	PR 66	AB

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Stephanodiscus astraea (Ehr.) Grun.	1/15/68-1GG	Hu 30	ABD
Stephanodiscus astraea var. intermedia Fricke	1/15/68-1Z	Hu 30	
Stephanodiscus astraea v. minutula (Kütz.) Grun.	1/15/68-1B	Hu 30	ABD
Stephanodiscus dubius (Fricke) Hust.	10/16/68-1F	Hu 30	B
Stephanodiscus hantzschii Grun.	1/15/68-1U	Hu 30	BD
Stephanodiscus invisitatus Hohn	1/15/68-1AA	US 66	
Stephanodiscus niagarae Ehr.	4/20/68-1 0	US 66	ABCD
Surirella angustata Kütz.	1/15/68-1C	Hu 30	ABD
Surirella brightwellii W. Sm.	10/6/68-1C	US 66	B
Surirella gracilis (W. Smith) Grun.	3/8/68-1CC	Hu 30	B
Surirella ovata Kütz.	1/15/68-1L	Hu 30	AB
Surirella robusta var. splendida (Ehr.) V. H.	10/16/68-1B	Hu 30	AB
Surirella tenera Gregory	8/16/68-1G	Hu 30	A
Synedra acus Kütz.	1/15/68-1TT	PR 66	ABD
Synedra amphicephala Kütz.	1/15/68-1WW	PR 66	B

Table 5. (Continued)

Taxon	Voucher slide	Ident. source[a]	Also rep. by[b]
Synedra amphicephala var. austriaca (Grun.) Hust.	3/8/68-1H	PR 66	
Synedra delicatissima W. Sm.	5/17/68-1M	PR 66	
Synedra gaillonii (Bory) Ehr.	8/16/68-5B	PR 66	B
Synedra radians Kütz.	1/15/68-1MM	PR 66	A
Synedra rumpens Kütz.	1/15/68-1W	PR 66	B
Synedra socia Wallace	3/8/68-1L	PR 66	
Synedra ulna (Nitz.) Ehr.	1/15/68-1A	PR 66	ABD
Synedra ulna var. chaseana Thomas	11/13/68-1D	PR 66	
Synedra ulna var. longissima (W. Sm.) Brun.	7/12/68-1I	PR 66	
Synedra ulna var. obtusa V. H.	1/15/68-1A	PR 66	
Synedra ulna var. oxyrhynchus (Kütz.) V. H.	1/15/68-1LL	Hu 30	
Synedra ulna var. spathulifera (Grun.) V. H.	5/17/68-1B	PR 66	
Synedra ulna var. subaequalis (Grun.) V. H.	6/14/68-1F	PR 66	
Thalassiosira fluviatilis Hust.	6/14/68-1L	Hu 30	B

Table 6. Comparison of numbers of the 10 most important taxa of diatoms found in diatom proportional counts of Station 1 slides[a]

Cyclotella			Melosira				Stepha	WEEK	Nitzschia			Synedra
atom	mene	mich	gr	an	it	te	hant		acic	hols	pale	deli
							297	2				
							297	4				
38							256	6		1	2	
							295	7				
	7						278	8	1			
							286	9	1		2	
			1				262	10		3		
	2		1				256	11		10	2	
	1		1				262	12	2	7	3	
			13				248	13	3	9	2	
			2				275	14	1	2		
2			2				268	15	3		2	
6		4	9				238	16	7	3	2	
3	5	4	1				240	17	2	12	2	
3	2		1				223	18	28	5	5	
8	18	5	1				203	19	18		4	
5	25		7				219	20	5	7	5	
25	8		3				217	21	18	4	1	
7			8				217	22	15	9	3	3
6	25	3	3				182	23	26	20	2	2
18	21	1	106				92	24	1	10		4
41	54	21	20				102	25	8	15	3	
12	37	18	15				107	26	1	4	2	
18	45	5	71		7		77	27	4	10	1	
142	80	4	31				23	28	4	2	8	
117	26	7	10				53	29			8	
211	17	6	39				6	30	1	5	3	

[a] Taxa listed in order are: Cyclotella atomus, C. meneghiniana, C. michiganiana, Melosira granulata var. angustissima, M. italica var. tenuissima, Stephanodiscus hantzschii, Nitzschia acicularis, N. holsatica, N. palea, and Synedra delicatissima.

Cyclotella			Melosira				Stepha	WEEK	Nitzschia			Synedra
atom	mene	mich	gr	an	it	te	hant		acic	hols	pale	deli
89	36	13	40		4		32	31	5	16	19	
238	12	5	19				6	32	1		8	
137	14	17	55		25		22	33		1		
49	12	13	177		1		4	34		1	1	
121	26	15	63		14		7	35	13	6	4	
120	8	33	121		4		5	36	3			
239	4	20	7		5		15	37	1		1	
185	9	23	16		9		41	38			3	
78	34	54	33		28		49	39		6		
25	10		81		52		35	40		6		
80	18	11	28		38		48	41		3	2	
88	10	21	30		28		56	42	2	1	4	8
70	18	17	9				77	43	1	3		3
62	23	19	22		6		58	44		17		
30	13	6	5		2		120	45	2	53		
15	8	2	9		3		190	46	3	23	4	1
17	4	4	3				170	47	11	23	3	10
3	4	2	2				237	48	6	1	6	6
5	6	2					224	49	9	4	4	10
6	3		1		5		248	50	2	2	1	1
5	1						269	51	4	1		2
23	1						249	52	2			15
63	2						218	53	3			12
35	3						204	54	5	3	1	26
83							177	55	1	2		12

