DYNAMICS OF THE PHYTOPLANKTON COMMUNITY IN NAVIGATION POOL NO. 7 OF THE UPPER MISSISSIPPI RIVER

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ABSTRACT

A study of the phytoplankton community dynamics was conducted on Navigation Pool No. 7 of the Upper Mississippi River from May through October 1982. The objectives of this study were to estimate total standing crops, determine the taxonomic composition and examine the seasonal succession of the phytoplankton community. Four sampling sites were established: two in Lake Onalaska, a large backwater lake on the Wisconsin side of the main channel; one in the main channel near Dakota, Minnesota; and one in the main channel just upstream from Lock and Dam No. 7.

The phytoplankton communities at all sampling sites were dominated by diatoms except during July and August when a bloom of blue-green algae was observed. The dominant diatoms from May through mid-July were Melosira italica, Melosira varians, Stephanodiscus niagarae, Stephanodiscus hantzschii, Stephanodiscus astrea, and Synedra ulna. Aphanizomenon flos-aquae and Microcystis aeruginosa were the most prevalent blue-green algae during the mid-summer bloom. The diatoms Melosira italica and Melosira granulata were dominant in September and October. Lesser amounts of green algae, cryptomonads and euglenoids were also observed at various times of the sampling period.

Total standing crops based on cell volume were usually greatest at the Lock and Dam No. 7 site. The maximum standing crop (10.4 mm^3/L) was observed at the Lock and Dam No. 7 site on 4 September; the minimum standing crop (0.4 mm^3/L) was observed at the eastern Lake Onalaska site on the same date. Concentrations of nitrogen, phosphorus, and silica remained at high levels throughout the study period and did not appear to limit phytoplankton standing crops. An inverse correlation was observed between nitrate + nitrite concentration and total cell volume.

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INTRODUCTION

The Mississippi River flows from its headwaters in northern Minnesota to the Gulf of Mexico and drains approximately 40% of the contiguous United States. The upper reach of the river (between Minneapolis/St. Paul, MN and St. Louis, MO) has been modified several times during the past 100 years. Wing dams were constructed along the main channel during the 1870's in an effort to improve the channel for navigation. Additional wing dams were constructed from 1900 to 1910. A series of 29 locks and dams were constructed on the Mississippi River between St. Louis and St. Paul by the U.S. Army Corps of Engineers during the 1930s. The closure of the dams inundated the floodplain and created a series of shallow, low-storage reservoirs (navigation pools). These efforts to make the river navigable have essentially separated the river system into distinct main channel and backwater areas. Vast aquatic habitats were created as a result of the construction of the locks and dams; however, the quality of these habitats has been declining. Dredging in the main channel and sedimentation and eutrophication in the highly productive backwater areas are among the major problems of the river. Fremling and Claflin (1983) have reviewed the ecological history of the Upper Mississippi River.

The Upper Mississippi River is a vast, diverse ecological resource that is used for commercial navigation in the main channel and recreation primarily in backwater areas. The problems of managing this resource to include these potentially conflicting activities have led to increased interest and investigation of the Upper Mississippi River. Many hydro-

logical and ecological studies have been conducted on several pools of the Upper Mississippi River.

Sedimentation is steadily degrading many of the highly productive backwater habitats (Nielsen et al. 1983). The sedimentation problem, addressed in numerous sedimentological and engineering studies, is primarily a result of sediment input by tributaries of the Mississippi River and the subsequent deposition of these sediments in slow flowing backwater areas (e.g. McHenry and Ritchie 1976, 1978; McHenry et al. 1978a, 1978b, 1983; Simons et al. 1981a, 1981b, Smart et al. in review).

Many biological studies have focused on the fishery and migratory waterfowl because of the importance of fish and wildlife resources in the Upper Mississippi River System (Jackson et al. 1981). Thiel (1977) investigated the food habits of four selected cyprinids in Pool 8 and found that algae were the most important food for all four species. Bahr (1977) studied homing, swimming behavior, range, and activity patterns of walleyes by radio telemetry in Pool 7 and 8 and found that this species resided in the main channel only 8.3% of the time. The Wisconsin Department of Natural Resoures is continuing to study walleye movements on the Upper Mississippi River (Gebkin and Wright 1972; Holzer, Wisconsin DNR, La Crosse, WI. pers. commun.). Several studies are being conducted in Pool 7 as well as in other pools of the Upper Mississippi River (Jackson et al. 1981).

Migratory waterfowl have been the subject of numerous studies on the Upper Mississippi River. The Mississippi Flyway attracts waterfowl from breeding grounds that reach north to the Mackenzie River Delta and Alaska in the west to Hudson Bay and Baffin Island in the east (GREAT I

1980b). The United States Fish and Wildlife Service and the Illinois Natural History survey has been conducting waterfowl surveys since 1953 and 1948, respectively (Jackson et al. 1981).

Several investigators have surveyed benthic macroinvertebrate communities in various other pools of the Upper Mississippi River (e.g. Elstad 1977, Trapp 1979, Fuller 1978, 1980, Thiel 1981). Biltgen (1981) investigated macroinvertebrate communities and their relationship to macrophytes and sediments in Lake Onalaska (Pool 7). Merz (1974) studied the utilization of aquatic invertebrates as a fish food in Pool 8. Additional investigations of the invertebrates of the Upper Mississippi River have been completed by the Wisconsin Department of Natural Resources and the United States Fish and Wildlife Service (Jackson et al. 1981).

Much of the vascular flora of Pools 7 and 8 has been categorized in one or more of the following studies: Sternberg (1971), Sohmer (1973), Olson and Meyer (1976), Swanson (1976), Ziegler (1976), Minor et al. (1977). Korschgen (USFWS, La Crosse, WI, pers. commun.) mapped the aquatic and terrestial vegetation of several pools with aerial photography. Studies of various aquatic macrophytes in Pools 8 and 9 have demonstrated that productivity is high when compared with other aquatic systems (Sefton 1976, Donnermeyer 1982). In addition, aquatic macrophytes have been shown to play an important role in the cycling of nitrogen and phosphorus in Lake Onalaska (Smart 1977, Strodthoff 1978).

Algal communities, however, have not been extensively studied in the Upper Mississippi River System. Studies on Pool 5 (Luttenton 1982), Pool 9 (Van Steenberg 1983) and the Black River just upstream from Lake Onalaska (Strenski 1979) indicate that periphyton communities are diverse

and are dominated by diatoms. Two general surveys of phytoplankton were completed in Pools 7 and 8 (Ozburn 1969) and in Pool 8 (Cary 1972). Baker and Baker (1979) studied the effects of various environmental factors on the phytoplankton in a reach of Pool 3.

The present study was conducted to determine the basic ecological relationships of the phytoplankton community in Pool 7. The specific objectives of the study were to:

1. determine taxonomic composition of the phytoplankton community.
2. determine total phytoplankton standing crops.
3. examine the seasonal succession of major algal groups.
4. evaluate the effects of selected physical and chemical variables on the phytoplankton standing crops and community composition.
5. examine similarities and differences between phytoplankton communities in the main channel of the Mississippi River and Lake Onalaska.

DESCRIPTION OF THE STUDY AREA

Navigation Pool No. 7 was inundated in 1937 and lies between Lock and Dam No. 7 at Dresbach, Minnesota (River Mile 702.5) and Lock and Dam No. 6 at Trempealeau, Wisconsin (River Mile 714.3) (Fig. 1). Dakota, Minnesota and Onalaska, Wisconsin are located along Pool 7. La Crosse, Wisconsin is located 7.4 km downstream from Lock and Dam No. 7. Several morphometric features of Pool 7 are summarized in Table 1. The main channel of the river flows adjacent to bluffs of the Minnesota shoreline on the west and along a broken chain of islands on the east. The chain of islands separate the main channel from a series of backwater and side channels on the Wisconsin side (Fig. 1). The Black River enters the Mississippi River in the northern portion of Pool 7.

Lake Onalaska, which occupies the downstream one-third of Pool 7, is a shallow, open-water lake separated from the main channel by a series of islands (Fig. 2). Much of the area that is now Lake Onalaska was once a floodplain meadow. Trees were cut from most areas that were to be flooded as a result of closure of the dam. At flat pool the lake has a surface area of approximately 2025 ha (Jackson et al. 1981) and a depth of less than two meters in most places (Claflin 1977). Water enters the lake from branches of the Black River Delta and from several major and minor side chutes of the main channel of the Mississippi River. Two major outlets drain Lake Onalaska into the main channel near Lock and Dam No. 7 (Fig. 2). During periods of moderate to high discharge, water also exits the lake through the French Island and Onalaska spillways. Although the total capacity-inflow ratio of Pool 7 is low, the capacity-