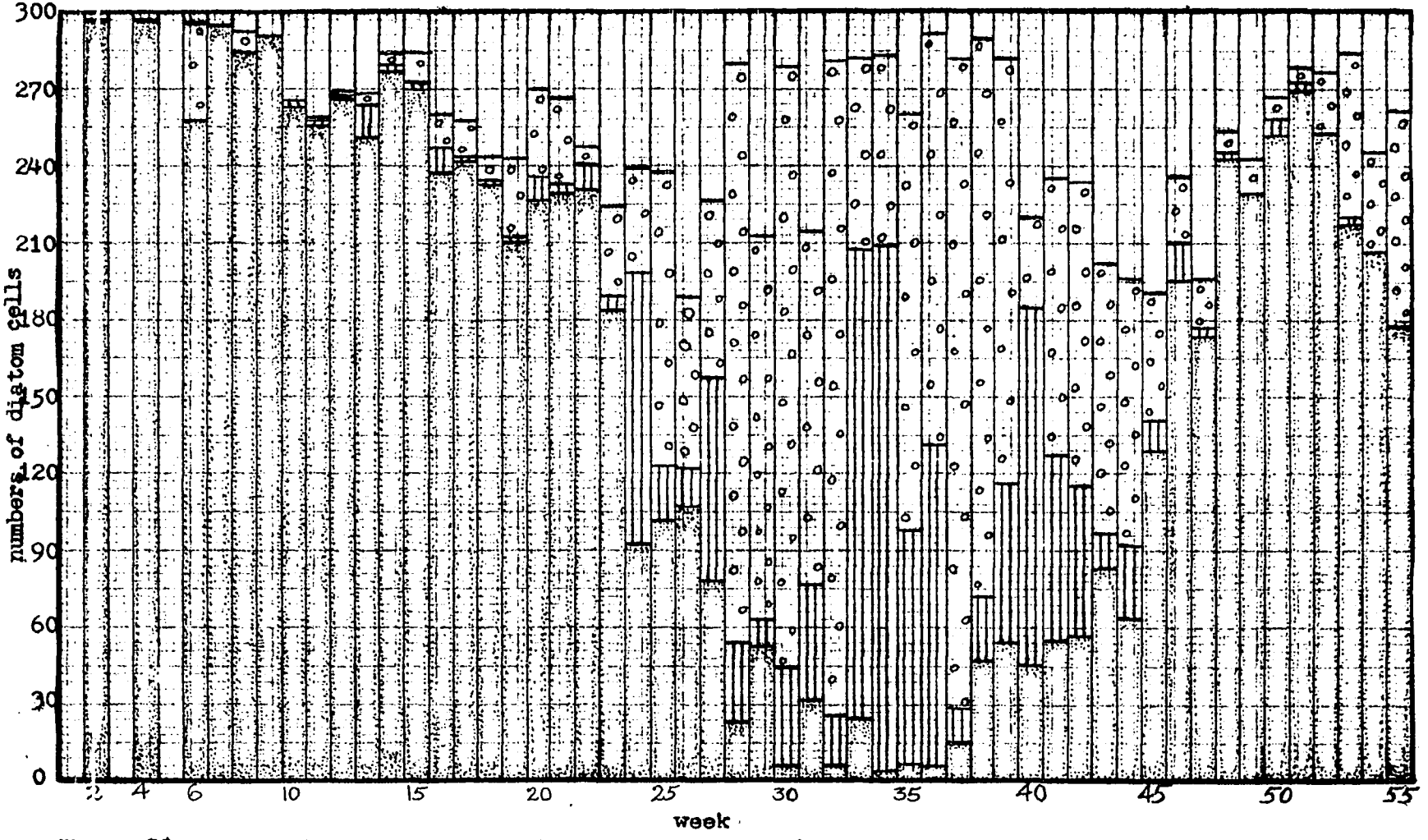

Figure 33. Proportions of Stephanodiscus sp.(stippled), Melosira sp.(striped), Cyclotella sp. (with circles) and pennate diatoms (plain) in diatom proportional counts at Station 1

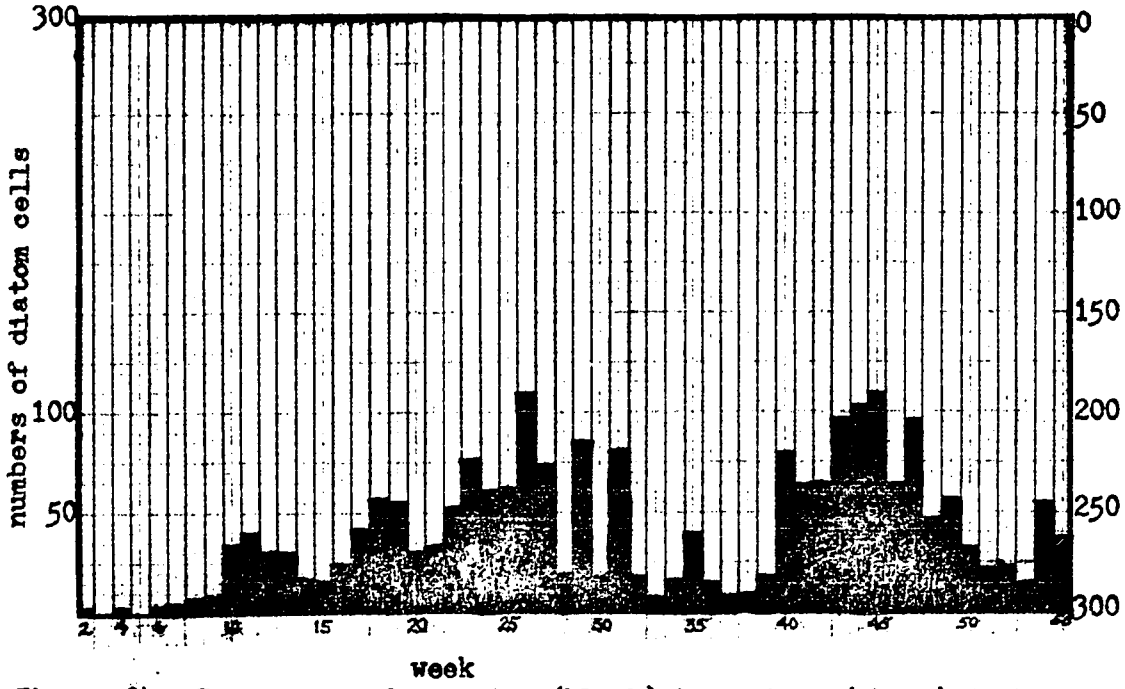

Figure 34. Proportion of pennates (black) to centric (white) diatoms in diatom proportional counts at Station 1

Proportional analyses of centric and pennate diatoms, based on a total of 300 per slide, were made of the Hyrax mounted diatom populations. These data are presented in Table 7, Figures 33 and 34. As the basis for a possible comparison of counting methods, similar proportional analyses, derived from the Sedgewick-Rafter data, are included in Table 7.

Centrics were always the most abundant group (Figure 34), increasing in species diversity in the summer (Table 6), with different species "blooming" in succession. Pennate numbers exceeded 100 on only three sample dates, and were over 75 on only nine dates (at Station 1).

Table 7. Relative numbers of centric and pennate diatoms determined in Sedgewick-Rafter and diatom proportional counts

Week	Sample	Sedgewick-Rafter counts			
		Centrics	Pennates	Total diatoms	Percent centrics
	1968				
1	1/5	(no phytoplankton sample taken)			
2	1/12	66,794	311	67,105	99.5
3	1/19	(no phytoplankton sample taken)			
4	1/26	48,890	57	48,947	99.9
5	2/2	(no phytoplankton sample taken)			
6	2/9	31,651	170	31,821	99.5
7	2/16	73,759	594	74,353	99.2
8	2/23	14,130	1,215	15,345	92.1
9	3/1	76,019	848	76,867	98.9
10	3/8	8,761	876	9,637	90.9
11	3/15	32,810	509	33,319	64.5
12	3/22	93,541	2,741	96,282	97.2
13	3/29	94,671	5,313	99,984	94.7
14	4/5	133,274	1,554	134,828	98.8
15	4/12	117,986	3,080	121,066	97.5
16	4/20	135,435	8,874	144,309	93.8
17	4/26	104,703	5,935	110,638	94.6
18	5/3	155,317	31,086	186,403	83.3
19	5/10	181,627	61,607	243,234	74.7
20	5/17	70,933	10,315	81,248	87.3
21	5/24	59,939	16,673	76,612	78.2
22	6/1	105,777	3,476	109,253	96.8
23	6/7	14,526	4,748	19,274	75.4
24	6/14	18,086	2,346	20,432	88.5
25	6/21	51,264	5,709	56,973	90.0
26	6/28	10,908	8,648	19,556	55.8
27	7/5	10,513	4,041	14,554	72.2
28	7/12	97,271	13,367	110,638	87.9
29	7/19	11,304	6,952	18,256	61.9
30	7/27	132,822	16,814	149,636	88.8

Diatom proportional counts			
Percent centrics	Total diatoms	Centrics	Pennates
	(no phytoplankton sample taken)		
99.0	300	297	3
	(no phytoplankton sample taken)		
99.0	300	297	3
	(no phytoplankton sample taken)		
98.6	300	296	4
98.3	"	295	5
97.3	"	292	8
97.0	"	291	9
88.3	"	265	35
86.3	"	259	41
89.7	"	269	31
89.7	"	269	31
94.3	"	283	17
94.7	"	284	16
91.7	"	275	25
85.7	"	257	43
81.0	"	243	57
81.3	"	244	56
89.7	"	269	31
88.7	"	266	34
82.3	"	247	53
74.7	"	224	76
79.7	"	239	61
79.3	"	238	62
63.3	"	190	110
75.3	"	226	74
93.3	"	280	20
71.7	"	215	85
93.7	"	281	19

Table 7. (Continued)

Week	Sample	Sedgewick-Rafter counts			
		Centrics	Pennates	Total diatoms	Percent centrics
31	8/2	12,971	6,048	19,019	68.2
32	8/9	109,451	28,260	137,711	79.5
33	8/16	59,855	7,913	67,768	88.3
34	8/23	87,889	7,206	95,095	92.4
35	8/29	63,387	13,084	76,471	82.9
36	9/4	26,282	7,348	33,630	78.2
37	9/12	15,882	3,589	19,471	81.6
38	9/18	26,847	5,822	32,669	82.2
39	9/25	23,484	1,809	25,293	92.8
40	10/2	16,956	2,967	19,923	85.1
41	10/10	21,704	6,839	28,543	76.0
42	10/16	8,478	4,748	13,226	64.1
43	10/23	2,148	1,272	3,420	62.8
44	10/30	1,583	1,046	2,629	60.2
45	11/7	2,798	1,102	3,900	71.7
46	11/13	5,850	763	6,613	88.5
47	11/21	4,069	396	4,465	91.1
48	11/28	8,252	650	8,902	92.7
49	12/5	7,828	1,017	8,845	88.5
50	12/11	9,467	141	9,608	98.5
51	12/19	13,084	763	13,847	94.5
52	12/26	5,426	198	5,624	96.5
	1969				
53	1/2	4,013	565	4,578	87.7
54	1/9	650	396	1,046	62.1
55	1/15	820	254	1,074	76.4