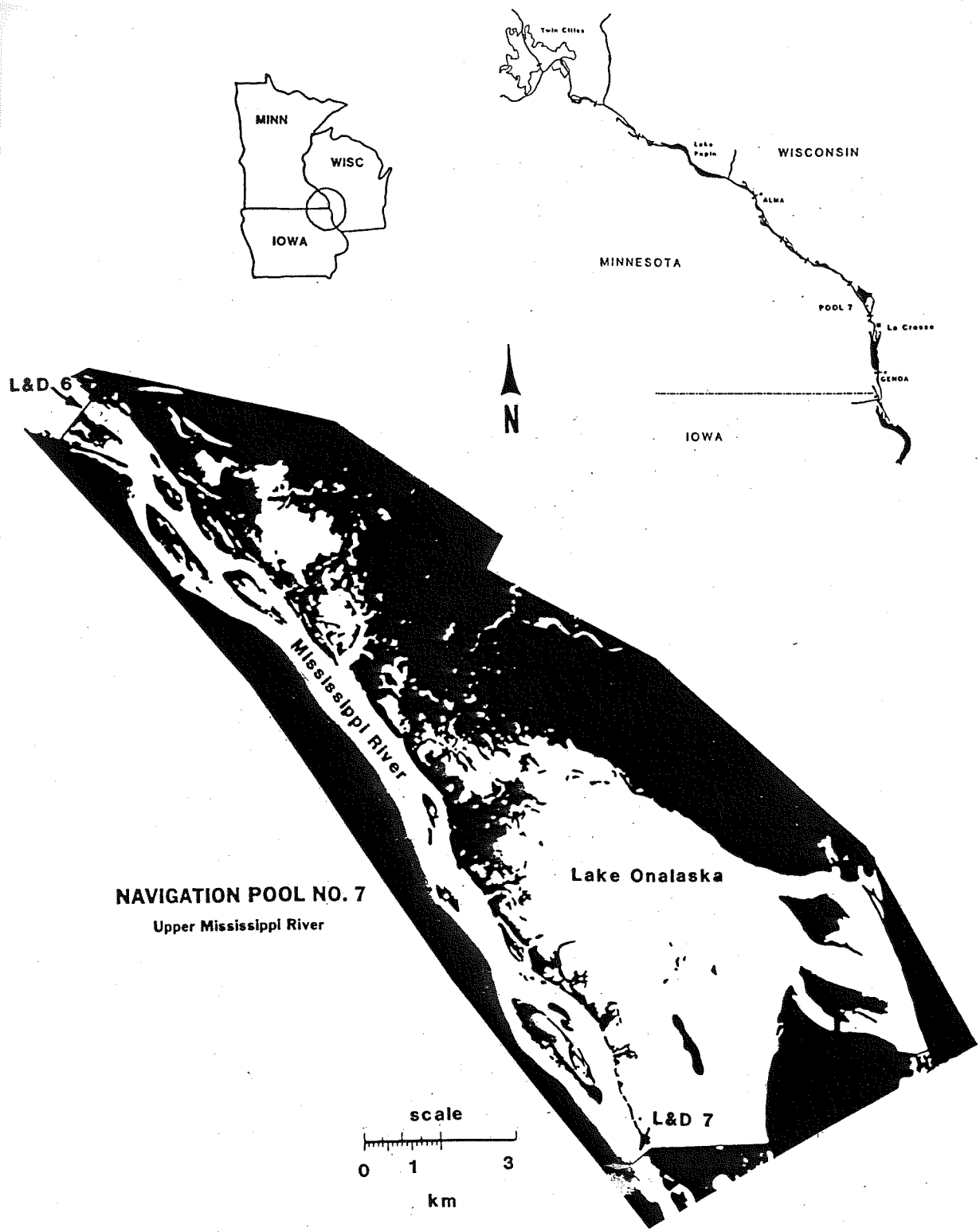


Figure 1. Map of Navigation Pool No. 7 of the Mississippi River and its regional location.

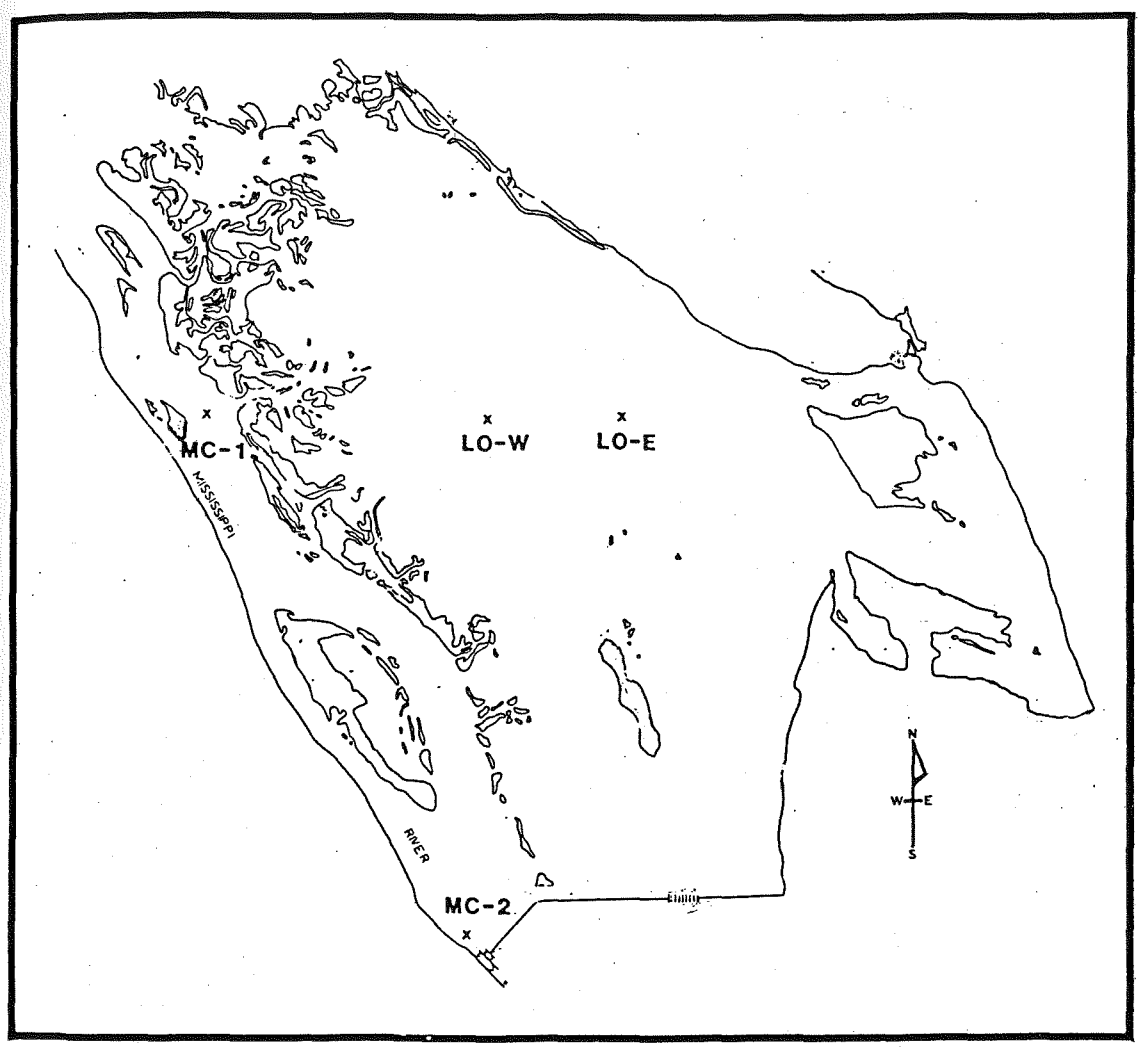


Figure 2. Map of Lake Onalaska and the southern part of Navigation Pool No. 7 showing location of the four sampling sites.

Table 1. Morphometric parameters of Navigation Pool No. 7 of the Upper Mississippi River (from Claflin 1974).

Length of Pool	19	km
Pool elevation (flat pool)	194.6	m
Area of Pool	5439	ha
Shoreline (perimeter)	59.7	km
Total lands above water	2861	ha

inflow ratio of Lake Onalaska is high due to the lack of circulation in much of the lake. The trapping efficiency of the lake for sediments is between 55% and 60% of suspended load and 100% of the bed load (Claflin 1977).

Recreational use is an important feature of Pool 7. Of Pools 1-13, Pool 7 is one of the most heavily used for recreation (GREAT I 1980a). Permanent private residences exist along much of the northern and eastern shores of the lake. The close proximity of the city of La Crosse, Wisconsin (pop. ~50,000) is partly responsible for this heavy recreational use. Hunting, fishing, and pleasure boating are among the most common recreational pursuits on Pool 7 (GREAT I 1980a).

The sport fishery of Pool 7 is extensive. Creel census data show that bluegill (Lepomis macrochirus), crappie (Poxomis nigramaculatus and p. annularis), and other sunfish (Lepomis sps.) are the major species taken from Pool 7 (Nord 1964, Wright 1970, Fleener 1975, Rach 1977). Largemouth bass (Micropterus salmoides), walleye (Stizostidion vitreum vitreum), yellow perch (Perca flavescens), and northern pike (Esox lucius) are also important sport fishes in Pool 7 (Rach 1977, Holzer and Ironside 1977). Fishing pressure ranges from 17.81 to 22.70 man-hours per acre, and success rates range from 1.06 to 2.41 fish per hour (Nord 1964, Wright 1970, Fleener 1975, Rach 1977). Most of the sport fishing takes place in areas other than the main channel.

Pool 7 supports a substantial commerical fishery. Commerical fishing catches recorded since 1953 show substantial yearly variations with an annual mean of about 450,000 lbs/yr (GREAT I 1980a, Jackson et al. 1981). Much of the variation is explained by fluctuations in fishing

pressure due to market demand (Claflin 1974).

A seasonal waterfowl harvest of 10-15 thousand ducks accounts for the majority of the sport hunting on Pool 7 (GREAT I 1980a). During spring and fall migrations, Lake Onalaska has exceptionally high waterfowl value (Jackson et al 1981). The use of Lake Onalaska as a migratory stop-over and feeding location for canvasback ducks (Aythya valisinaeria) has been important to recent population increases of this species in the Mississippi Flyway (C. Korschgen pers. commun.). Most of Lake Onalaska is closed to waterflow hunting to protect the canvasback. Areas of Pool 7 provide feeding, resting, or nesting habitat for a large number of aviafauna including various shorebirds and raptors. A great blue heron rookery has recently been documented in the Black River Delta in Pool 7 (Jackson et al. 1981).

Much of Lake Onalaska is overgrown with rooted aquatic macrophytes from late spring through fall. Thick macrophyte beds in the open water areas of the lake are dominated by Vallisneria americana (Fig. 3). Filamentous algae have recently colonized these beds and form thick mats in July and August (Korschgen pers. commun.).