Diatom proportional counts			
Percent centrics	Total diatoms	Centrics	Pennates
73.0	300	219	81
94.0	"	282	18
97.3	"	292	8
94.7	"	284	16
86.7	"	260	40
95.0	"	285	15
97.3	"	292	8
96.7	"	290	10
94.0	"	282	18
73.3	"	220	80
78.7	"	236	64
78.3	"	235	65
67.7	"	203	97
65.3	"	196	104
79.3	"	190	110
78.7	"	236	64
67.7	"	203	97
84.7	"	254	46
81.0	"	243	57
89.0	"	267	33
92.7	"	278	22
92.3	"	277	23
95.0	"	285	15
81.7	"	245	55
87.3	"	262	38

E. Midsummer Surge Sequence

During the months of June, July, and August (Weeks 28 to 31), a series of short-term, extreme surges in the volume of runoff water were recorded (see Figure 7). In an effort to evaluate some effects of these surges on the variables being considered, Table 8 was constructed. The symbols were chosen simply to illustrate trends and no numerical values are used in it.

F. Calculation of Phytoplankton Numbers and Biomass on a Monthly Basis

The approximate number of phytoplankters passing a station during each month can be calculated from phytoplankton density and the volume of streamflow during that month. For instance, in January 1968 at Station 1, the mean phytoplankton count was 5.2×10^4/ml and the total streamflow volume during the month was 5.6×10^{12} ml (4,540 acre-feet). Their product is 2.9×10^{17} phytoplankton units, which is a fair approximation of the number passing Station 1 that month.

To calculate the biomass, assume each phytoplankter to be 0.01 mm (10 μ) on each side, and thus 10^{-6} mm^3 in volume. Assume protoplasm to be 90 percent water and to have a specific gravity of 1, and the January biomass becomes

Table 8. Midsummer surge sequence at Station 1[a]

Sampling date	June 28	5	July 12	19	26	Aug 2	9
Week	26	27	28	29	30	31	32
Basin solar radiation	-	↗	+	-	+	↘	-
Streamflow	+	↘	-	+	-	+	↘
Factors varying with solar radiation							
Basin solar radiation	-	↗	+	-	+	↘	-
Water temperature	-	↗	+	-	+	-	↗
Total phytoplankton	-	-	+	-	+	-	+
Coccoid blue-greens	-	-	+	-	+	-	+
Filamentous blue-greens	-	-	+	-	↗	↗	+
Coccoid greens	-	↗	+	-	+	-	↗
Green flagellates	-	↗	+	-	+	-	+
Diatoms	-	-	+	-	+	-	+
Chlorophyll a	-	-	+	-	+	-	+
Chlorophyll b	+	-	+	↘	↘	-	+
Dissolved oxygen	-	↗	+	-	+	-	+
DO difference	-	-	+	-	+	-	+
Factors varying erratically							
BOD	↘	-	+	↘	↘	-	↗
COD	+	-	↗	+	↘	-	↗
Nitrate nitrogen	↗	+	↘	→	→	↘	↘
Factors varying with streamflow							
Streamflow	+	↘	-	+	-	+	↘
Turbidity	+	↘	-	+	-	+	+
Specific conductance	-	+	-	-	↗	+	-
Dissolved silica	↗	+	-	↗	↗	+	-
Orthophosphates	+	+	-	+	-	+	↘
Filamentous green algae	+	+	-	+	-	+	-
Pennate proportion	+	↘	-	+	-	+	↘

[a]Symbols: + maximum peak;
- minimum peak;
↗ ascending value;
↘ descending value;
→ steady at an intermediate value.

$$\frac{10^{-9}\ \text{g}}{\text{phytoplankton unit}} \times \frac{2.9 \times 10^{17}\ \text{ppkn units}}{\text{Jan 1968}} = \frac{2.9 \times 10^{8}\ \text{g}}{\text{Jan 1968}}$$

$$\frac{2.9 \times 10^{8}\ \text{g}}{\text{Jan 1968}} \times \frac{1\ \text{kg}}{10^{3}\ \text{g}} = \frac{2.9\ \text{kg biomass}}{\text{Jan 1968}} \times \frac{1\ \text{metric ton}}{10^{3}\ \text{kg}}$$

$$= \frac{2.9 \times 10^{2}\ \text{metric tons (dry weight) of plankton algae}}{\text{Jan 1968 at Station 1}}.$$

This estimate can be compared with the estimated mass of suspended sediment passing Station 5 that month: 2.0×10^{2} metric tons (U.S. Department of the Interior, 1969). In fact, it is probably what the USGS is measuring since most soil particles are frozen in place in January.

V. DISCUSSION

My original intention in making this study was to ascertain the quantity and fluctuations of upper Des Moines River phytoplankton populations during one year and, by using laboratory procedures developed and used by the Federal Water Pollution Surveillance System, have a solid basis of comparison with other rivers in the United States. Also, with the impoundment of Saylorville Reservoir imminent, I wanted to find out what magnitude of phytoplankton biomass might be flowing into it. Largely because of the volume of weekly data available to me, this study uncovers interesting aspects of these fluctuations.