Location of Sampling Sites

Four sampling sites were established in Pool 7, two in Lake Onalaska and two in the main channel (Fig. 2). One of the main channel sites (MC-1) was located in the center of the main channel near Dakota, Minnesota (River Mile 706.5). This site was adjacent to Sommer's Chute, which is the largest inlet to Lake Onalaska from the Mississippi River. The second main channel site (MC-2) was approximately 20 m upstream from Navigation Lock No. 7. The two sampling sites in Lake Onalaska (LO-W

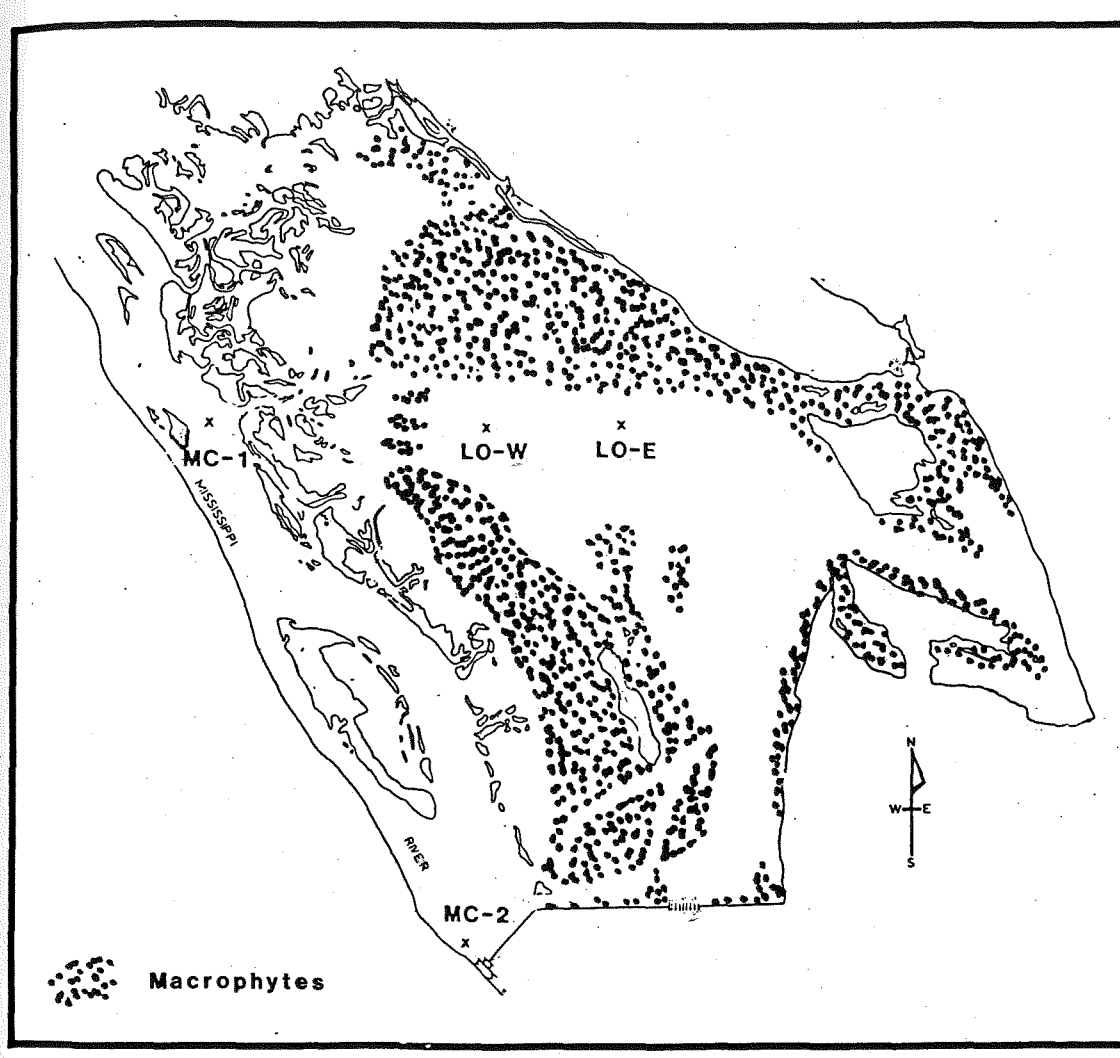


Figure 3. Map of maximum summer growth of aquatic macrophytes in Lake Onalaska, August 1982. (from Korschgen pers. comm.)

and LO-E) were situated in the middle of the lake about 1 km apart (Fig. 2). The Lake Onalaska sampling sites were located in an area that did not experience extensive macrophyte growth (Fig. 3).

METHODS AND MATERIALS

All samples and in situ measurements were taken from each of the four sampling sites at approximately 10-day intervals from 21 May-14 August 1982 and at 14-day intervals from 4 September-2 October 1982.

Water Chemistry

Water samples for chemical analyses were taken by lowering a 1-L screw cap polyethylene bottle from the surface to approximately 1 meter while it filled. The bottle was capped while submerged to prevent entrapment of gases. The samples were held on ice in a cooler during transport to the laboratory.

A portion of each sample was filtered through a glass fiber filter (Gelman, Type A/E or Whatman GF/C) and was used for analyses of orthophosphorus and nitrate + nitrite nitrogen. All other analyses were conducted with unfiltered water. All determinations were completed within the holding times recommended by the EPA (USEPA 1979). The methods of analyses, references, abbreviations, and reporting units for each variable are presented in Table 2.

Water Temperature and Transparency

Water temperature at each sampling site was measured with a dissolved oxygen meter (Yellow Springs Instrument Co. model 54A) at four depths in the water column: surface, 0.5 m, 1.0 m, and 0.5 m above the bottom. Transparency of the water was estimated with a Secchi disc. The Secchi depths were measured between 10 am and 2 pm from the shady side of the boat.

Table 2. Variables tested and methods used in chemical analyses of water from Navigation Pool No. 7 of the Upper Mississippi River.

Variable	Method	Reference	Reporting Units
Conductivity	Specific Conductance	USEPA 1979 APHA 1981	µmhos/cm
pH	Electrometric	USEPA 1979	-log (H+)
Alkalinity	Potentiometric	USEPA 1979 APHA 1981	meg/L, mg/L as $CaCO_3$
Turbidity	Nephelometric	USEPA 1979	NTU
Total Hardness	Titrametric, CDTA	USEPA 1979	meg/L, mg/L as $CaCO_3$
Silica	Colorimetric, Molybdosilicate	APHA 1981	mg/L as SiO_2
Ortho and Total Phosphorus	Colorimetric, Ascorbic Acid, Two Reagent	USEPA 1979	mg P/L
Nitrate + Nitrite	Colorimetric, Hydrazine Reduction	Barnes 1959	mg N/L
Total Persulfate Nitrogen	Potentiometric, ion selective electrode	Smart et al. 1983	mg N/L

Phytoplankton

Water was taken from the surface and depths of 0.5 m, 1.0 m, and 1.5 m with a 1.5 L Kemmerer sampler. Equal subsamples (0.5 L) of water from each depth were mixed to form a euphotic zone composite sample. Approximately 0.9 L of composite sample was perserved with "M3" solution (APHA 1981) and used for phytoplankton identification and enumeration. In preparation for microscopic analyses, the samples were shaken until the phytoplankton were homogenously distributed. Subsamples (5-15 mL) were then withdrawn and filtered through membrane filters (25 mm filter dia, 0.45 µm pore dia) (APHA 1981). The phytoplankton mounts were examined at magnifications of 125X, 500X, and 1250X with a bright field microscope (Leitz Ortholux model 10.4.5.1 50/76) fitted with a whipple ocular micrometer. Phytoplankton were identified to the species level when possible with the following taxonomic keys: Prescott 1951, 1961, and 1970; Hustedt 1959, 1961, and 1962; Patrick and Reimer 1966 and 1975; Taft and Taft 1971; Weber 1971; Whitford and Schumacher 1973. Enumeration of taxa was accomplished by making strip counts until at least 350 phytplankters were counted. The average cell volume of each taxon was calculated by assuming an appropriate geometrical shape (i.e., sphere, cylinder, etc.) and inputing the observed dimensions into the volumetric formula of that shape (Findenegg 1969, APHA 1981).

A 100 to 200 mL subsample of the composite sample was filtered in the field through a glass fiber filter (Whatman, Type C) for pigment analyses. The filter was tranferred to a screw-cap test tube and held on ice during transport to the laboratory. Chlorophyll a and pheophytin a fluorescences of the pigment extract were measured before and after

acidification with HCl (APHA 1981, Yentsch and Menzel 1963). The fluorometer (Turner model 111) was equipped with a high sensitivity F4T.5 blue lamp, R-136 red sensitive photomultiplier tube, CS-2-64 emission filter, 25% neutral density emission filter, CS-5-60 excitation filter, and high sensitivity door. Most readings were taken at the 1X or 3x sensitivity settings.

RESULTS AND DISCUSSION

Chemical and Physical Characterization of the Water

Turbidity, Transparency and Temperature

The turbidity of the water in the study area ranged from 4 to 30 NTU with a mean of 15 NTU (Table 3, Appendix I). It was greatest from 30 May to 8 June, decreased in June, and remained relatively constant from July through October. The turbidity of the main channel was primarily a function of runoff and turbulence caused by boat traffic. The turbidity of Lake Onalaska was mainly affected by runoff and resuspension of bottom sediments by wind. The turbidity of the main channel and Lake Onalaska was increased by phytoplankton blooms during the summer. The mean turbidity of the lake was less than that of the main channel because of the reduced current velocities.

Water transparency fluctuated throughout the sampling period. The secchi depths for all sites ranged from 0.5 to 1.0 m with a mean of 0.7 m (Table 3). The smallest secchi depths were observed on 8 and 22 June. Many of the same factors that influenced turbidity should also have influenced secchi depth, but a strong correlation was not found between these two variables.

Water temperatures ranged from 14.5 to 27.0^{o}C (Table 3). Temperature maxima occurred in early August, whereas minima were in October. All sites had similar temperatures on each date. Thermal stratification of the water column was not observed at any time during the study.

Specific Conductance, Total Hardness, Alkalinity and pH

Table 3. Values of means and ranges of physical, chemical, and phytoplankton variables determined from samples from Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982.