A. The Upper Des Moines River: Calendar Year 1968

The autumn of 1967 was relatively dry, and so was the following year. There was a moderate thaw in late January and early February in Iowa and precipitation throughout the basin was limited. As a result, customary spring flooding did not occur; March flows were only 15 percent of normal median flows at Station 1 (Table 2). During this three-month period, the concentration of dissolved solids (including orthophosphates) and dissolved oxygen were high, and phytoplankton was at a higher density than during the following winter which had normal flows (six times larger). Streamflow, water temperature, and turbidity were low, as well as

the density of suspended sediment (probably because flow consisted mainly of groundwater). Many changes began to occur in the river immediately after the ice melted (around 7 March 1968). Water temperature, COD, BOD, chlorophyll *a*, and the total phytoplankton count started to rise then.

Compared to most other rivers of the world (Table 1a), the Des Moines River is highly calcareous. According to Williams (1964), high calcium hardness is often associated with high plankton density. Phytoplankton population densities are relatively high at all seasons of the year in the upper Des Moines compared both with itself 21 years ago (Starrett and Patrick, 1952) and with other rivers in this country (U.S. Department of Health, Education, and Welfare, 1963).

Phytoplankton density fluctuated between 100,000 and 150,000 units/ml from 22 March to 27 April, varying in most cases as the values of solar radiation varied. The latter rose sharply to its second-highest peak between 27 April and 3 May, and the phytoplankton count was up to 200,000 on 3 May and 280,000 (its 1968 peak) on 10 May. During those two weeks, nitrate nitrogen, orthophosphate and dissolved silica concentrations went down to very low (sometimes zero) values, BOD was at its second highest peak, and COD at its fifth highest peak.

During the surges of runoff in midsummer, disturbances occurred in most of the variables (see Table 8). Some

changes were caused directly by the rains that produced the surges. This surge sequence offered an excellent opportunity to see how quickly the other variables responded, qualitatively and quantitatively, to these sudden changes.

Due to heavy rains in southern Minnesota, streamflow volume surged to the 1968 peak of 223 m^3/sec on 23 October while turbidity rose gradually. Water temperature dropped 3 centigrade degrees in one week (2-10 October) as mean basin solar radiation dropped 1000 g·cal/cm^2 and the great volume of cooler runoff flowed from the northern reaches. Phytoplankton counts dropped steadily from a small Station 1 peak of 53,000/ml in late September to 6,000/ml on 23 October. There was a slight rise to around 10,000/ml until mid-December when it rose to 17,000/ml. Ice cover at Station 1 was 5 percent on 11 December and 100 percent on 19 December. From the third week in December until the end of the study on 15 January 1969, the density dropped from 7,500/ml to approximately 4,000/ml.

B. Comparison with the Upper Des Moines River of 1946-1947

There is evidence that the river has undergone great changes in the algal flora since Starrett and Patrick (1952) made their study. The river then carried considerably more blue-green algae and much less total phytoplankton than it did in 1968. They state that Microcystis aeruginosa was the

main summer plankter (38.5 percent of the count). It was rare in the 1968 summer samples. Diatoms were their main plankters at all other seasons, which agrees with my 1968 data.

Total counts recorded by them were much lower, ranging from 0.3/ml on 1 March 1947 to 47.6/ml on 2 November 1946. The 1968 range is from 3,363/ml (9 January 1969) to 281,074/ml (10 May 1968), approximately 10,000 times greater now. However, this difference must be somewhat smaller, because the plankton net they used (No. 20) must have permitted most of the small centrics (approximately 10 μ x 10 μ) to pass through its 76 μ apertures. Therefore, no valid comparison is possible between our sets of data on total phytoplankton numbers.

Asterionella formosa var. subtilissima was considered the typical spring plankter in 1946 and 1947. It did not appear in any of the 1968 samples.

Zooplankters were scarce then as they are now.

It is possible that the change from many blue-greens to few is related to raising of the phosphate content of the river. Fogg (1969) noted that blue-green algae can be inhibited by such increases. No data on phosphates were given by Starrett and Patrick but synthetic detergents, many of which have phosphates for "filler" material, began coming into use gradually in the mid-1940's, and began to increase available phosphates in the rivers. Much more phosphate is

available now in waters which carry effluents from human populations than in the pre- or early-detergent period. It is possible that such concentrations of phosphate not only suppress the growth of blue-greens but also now remove a former limiting factor on the growth of most other forms of algae.

Comparing the upper Des Moines with rivers sampled by the Water Pollution Surveillance System could not be done. No sample point in the Midwest was as close to a river's source and within a similar climatic zone.

C. Problems of Relating Chlorophyll Analyses to Sedgewick-Rafter Counts

Inspection of data obtained by analyzing chlorophyll extracts spectrophotometrically showed a poor agreement with phytoplankton fluctuations as determined by Sedgewick-Rafter counts.

It has long been known that phytoplankton counts alone are difficult to relate to the larger problems of water quality. Since all photosynthesizing algae contain chlorophyll *a*, it is a useful first assumption that a direct measure of the total amount of chlorophyll *a* in a sample would bear a direct relation to the number of algae present. However, any given cell may vary considerably in the amount of chlorophyll *a* actually present due to various physiological as well as genetic factors. Exposure to intense insolation at the water surface, for instance, may result in a given

cell's having a reduced chlorophyll a content compared to a similar cell existing at a deeper level in the same environment. On another basis, if the availability of iron should become critical, the rate of chlorophyll production in a population would be greatly inhibited.