Site	Depth m	Secchi Depth cm	Temperature C	Turbidity NTU	Conductivity umhos/cm	Hardness me/L	Alkalinity me/L	pH -log H+	Nitrate + Nitrite mg N/L	Total Nitrogen mg N/L
MC-1	4.0 (3.5-4.5)	70 (55-80)	19.4 (14.5-26.8)	16 (12-24)	370 (290-427)	3.3 (2.0-4.4)	2.3 (1.1-4.3)	8.2 (7.6-8.8)	0.63 (0.30-1.11)	2.70 (1.83-5.09)
MC-2	6.9 (6.5-7.0)	66 (50-80)	20.8 (14.5-26.8)	16 (12-30)	376 (300-425)	3.3 (2.1-4.4)	2.5 (1.0-5.5)	8.3 (7.7-8.7)	0.59 (0.17-0.93)	2.66 (1.62-3.99)
LO-W	1.6 (1.4-2.0)	66 (45-80)	20.7 (14.5-26.7)	14 (9-19)	334 (231-410)	3.0 (1.6-4.3)	2.2 (0.7-4.1)	8.2 (7.7-8.8)	0.58 (0.24-0.92)	2.61 (1.67-4.69)
LO-E	1.6 (1.5-1.8)	68 (45-100)	20.8 (14.5-27.0)	12 (4-23)	317 (197-460)	2.7 (1.1-4.2)	2.0 (0.7-4.2)	8.0 (7.2-8.7)	0.44 (0.08-0.78)	2.61 (1.67-5.09)

Table 3. Values of means and ranges of physical, chemical, and phytoplankton variables determined from samples from Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982. (Continued)

Site	Ortho-P mg P/L	Total-P mg P/L	N:P	Silica mg SiO^2/L	Chloro-phyll a $\mu g/m^3$	Total Cell Volume (mm^3/L)	Diatom Cell Volume (mm^3/L)	Blue -green algae Cell Volume (mm^3/L)
MC-1	0.11 (0.05-0.20)	0.15 (0.08-0.20)	44:1 (24:1-91:1)	13.6 (9.4-18.3)	16.4 (1.7-35.0)	3.98 (1.67-7.6)	3.19 (0.6-7.3)	0.53 (0.03-2.1)
MC-2	0.11 (0.04-0.19)	0.14 (0.05-0.20)	54:1 (18:1-153:1)	13.1 (9.4-17.3)	26.2 (5.8-80.0)	6.14 (2.3-10.4)	4.16 (1.4-8.8)	1.58 (0.02-7.4)
LO-W	0.12 (0.06-0.19)	0.15 (0.09-0.19)	40:1 (21:1-86:1)	13.0 (9.6016.3)	20.7 (1.7-111.0)	4.12 (1.7-8.5)	2.90 (0.4-8.0)	0.86 (0.03-3.9)
LO-E	0.12 (0.04-0.21)	0.15 (0.05-0.21)	49:1 (19:1-172:1)	12.9 (9.5-15.0)	16.1 (0.9-129.0)	2.49 (0.4-5.7)	1.76 (0.2-4.8)	0.38 (0.02-2.4)

Conductivity in the main channel (Table 3) was similar to that of the main channel in other reaches of the river (Fremling et al. 1975, Rada et al. 1980, Dawson et al. 1983). The conductivity of Lake Onalaska (Table 3) was less than the main channel. This difference was mainly due to the influence of water entering the lake from the Black River, which has lower conductivity (annual average Ks-151 µmhos/cm) than the main channel of the Mississippi River.

Total hardness ranged from 2.02 to 4.38 me/L (mean =3.30) in the main channel and from 1.10 to 4.32 me/L (mean =2.84) in Lake Onalaska (Table 3). These waters would be classified as very hard (Hem 1970). Total hardness in Lake Onalaska was less than the main channel because of softer water entering the lake from the Black River (annual average =1.2 me/L, Dawson et al. 1983). Hardness at all sites steadily increased from 21 May to July, decreased to minima in early August, and increased slightly and leveled off through October. Variations in hardness were a function of runoff events. The hardness was due to Ca and Mg from calcite and dolomite deposits in the local drainage basin (Martin 1965).

The pH for all sites ranged from 7.2 to 8.9. The pH at all four stations was similar from the beginning of the sampling period through 1 July. The pH at LO-E was lower than the other sites from 10 July to 4 August. Both main channel sites remained similar throughout the sampling period. The pH at LO-W was influenced by water from the Black River and from the main channel of the Mississippi River and therefore was not consistantly similar to any one of the other sites.

Alkalinity ranged from 1.0 to 4.4 me/L in the main channel and from 0.6 to 4.2 me/L in Lake Onalaska (Table 3). These alkalinites

(mainly as HCO_3) were indicative of strongly buffered waters. Alkalinity was greatest at all sites on 21 May. It then decreased and remained relatively uniform through 10 July. It decreased again and remained steady at lower levels from 4 August to 2 October. Alkalinity was similar at all sites from 21 May to 1 July. Alkalinity of LO-E was much lower than the other sites from 10 July to 4 August. This is again evidence of less buffered Black River water influencing this site.

Nitrogen, Phosphorus, and Silica

Concentrations of nitrate + nitrite were similar at all sites and ranged from 0.08 to 1.11 mg N/L (Table 3). Levels steadily increased from 21 May to 1 July, remained relatively constant from 1 July to 4 August, and declined and remained constant from 14 August to 2 October. Concentrations were greater than 0.15 mg N/L in all samples with the exception of the 4 September LO-E sample, which was 0.08 mg N/L. Total persulfate nitrogen ranged from 1.62 to 5.09 mg N/L. Seasonal and among site differences in total nitrogen were variable and trends were not apparent. Maximum concentrations of total nitrogen were on 4 August at all sites.

Seasonal trends of ortho-phosphorus and total phosphorus concentrations paralleled one another and ranged from 0.04 to 0.21 mg P/L and from 0.05 to 0.21 mg P/L, respectively (Table 3). Seasonal trends were variable, but general increases in phosphorus concentrations were observed at all sites from 21 May to 2 October. Low water levels and the decay of aquatic vegetation were probably responsible for the observed trends (Smart 1977). Concentrations of nitrogen and phosphorus in Pool 7 were at levels indicative of a eutrophic system (Sawyer 1947,

1952, Vollenweider 1968, 1969, Hutchinson 1973).

Concentrations of silica for all sites ranged from 9.4 to 18.3 mg SiO_2 L, and the mean was 13.3 mg SiO_2L (Table 3). Concentration at all sites remained similar on all dates. Minimum and maximum concentrations were observed in July and August, respectively.

Phytoplankton

Taxonomic Composition

The phytoplankton observed in Pool 7 represented five divisions (classification of Smith 1950): Chlorophyta (green algae), Chrysophyta (yellow-green algae), Cyanophyta (Blue-green algae), Euglenophyta (euglenoids), and Pyrrophyta (cryptonmads). A total of 114 taxa were identified; 66 taxa had a frequency of occurrence of less than 10% (Appendix II). Melosira italica, Melosira granulata, Aphanizomenon flos-aquae, Microcystis aeruginosa, Stephanodiscus hantzschii, Cyclotella meneghiana, Cyclotella, spp., Cryptomonas ovata, Kirschneriella lunaris, and a group of green coccoid algae were found in at least one sample on every sampling date. The list of taxa (Appendix II) is probably incomplete because the limited sample size and enumeration technique decreased the probability of observing rare species (Hurlbert 1971).

The maximum number of taxa identified in any sample was 41 in the 21 May LO-W sample and in the 30 May MC-2 sample (Table 4). A minimum of 13 taxa were identified from the 10 July LO-E sample. The mean number of taxa per sample was 28. Jaccard's coefficient was used to qualitatively evaluate the community similarity of the four sites

Table 4. Total number of taxa identified per site and the mean, maximum, and minimum number of taxa identified per sample from four sites in Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982.

Site	Total Number of Taxa	Mean Number of Taxa Per Sample	Minimum Number of Taxa Per Sample	Maximum Number of Taxa Per Sample
MC-1	65	27	21 (10 July)	37 (21 May)
MC-2	72	28	20 (4 Sept.)	41 (30 May)
LO-W	83	29	19 (10 July)	41 (21 May)
LO-E	71	26	13 (10 July)	38 (30 May)

(Table 5). The largest values indicate the greatest community similarity based on number of taxa present. MC-2 and LO-W were the most similar (65%) and MC-1 and LO-E were the least similar (53%). Greatest numbers of taxa per sample were in May, June, and October; whereas, the fewest taxa were found in July and August during a blue-green algal bloom. The few taxa found in July and August may have been partly a result of the enumeration method, because smaller volumes of water were examined during this period.

The division Chrysophyta was represented by 73 species and accounted for 72% of the total cell volume. Melosira italica composed 13.5% of the total cell volume, which was the largest standing crop of all identified taxa. Melosira amibigua, which has been reported as a dominant species in Pool 7 (Ozburn 1969) and in Pool 12 (Weber 1971), was present in only two samples. A possible descrepancy in taxonomy may explain the difference in Ozburn's findings in Pool 7. Other major diatom species were Melosira granulata, Stephanodiscus niagare, S. hantzschii, Melosira varians, and Synedra ulna, which ranked second, third, sixth, seventh, and eighth in mean cell volume, respectively.

The 13 taxa of Cyanophyta collectively composed 20.5% of the total standing crop during this study. Aphanizomenon flos-aquae and Microcystis aeruginosa accounted fro 94% of the total Cyanophyta cell volume and ranked fourth and fifth, respectively, of all taxa on a cell volume basis.

The Chlorophyta were represented by 24 taxa, including a group simply identified as green coccoid algae. The green coccoid group was composed of a few species of small (~5μ-dia) spherical phyto-

Table 5. Community similarity coefficients between four sites in Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982 (Jaccard's similarity coefficient).

	MC-1	MC-2	LO-W	LO-E
MC-1	-	0.59	0.57	0.53
MC-2		-	0.65	0.61
LO-W			-	0.57
LO-E				-

plankters (e.g., Chlamydomonas, Chlorella). The Chlorophyta accounted for 6% of the total standing crop.

Only three taxa of the Division Pyrrophyta were found and made a minimal contribution to the total cell volume. Euglenophyta was also of little significance to the total cell volume.

Comparisons Among Sites

The average total standing crop per sample was 4.18 mm^3/L and ranged from 0.36 mm^3/L (LO-E on 4 September) to 10.4 mm^3/L (MC-2 on 4 September). Standing crops of this magnitude would be similar to those found in other eutrophic waters (Hutchinson 1967, Vollenweider 1970). These levels are also similar to those found in portions of the Missouri River (Rada 1974). Eight diatom taxa and two blue-green algal species made up the ten most dominant taxa as ranked by total cell volume (Table 6). The two major groups at all sites were the Chrysophyta and the Cyanphyta (Fig. 4). The mean total cell volumes of LO-E and MC-2 were significantly different ($p<0.05$) when evaluated by analysis of variance followed by a Tukey's hsd test (Table 7). Other comparisons between sites did not reveal any significant differences. Comparisons of the Chrysophyta cell volumes among stations revealed differences similar to those demonstrated for total cell (Table 7). Differences among sites were not detected for the Cyanophyta.