Blue-green algae lack chlorophyll b but, during this study, the numbers of blue-green algae in the Des Moines River were not great enough to effect rough estimates of a ratio between chlorophylls a and b. On the other hand, the proportion between diatoms and green algae constantly changed during the year. Diatoms contain chlorophylls a and c but not b. Reliable techniques for extracting chlorophyll c were not available and thus no values for this were obtained. Again, however, the ratio between chlorophylls a and b would be expected to change with the fluctuations in diatom/green algae ratios. Most significant of all is the fact that there is as yet no simple, reliable and easy-to-use technique for relating the numbers obtained in making plankton counts to the mass of functional photosynthetic protoplasm in the various species.

Thus, one cannot reasonably expect a usable correlation between plankton counts and chlorophyll extract assays from non-laboratory populations. This assumption is borne out by the lack of any clearly discernible pattern in the scatter diagram, Figure 25.

D. Pollution-tolerant Species

Palmer (1969) listed 80 species of algae which are considered to be tolerant of organic pollution. This does not mean that these species are restricted to polluted waters, but if species from the list are dominants in a given habitat, it would suggest the possibility of a significant level of pollution.

In the present study, at least 63 taxa of algae were encountered in addition to the 184 diatom taxa. Of these, 27 species are also included in Palmer's list of pollution-tolerant species. Of this group, only the following have occurred more than occasionally: Scenedesmus quadricauda, Cyclotella meneghiniana, Stephanodiscus hantzschii, Actinastrum hantzschii, and Scenedesmus acuminatum.

E. Diatom Identifications and Counts

My identifications resulted in a total of 184 species, varieties and forms (in 34 genera), 85 of which have not been reported by previous investigators of the Des Moines River. Eighty-four taxa of the 184 are listed as principal U.S. plankton diatoms by Williams and Scott (1962). Two genera I found, Perc[illegible] and Biddulphia have not been reported for Iowa heretofore.

Seasonal variations among the ten dominant diatom species can be followed in Table 6, and the changing proportions of Stephanodiscus, Melosira, and Cyclotella are

shown in Figure 34.

Table 7 was set up to compare results of Sedgewick-Rafter and diatom-proportional counts. Inspection of the table indicate the two methods compare favorably.

F. Summary

1. Phytoplankton population densities are relatively high at all seasons of the year in the upper Des Moines compared both with itself 21 years ago and with other rivers in this country.
2. When this river's dominant phytoplankters are compared with those consistently found in organically polluted waters (Palmer, 1969), relatively few of the organisms commonly encountered are also on his list of the 80 most pollution-tolerant species.
3. The July 1968 series of surges presented an excellent opportunity to see what high streamflow and turbidity, coupled with low solar radiation and temperature do to various groups of phytoplankters. Trends in the data collected during this short period of fluctuations are noted in Table 8. They will be studied more thoroughly at a later date.
4. A total of 184 diatom taxa were identified. These were in 34 genera, with Biddulphia laevis Ehr. and Peronia fibula (Bréb. ex Kütz.) Ross new to Iowa records.

5. Comparison with the data of Starrett and Patrick, based on material collected in 1946-47 indicates that the algal flora has changed considerably in the river. The most notable change is the decrease in numbers of blue-green algae. This may be due to an inhibition caused by increased phosphate levels.
6. Differences among the five sampling stations appear insignificant, so Station 1 data are used almost entirely, since phytoplankton samples were taken there every week.
7. The comparatively greater numbers of individuals as well as species reported herein probably reflect both a greater intensity of collection and differences in collecting techniques from those of previous workers.

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VIII. APPENDIX

Table 9. Non-diatom algae taxa present in the Des Moines River in 1968 as seen in Sedgewick-Rafter counts and "wet mounts" on slides, with dates of first and last appearance during the phytoplankton sampling year (15 Jan 1968-15 Jan 1969)

Taxon	First seen	Last seen
	BLUE-GREEN ALGAE	
Agmenellum (Merismopedia)	2/9	1/9/69
Anabaena	1/26	1/15/69
A. spiroides	5/24	-a
Anacystis (Aphanocapsa)	4/5	4/12
Anacystis (Microcystis)	3/29	12/26
Chroococcus	9/12	10/2
Coccochloris (Aphanothece)	4/26	11/13
Gomphosphaeria (Coelosphaerium)	7/12	9/25
Marssoniella	4/20	9/12
Oscillatoria	2/16	1/15/69
Phormidium	1/26	1/26
Spirulina	1/26	1/15/69
	GREEN FLAGELLATES	
Chlamydomonas	1/15/68	1/15/69
Eudorina	8/29	8/29
Euglena	1/26	1/15/69
Pandorina	5/3	11/28
Phacus	8/29	8/29
Trachelomonas	2/9	12/19
	OTHER FLAGELLATES	
Dinobryon	5/24	1/15/69
Glenodinium	8/29	1/15/69
Gymnodinium	8/29	8/29

[a]"Last seen" dates are not included on most species identifications because the extra time needed to tabulate each separate species not assigned a button on the tabulator precluded their regular recording. It may be assumed that these are less abundant than those for which "last seen" dates are listed.