Seasonal succession of the main phytoplankton groups in Pool 7 is illustrated in Fig. 5. Diatoms dominated the early part of the sampling period and were gradually replaced by blue-green algae for a short time during mid-summer. Diatoms became dominant again in September. Similar seasonal succession of diatoms and blue-green

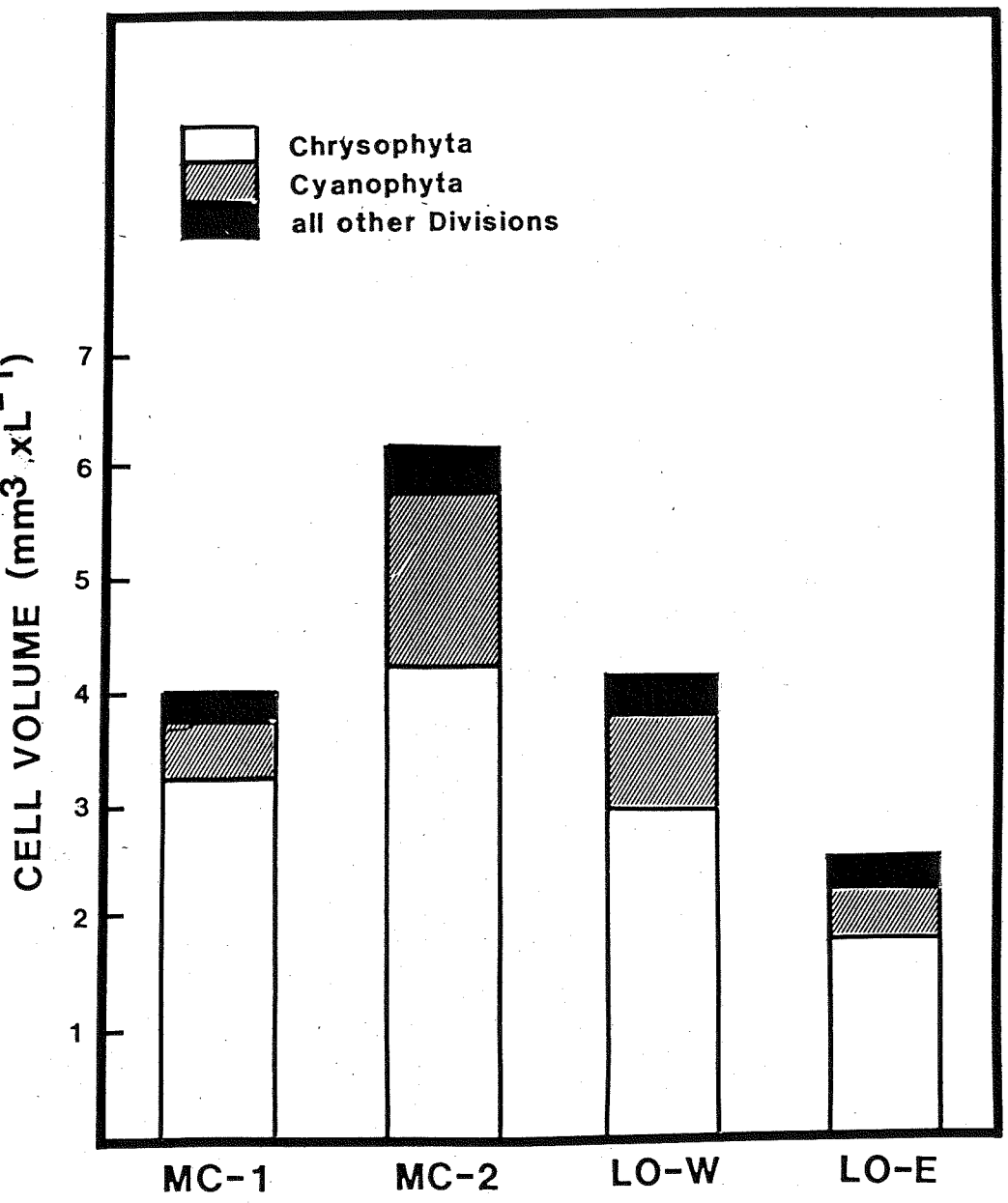


Figure 4. Mean cell volumes (mm^3 / L) of the phytoplankton at each sampling site in Navigation Pool No. 7 during May - October 1982.

Table 6. Rank of the ten most dominant phytoplankters on a cell volume basis from four sites in Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982.

Taxa	Overall Rank	Rank By Location MC-1	MC-2	LO-W	LO-E
Melosira italica	1	1	2	4	1
Melosira granulata	2	2	1	5	3
Stephanodiscus niagarae	3	3	6	1	2
Aphanozomenon flos-aquae	4	4	3	6	5
Microcystis aeruginosa	5	6	4	2	4
Stephanodiscus hantzschii	6	5	7	7	6
Melosira varians	7	12	14	3	7
Synedra ulna	8	8	5	9	15
Cyclotella spp.	9	7	8	8	8
Cyclotella meneghiniana	10	10	9	10	9

Table 7. Comparisons of mean total, Chrysophyta, and Cyanophyta cell volumes (mm^3/L) of phytoplankton collected from four sites in Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982. Means that do not share the same superscript were judged to be significantly different.

Taxonomic Group	Sites MC-2	LO-W	MC-1	LO-E
Mean Total	6.14a	4.12a	3.98ab	2.49b
Chrysophyta	4.16a	2.90ab	3.19ab	1.76b
Cyanophyta	1.58a	0.86a	0.53a	0.38a

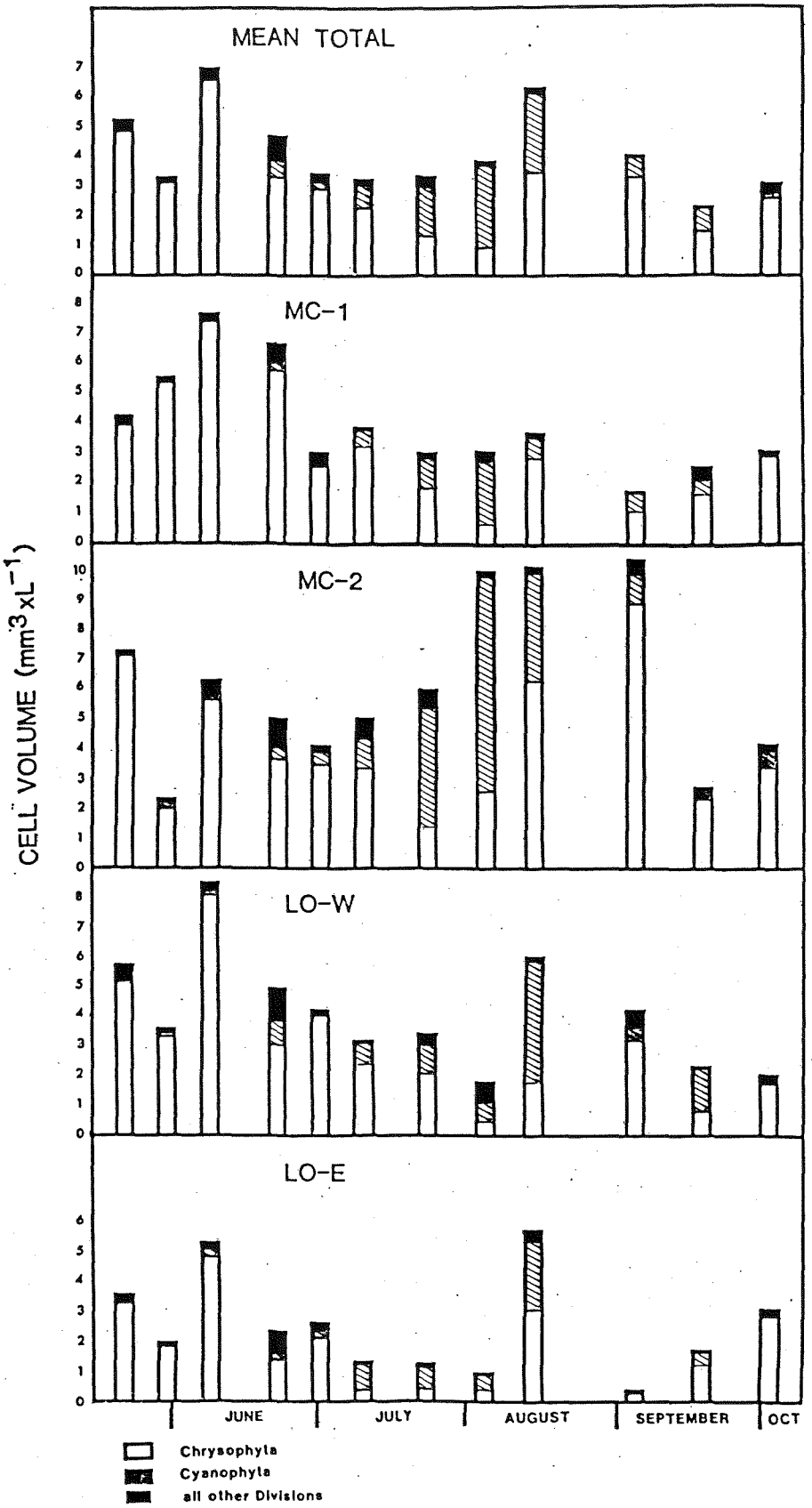


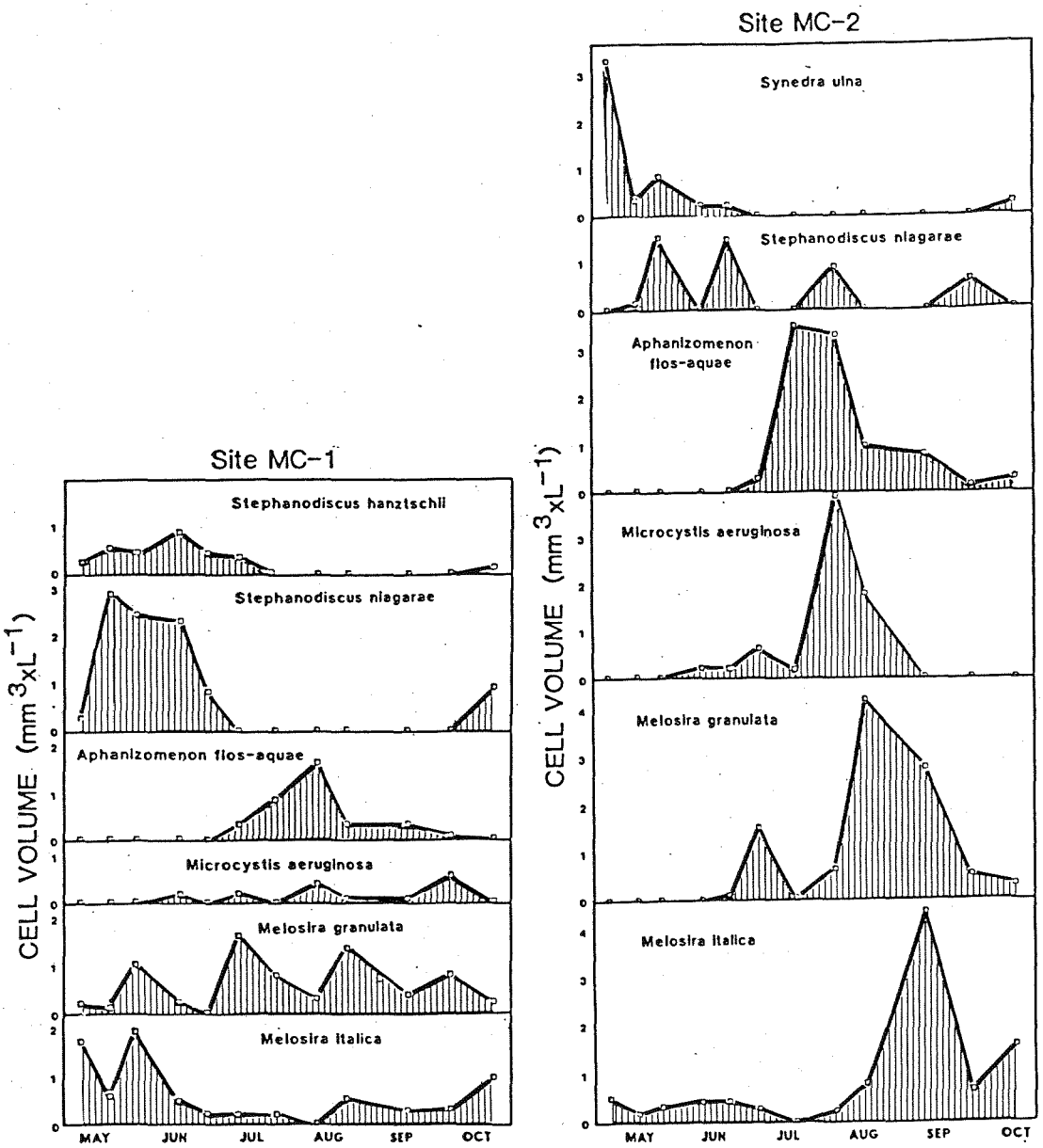
Figure 5. Seasonal changes in cell volume (mm^3 / L) of the phytoplankton in Navigation Pool No. 7 during May - October 1982.

algae has been observed in many temperate freshwater lakes and reservoirs (Hutchinson 1967). Diatoms typical of the early period of diatom dominance in Pool 7 included Stephanodiscus niagare, S. hantzshii, Melosira italica, M. varians, and Synedra ulna. The late diatom bloom was dominated by Melosira granulata and M. italica.

The early and late periods of diatom dominance were similar in magnitude but were often dominated by different species (Figs. 6 and 7). For example, Stephanodiscus niagarae was the major diatom at LO-W during the spring diatom bloom, but the late summer diatom bloom was dominated by Melosira granulata and M. italica.

The blue-green algal bloom formed a conspicuous green film on the surface of the water from mid-July to the end of August. Aphanizomenon flos-aquae and Microcystis aeruginosa dominated the bloom at all sites. Blue-green algal blooms were usually smaller than the diatom blooms on a cell volume basis (Fig. 5).

The dominant species at any one time were often different among sites (Appendix III). To examine the effect of phytoplankton transported from backwaters to the main channel, MC-1 can be considered a reference site and MC-2 an experimental site. The community composition and standing crop of MC-2 was often different than that observed at the other sites (Appendix III). For example, the dominant species on 21 May at MC-2 was Synedra ulna, yet this species was not among the top three taxa on any of the other sites on this date. The dominance of S. ulna on 21 May suggests that the phytoplankton community at MC-2 was strongly influenced by some reach of the river other than the area of the lake that was sampled. The community structure at MC-2 was seldom the same as the other main channel site (MC-1), which is located



gure 6. Seasonal changes in cell volume (mm^3 / L) of six dominant phytoplankton species for the two main channel sampling sites in Navigation Pool No. 7 during May - October 1982.

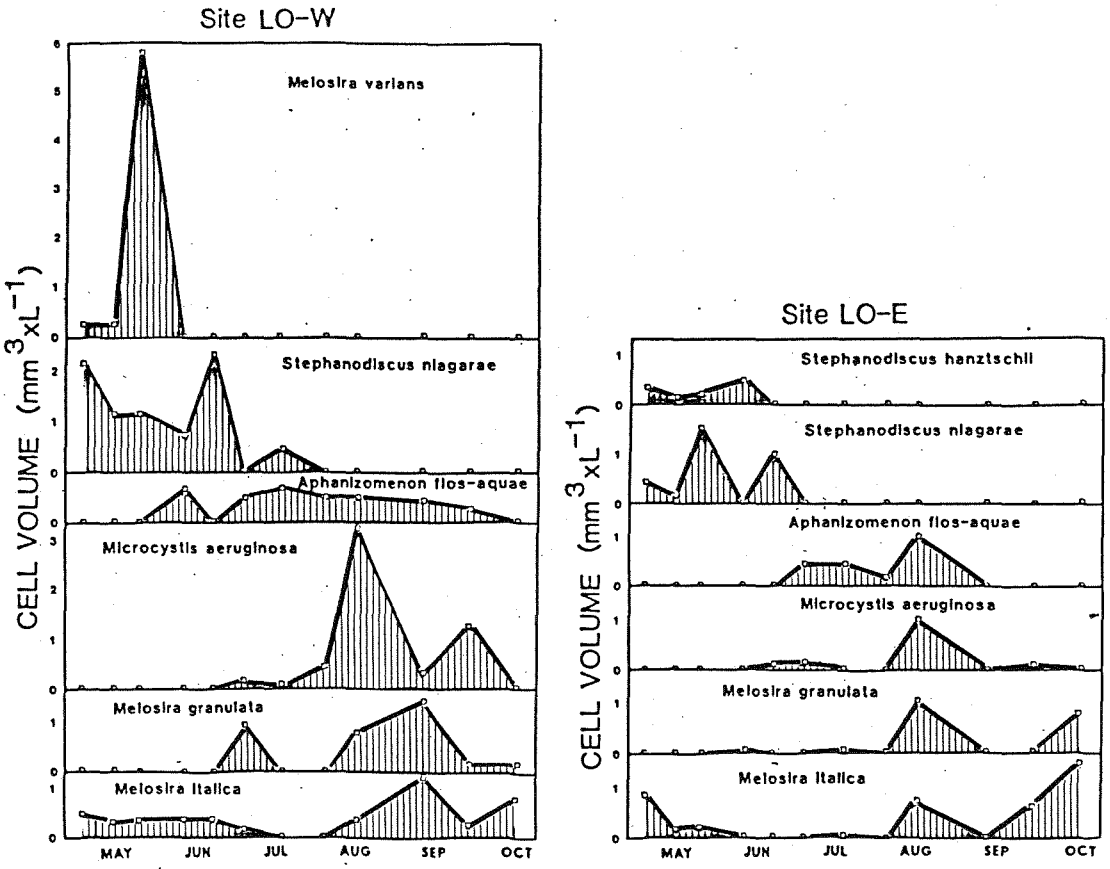


Figure 7. Seasonal changes in cell volume (mm^3 / L) of six dominant phytoplankton species for the two Lake Onalaska sampling sites in Navigation Pool No. 7 during May - October 1982.

approximately 6.5 km upstream. This demonstrates that the phytoplankton community of the main channel can be substantially influenced by input from slow flowing side channels such as those running parallel to the main channel of Pool 7 as well as backwater ponds and lakes in relatively short stretches of the river.

Chlorophyll a and Pheophytin a

The maximum chlorophyll a concentration was 128 $\mu g/m^3$ at LO-E on 14 August. The minimum chlorophyll a concentration was 0.93 $\mu g/m^3$ at LO-E on 4 September. The concentration of chlorophyll a remained relatively constant during most of the sampling period with the exception of large peaks at all sites during August (Fig. 8). A significant correlation between cell volume and chlorophyll a that has been reported in various studies was not found in this study (Brylinsky and Mann 1973, Wright and Soltero 1973, Rada 1974). Similarily, Mullin et al. (1966) and Martin (1967) were also unable to find a linear relationship between cell volume and cholorophyll.

Environmental Factors Influencing Community Variation

Seasonal changes of phytoplankton communities are controlled primarily by physical (e.g., temperature, turbidity), chemical (e.g., nutrient concentrations, pH, organic matter), and biological (e.g., predation, competition) factors (Hutchison 1967). It is difficult to make specific inferences regarding the environmental factors responsible for the abundance or succession of individual species because detailed knowledge of the physiology of many of the species observed is lacking. However, several trends of the major algal groups in this study were similar to those reported in the literature.