Taxon	First seen	Last seen
	GREEN ALGAE	
Actinastrum	3/8	1/15/69
Ankistrodesmus	1/15/69	1/15/69
A. spiralis	5/3	-a
Botryococcus	9/25	9/25
Cerasterias	9/12	9/12
Chlorella (type)	1/15/68	12/19
Chodatella	4/26	10/2
Closteriopsis	1/26	6/7
C. longissima var. tropica	5/10	-a
Closterium	6/21	11/13
Coelastrum	5/17	9/25
Crucigenia	4/26	12/19
Gloeocystis	4/12	10/10
Golenkinia	5/10	5/10
Kirchneriella	3/29	11/21
Micractinium	7/12	9/25
Micrasterias	5/3	8/29
Oocystis	3/5	12/19
Pachycladon	3/29	6/7
Pediastrum	2/16	11/28
P. boryanum	3/29	-a
P. duplex	3/15	8/29
P. duplex var. convergens	3/8	-a
P. tetras	3/15	8/29
Planktosphaeria	5/10	9/4
Scenedesmus acuminatus	1/15/69	12/19
S. bijuga	9/12	-a
S. obliquus	5/3	-a
S. quadricauda	2/9	12/19
Schroederia	4/12	5/10
Selenastrum	4/12	9/25
Sphaerocystis	5/3	5/3
Staurastrum	4/12	11/13
Stichococcus scopulinus	1/26	1/2
Tetraedron	4/12	1/9
T. caudatum	5/10	-a
T. regulare	4/12	-a
T. triappendiculatum	5/3	5/3
Tetraspora	4/12	4/20
Treubaria	5/10	4/25
Westella	5/3	9/25

SEDGWICK-RAFTER DATA

DES MOINES RIVER, IOWA Date Analyzed _____ Sample No. _____

Analyzed by 106 _____

Time Collected: _____

CODE	ORGANISM		TALLY	C/ML.	TOTALS
	Total coccoid blue-green algae per ml.				
	Total filamentous blue-green algae				
	Total coccoid green algae				
	Total filamentous green algae				
	Total green flagellates				
	Total other pigmented flagellates				

Centrics		c/ml.

Pennates		c/ml.

Most Abundant Algae

Diatoms

	Centric	Melos.	Others	Totals	c/ml.
Shells					
Live					
Total live centric diatoms					

	c/ml.
Pennate Shells	
Live Pennates	
Total live pennate diatoms	

S-R Factor:

TOTAL LIVE ALGAE _____

Remarks:

DIATOM ANALYSIS

DES MOINES RIVER, IOWA

107

Live Centrics _____ Dead Centrics _____ Sample Number _____

Live Pennates _____ Dead Pennates _____ Time Collected _____

Total Live _____ Total Dead _____ Analyzed by _____

S-R Count _____ Sample Size _____ Date Analyzed _____

Counting time _____

Species	Total	%	Species	Total	%
Coscinodiscus			Eunotia		
Cyclotella			Fragilaria crotonensis		
Meneghiniana			construens		
Melosira			Frustulia		
ambigua			Gomphonema		
granulata			Gomphoneis		
distans			Gyrosigma		
Rhizosolenia			Meridion circulare		
Stephanodiscus			Navicula		
hantzschii					
invisitatus					
astrea minutula					
Other centrics			Nitzschia		
Achnanthes					
Amphiprora					
Amphora					
Asterionella					
Caloneis					
Cocconeis			Pinnularia		
Cymatopleura			Pleurosigma		
Cymbella			Rhoicosphenia curvata		
Diatoma vulgare			Stauroneis		
Diploneis smithii			Rhopalodia		
Epithemia			Surirella		
			Synedra		
			ulna		
			acus		
			Tabellaria		

	FIRST	SECOND	THIRD	FOURTH	Percent others
Code					
%					

No. species _____ Total count

Remarks:

108
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
ST. PAUL, MINNESOTA 55101

June 4, 1969

Mrs. V.E.Gudmundson
3937 Lawnwood Drive
Des Moines, Iowa 50310

Re: Des Moines River

Dear Madam:

Your inquiry about the Des Moines River has been referred to this office by P.K.Sims, Director, Minnesota Geological Survey.

The Des Moines River is generally considered to have its source in Lake Yankton. It flows from there in a southeasterly direction through Long Lake and Shetek Lake.

Fremont Lake, Sarah Lake and Maria Lake are connected by short tributaries to Shetek Lake. The Des Moines River does not flow through these lakes.

Yours very truly

Eugene R. Gere, Director
Division of Waters, Soils and Minerals

By _____
Roger Williams, Supervisor
Investigations and Studies Unit

RW:ms

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STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
ST. PAUL, MINNESOTA 55101

July 10, 1969

Mrs. V.Emil Gudmundson
3934 Lawnwoods Drive
Des Moines, Iowa 50310

Re: Des Moines River

Dear Mrs. Gudmundson:

Our maps indicate that the East Fork Des Moines River has its source in Township 103, Range 34, north of Alpha in Jackson County, Minnesota, and flows from there southeasterly through Tuttle Lake

I know of no generally accepted criteria for determining the source of a river. Many rivers are un-named in their upper reaches. At some point downstream they acquire a name which is generally recognized, and above this point may have several tributaries. My feeling is that the longest of these tributaries should be considered the source.

Yours very truly,

Eugene R. Gere, Director
Division of Waters, Soils and Minerals

By _____
Roger Williams, Supervisor
Investigations and Studies Unit

RW:ms

PLANKTON POPULATION

Identification Codes of Algae Genera and Count Levels of Most Abundant Genera

KEY TO COUNT LEVEL (per ml.)