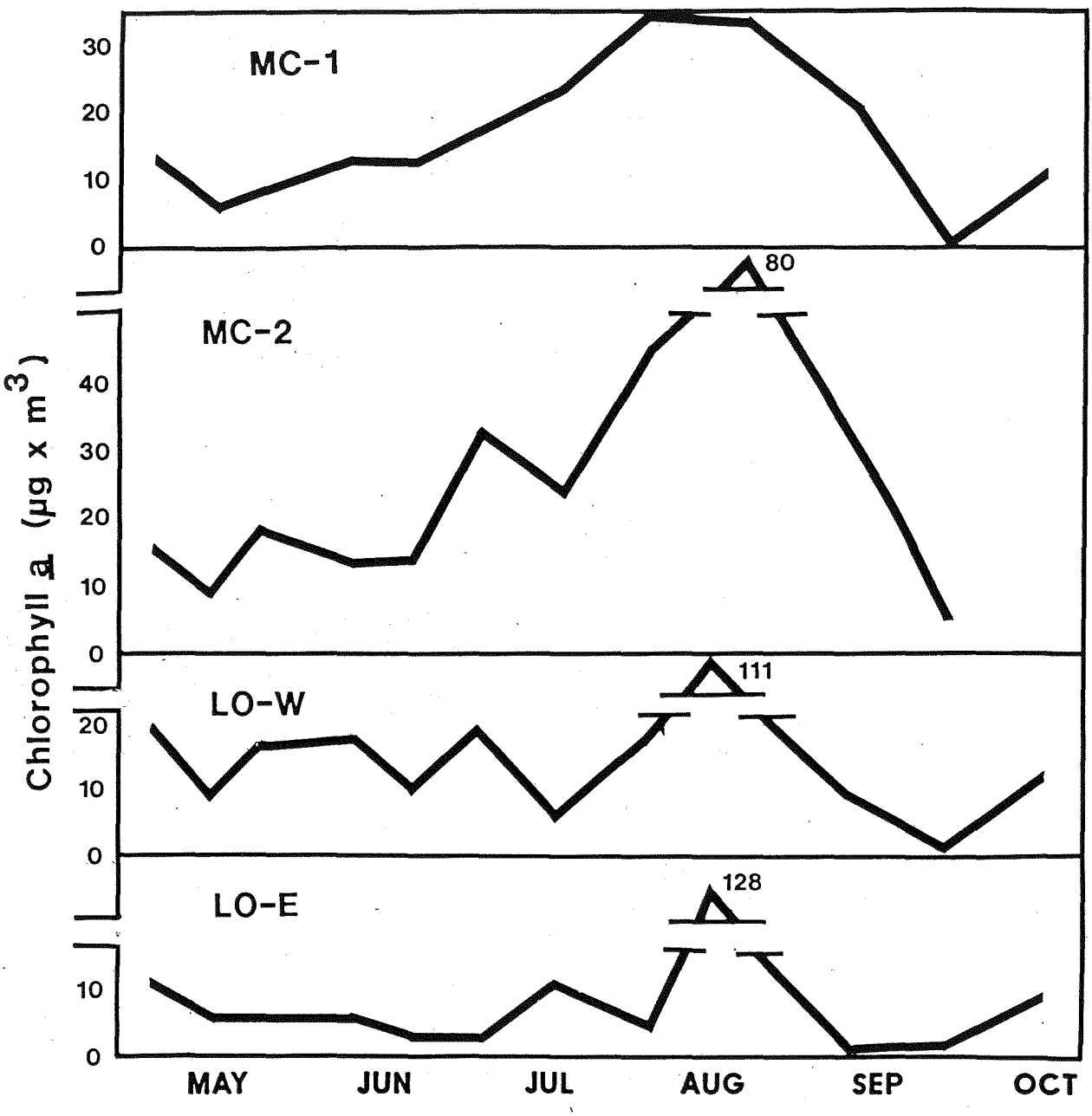


Figure 8. Concentration of chlorophyll a of four sampling sites in Navigation Pool No. 7 during May - October 1982.

Temperature may be involved in determining the community composition and standing crop. Blue-green algae in Pool 7 were dominant only during periods when the water temperature was greater than 24°C with the exception of one sample (LO-W 14 August). Temperature-controlled shifts from diatom dominated to blue-green algal dominated communities have been reported in other studies (Patrick 1969).

Significant correlations between turbidity and diatom or blue-green algal standing crops were not observed in this study. Turbidity has been cited as a factor affecting growth of phytoplankton by reducing light penetration. Examples of inhibition of diatom growth due to high turbidity have been found in Lake Erie (Chandler 1942) and the Kansas River (Patrick 1977). In contrast to diatoms, several blue-green algae including Aphanizomenon flos-aquae and Microcystis aeruginosa are able to increase their bouyancy, thus maintaining a suitable position for photosynthesis (Fogg 1969). A confounding factor in this study may have been that turbidity in Pool 7 can rapidly change due to winds or boat traffic; therefore, conditions that were present during the production of the observed phytoplankton standing crop may not be the same as those of the water when sampled. Consequently, strong correlations may be difficult to demonstrate.

Large standing crops of M. italica were continually observed from May to October in Pool 7 (Fig. 6 and 7). In contrast, M. italica is common only during the mixing periods of October to May in several monomictic lakes in England (Lund 1974, 1971). In these lakes, M. italica settles to the bottom during the summer. Summer populations of M. italica in Pool 7 were larger than those in the English lakes because the cells in Pool 7 were entrained longer and frequently

resuspended from the sediments. Thus it appears that the continuous mixing of the entire water column due to high current velocity or strong winds did not allow this species to settle into the sediments during the summer in Pool 7.

The concentrations of nitrogen, phosphorus, and silica have been shown to regulate phytoplankton growth and influence seasonal succession (Hutchinson 1957). The nutrient concentrations in Pool 7 remained at high levels throughout this study (Appendix I). The smallest concentration of nitrate + nitrite observed during this study was 0.08 mg N/L. Therefore, nutrient limitation was probably not important in regulating phytoplankton standing crops or seasonal succession in Pool 7 because concentrations remained consistently high throughout the study.

The high concentrations of nitrogen did not allow a competitive advantage for the nitrogen fixing blue-green algae as reported in other studies (Hutchinson 1973, Horne 1977, 1978, Rada 1979). The concentration of nitrate + nitrite was inversely correlated ($p<0.05$) to the total algal standing crop (Fig. 9). This probably resulted from nutrient uptake by phytoplankton. The concentrations of other nutrients were not as strongly correlated to standing crops ($p>0.05$). Phytoplankton nitrogen requirements are greater than that of phosphorus (Ryther and Dunstan 1971, Rhee 1974, 1978). The steady decline in nitrogen to phosphorus ratios from June to 2 October also indicates that more nitrogen was being utilized by the phytoplankton as compared to phosphorus. Changes in the nitrogen to phosphorus ratio do not markedly affect the growth of any phytoplankton species if their concentrations remain with the optimum range for any given species (Chu 1943).

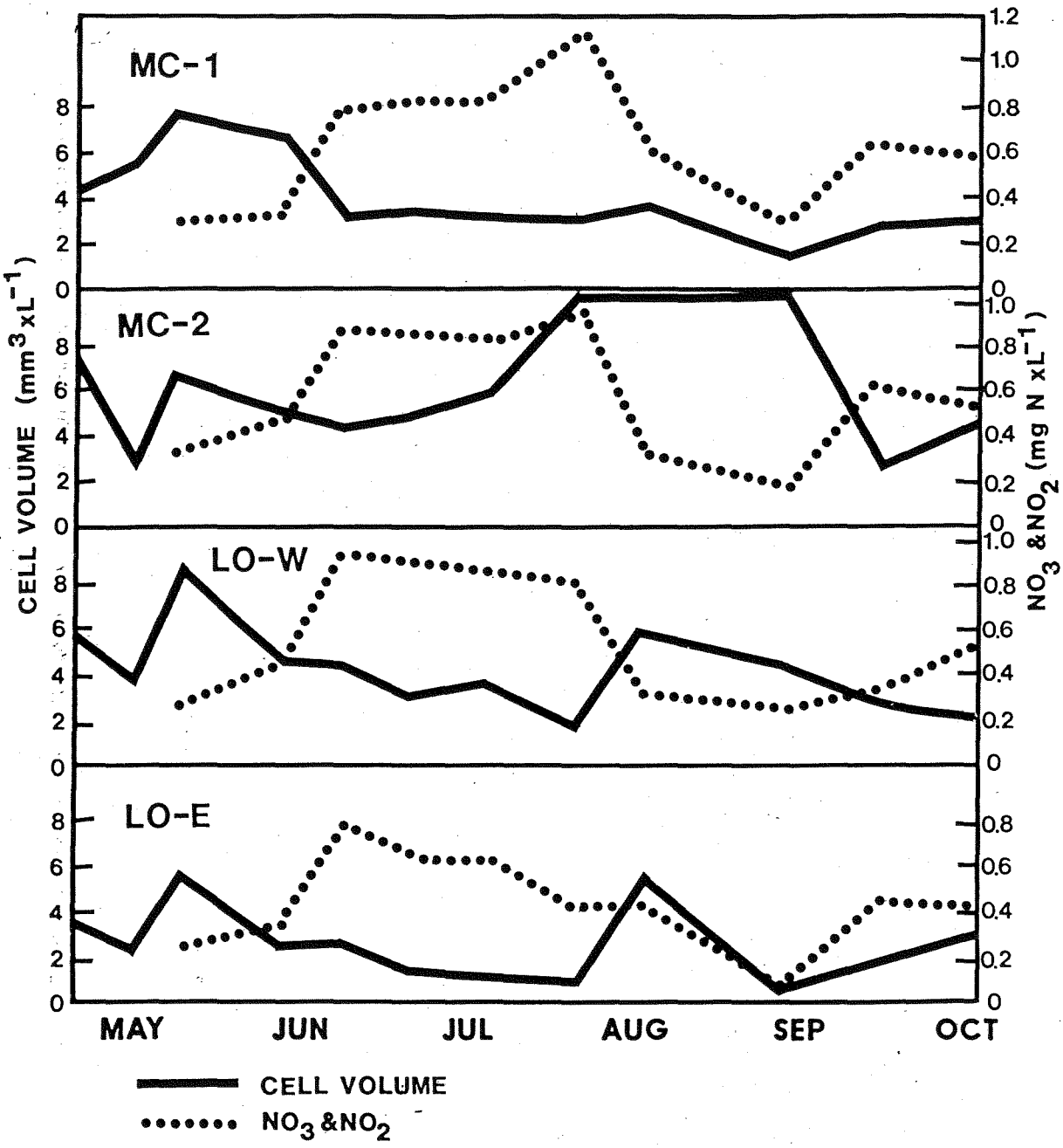


Figure 9. Seasonal relationship between total cell volume (mm^3 / L) and concentration of nitrate and nitrite nitrogen for four sampling sites in Navigation Pool No. 7 during May - October 1982.