1 150 to 300
2 301 to 600
3 601 to 1,200
4 1,201 to 2,400
5 2,401 to 4,800
6 4,801 to 9,600
7 9,601 to 19,200
8 19,201 to 38,400
9 38,401 and over

Code to ALGAE GENERA (Producers)

Blue-green Algae

01 Agmenellum (Merismopedia)
02 Anacystis (Microcystis)
03 Anacystis
04 Coccochloris
05 Gomphosphaeria
06, 07, 08 Reserve
09 Other genus
10 Other genus

Filamentous blue-greens

11 Anabaena
12 Aphanizomenon
13 Arthrospira
14 Lyngbya
15 Oscillatoria
16 Phormidium
17 Raphidiopsis
18 Spirulina
19, 20, 21 Reserve
22 Other genus
23 Other genus

Coccoid green algae

24 Actinastrum
25 Ankistrodesmus
26 Chlorella-type
27 Chlorococcum
28 Closterium
29 Coelastrum
30 Crucigenia
31 Dictyosphaerium
32 Golenkinia
33 Lagerheimia
34 Micractinium
35 Oocystis
36 Palmellococcus
37 Pediastrum
38 Scenedesmus
39 Staurastrum
40 Tetradesmus
41 Tetrastrum
42, 43 Reserve
44 Other genus
45 Other genus

Filamentous green algae

46 Cladophora
47 Stichococcus
48 Stigeoclonium
49 Reserve
50 Other genus

Green flagellates

51 Chlamydomonas including Carteria
52 Euglena
53 Lepocinclis
54 Pandorina
55 Phacotus
56 Phacus
57 Trachelomonas
58 Reserve
59 Other genus

Other pigmented flagellates

60 Chromulina
61 Dinobryon
62 Gymnodinium
63 Peridinium
64 Reserve
65 Other genus

Diatoms (with chromatophores)

Centric

66 Biddulphia
67 Coscinodiscus
68 Cyclotella
69 Melosira
70 Rhizosolenia
71 Stephanodiscus
72 Other genus

Pennate

73 Achnanthes
74 Amphiprora
75 Amphora
76 Anomoeoneis
77 Asterionella
78 Caloneis
79 Cocconeis
80 Cymatopleura
81 Cymbella
82 Diatoma
83 Diploneis
84 Fragilaria
85 Gomphonema
86 Gyrosigma
87 Navicula
88 Nitzschia
89 Pleurosigma
90 Rhoicosphenia
91 Surirella
92 Synedra
93 Tabellaria
94, 95, 96 Reserve
97 Other genus
98 Other genus
99 Other genus

PLANKTON POPULATION

Identification Code for Diatom Species

No.	Species	No.	Species	No.	Species
01	Achnanthes lanceolata	35	Diatoma elongatum	69	Nitzschia denticula
02	Achnanthes minutissima	36	Diatoma vulgare	70	Nitzschia (Lancelolatae group)
03	Achnanthes sp.	37	Diatoma sp.	71	Nitzschia sp. (first)
04	Amphiprora paludosa	38	Diploneis smithii	72	Nitzschia sp. (second)
05	Amphiprora sp.	39	Diploneis sp.	73	Opephora martyi
06	Amphora ovalis	40	Epithemia turgida	74	Pinnularia sp.
07	Amphora sp.	41	Epithemia sorex	75	Pleurosigma delicatulum
08	Anomoeoneis exilis	42	Epithemia sp.	76	Rhoicosphenia curvata
09	Asterionella formosa	43	Eunotia sp. (first)	77	Rhizosolenia eriensis
10	Bacillaria paradoxa	44	Eunotia sp. (second)	78	Rhopalodia gibba
11	Biddulphia laevis	45	Fragilaria capucina	79	Rhopalodia sp.
12	Caloneis amphisbaena	46	Fragilaria construens	80	Stephanodiscus astraea var. minutula
13	Caloneis sp.	47	Fragilaria crotonensis	81	Stephanodiscus dubius
14	Ceratoneis arcus	48	Fragilaria pinnata	82	Stephanodiscus hantzschii
15	Cocconeis pediculus	49	Fragilaria sp.	83	Stephanodiscus niagarae
16	Cocconeis placentula	50	Frustulia sp.	84	Stephanodiscus sp.
17	Cocconeis sp.	51	Gomphonema olivaceum	85	Surirella brightwellii
18	Coscinodiscus rothii	52	Gomphonema sp.	86	Surirella ovata
19	Coscinodiscus (brackish)	53	Gyrosigma kutzingii	87	Surirella striatula
20	Coscinodiscus sp.	54	Gyrosigma sp.	88	Surirella sp.
21	Cymatopleura solea	55	Hantzchia amphioxys	89	Synedra acus
22	Cymatosira belgica	56	Melosira ambigua	90	Synedra pulchella
23	Cyclotella atomus	57	Melosira distans var. alpigena	91	Synedra nana
24	Cyclotella comta	58	Melosira granulata	92	Synedra ulna
25	Cyclotella kutzingiana	59	Melosira binderana	93	Synedra vaucheriae
26	Cyclotella meneghiniana	60	Melosira islandica	94	Synedra sp.
27	Cyclotella pseudostelligera	61	Melosira italica	95	Tabellaria fenestrata
28	Cyclotella stelligera	62	Melosira varians	96	Tabellaria flocculosa
29	Cyclotella striata	63	Meridion circulare	97	Any entity not found above (first)
30	Cyclotella sp.	64	Navicula cryptocephala	98	Any entity not found above (second)
31	Cymbella ventricosa	65	Navicula sp. (first)	99	Reserved for future entity
32	Cymbella tumida	66	Navicula sp. (second)	xx	Insignificant or population inadequate
33	Cymbella sp.	67	Nitzschia acicularis		
34	Denticula sp.	68	Nitzschia tryblionella		