Silica can be limiting for diatoms when the concentration is depleted (Paasche 1980). Silica concentrations were greater than 9.4 mg/L in all samples, thus silica limitation was not suspected.

Zooplankton grazing, which was not investigated in this study, can be important to phytoplankton standing crops (Edmonson 1962, Richman 1966). The literature is conflicting on the selective use of the various taxa of phytoplankton as food for zooplankters. Lund (1969), Hutchinson (1973), and Horne (1975) have reported that grazing of blue-green algae was relatively unimportant. However, Knutson (1970) noted that Daphnia made use of Aphanizomenon flos-aquae during summer and fall in Lake Ashtabula, North Dakota. The formation of flake-like colonies of A. flos-aquae has been shown to inhibit grazing by Daphnia (Holm et al. 1983). Margalef (1958) and Goldman et al. (1968) have shown seasonal selectivity by zooplankters to be effective in regulating the seasonal succession of the diatoms and blue-green algae. The before/after acidification pigment fluorescence ratio can be used as an indicator of grazing pressure. As the chlorophyll a in phytoplankton passes through the digestive tract of a zooplankter, it is converted to pheophytin a because of the acidic conditions in the gut (Lorenzen 1965, Glooschenko et al. 1972). Low before/after acidification ratios observed at times in this study may indicate grazing (Fig. 10). However, this may also be due to increased caratenoid synthesis by blue-green algae during periods of high light intensity when chlorophyll a may be photooxidized (Paerl et al. 1983). Most of the low ratios were observed after peaks in phytoplankton standing crop.

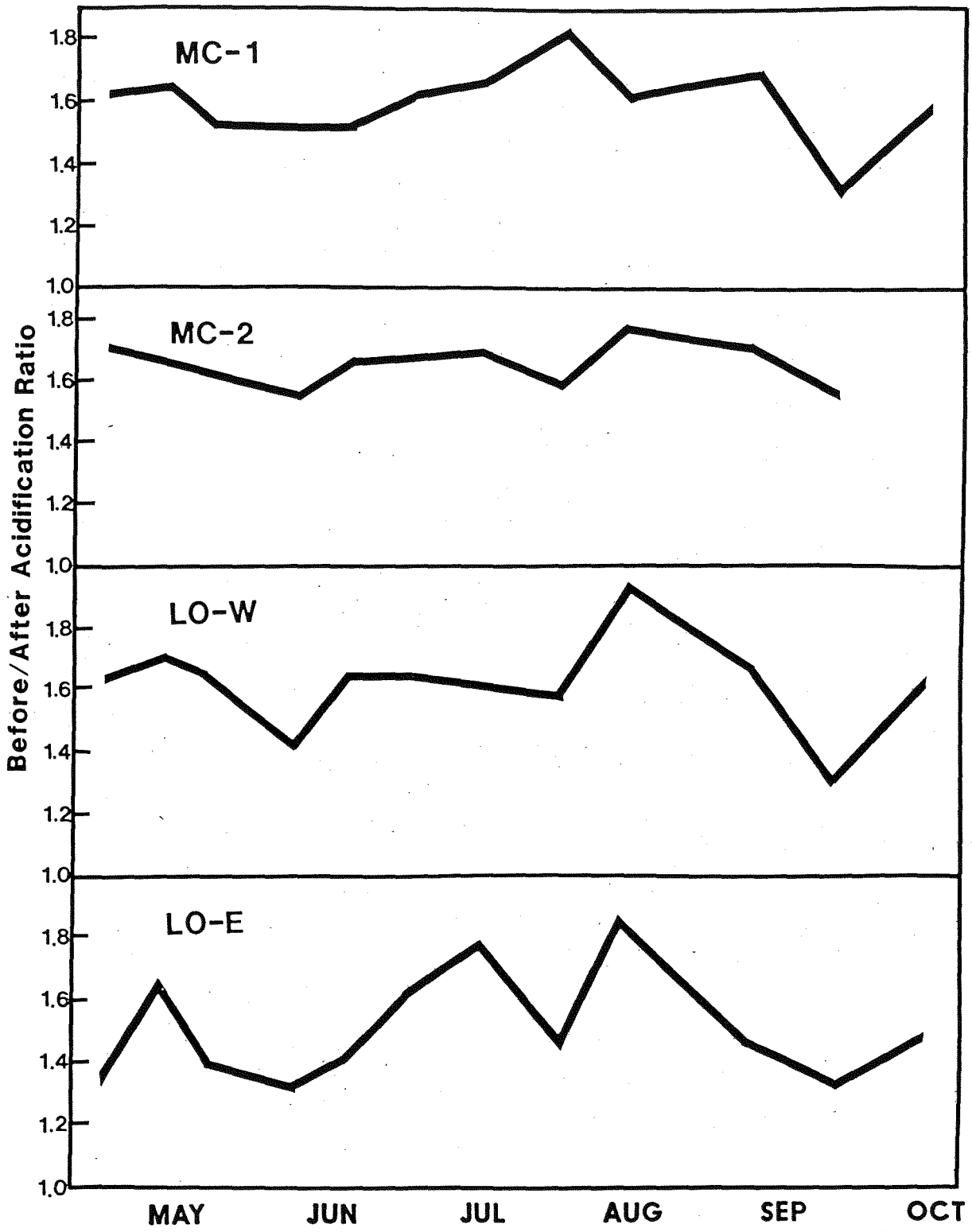


Figure 10. Before/after acidification ratio for four sampling sites in Navigation Pool No. 7 during May-October 1982.

SUMMARY

The dynamics of the phytoplankton community in Pool 7 was studied from May to October 1982. The phytoplankton represented five divisions: Chlorophyta (green algae), Chrysophyta (yellow-green algae), Cyanophyta (blue-green algae), Euglenophyta (euglenoids, and Pyrrophyta (cyrptomonads). A total of 114 taxa were identified. The divisions Chrysophyta and Cyanophyta accounted for 72% and 20% of the total cell volume, respectively. The most prevlent species was Melosira italica, composing 13.5% of the total cell volume. Other dominant species were the diatoms Melosira granulata, Melosira varians, Stephanodiscus nigarae, Stephanodiscus hantzschii, and the blue-green algae Aphanizomenon flos-aquae and Microcystis aeruginosa.

The total phytoplankton standing crop ranged from 10.4 mm^3/L (MC-2 on 4 September to 0.36 mm^3/L (LO-E on 4 September) with a mean of 4.18. A significant difference in mean total cell volumes was found between LO-E and MC-2. Other comparisons between sites did not reveal any significant differences. Chlorophyll a concentrations were not correlated with cell volumes.

The community composition varied slightly among sites, especially between the main channel and backwater sites. The phytoplankton community of the main channel was substantially influenced by input from slow flowing side channels and backwater areas in relatively short stretches of the river. Diatoms were dominant throught the sampling period except for a short period when blue-green algae were dominant during mid-summer. The early and late diatom blooms were of similar

magnitudes. The blue-green algal bloom was usually more conspicuous than either of the diatom blooms but was smaller in total cell volume.

Concentrations of nitrogen, phosphorus and silica remained at high levels throughout the study and did not appear to limit phytoplankton standing crops or influence seasonal succession. An inverse correlation between nitrate + nitrite concentration and total standing crop probably indicated nitrogen uptake by phytoplankton.

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Appendix I. Values of physical and chemical variables determined from water samples from Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982.

Date	Site	Depth m	Secchi cm	Temp. C	Turb. NTU	Cond. µmhos/ cm	Hardness me/L	Hardness (mgCa CO_3/L)	Alkalinity me/L	Alkalinity (mgCa CO_3/L)	pH
5/21	MC-1	4.0	80	18.0	13	290	2.9	(145)	4.3	(215)	7.6
	MC-2	7.0	80	18.0	9	329	3.1	(155)	5.5	(275)	7.9
	LO-W	2.0	80	18.1	9	258	2.7	(135)	4.1	(205)	7.7
	LO-E	1.7	80	18.2	8	252	2.6	(130)	4.2	(210)	7.6
5/30	MC-1	4.0	80	20.0	20	348	3.4	(170)	2.6	(130)	7.6
	MC-2	7.0	65	20.0	30	354	3.5	(175)	2.6	(130)	7.7
	LO-W	1.9	80	20.0	17	331	3.2	(160)	2.4	(120)	7.7
	LO-E	1.6	80	19.7	23	331	3.2	(160)	2.4	(120)	7.8
6/8	MC-1	4.0	50	18.5	24	363	3.8	(190)	2.8	(140)	8.2
	MC-2	7.0	50	18.2	24	373	3.7	(185)	2.8	(140)	8.1
	LO-W	1.4	45	18.5	19	362	3.6	(180)	2.7	(135)	8.2
	LO-E	1.7	45	18.5	17	360	3.7	(185)	2.8	(140)	8.2
6/22	MC-1	4.0	70	19.5	20	400	4.1	(205)	3.0	(150)	8.4
	MC-2	7.0	50	19.5	16	400	4.1	(205)	3.1	(155)	8.6
	LO-W	1.7	45	19.0	18	389	4.0	(200)	2.8	(140)	8.4
	LO-E	1.5	50	19.5	19	378	3.9	(195)	2.8	(140)	8.4
7/1	MC-1	4.0	60	22.0	14	402	4.3	(215)	3.0	(150)	8.3
	MC-2	6.8	80	22.5	12	407	4.3	(215)	3.1	(155)	8.3
	LO-W	1.5	60	23.5	13	395	4.2	(210)	3.0	(150)	8.5
	LO-E	1.5	60	24.5	12	394	4.2	(210)	3.0	(150)	8.4
7/10	MC-1	4.5	80	24.5	16	409	4.4	(220)	3.1	(155)	8.5
	MC-2	7.0	85	24.5	14	405	4.4	(220)	3.1	(155)	8.5
	LO-W	1.7	65	24.5	13	399	4.3	(215)	3.1	(155)	8.5
	LO-E	1.8	65	24.5	8	360	2.9	(145)	2.6	(130)	7.5
7/22	MC-1	4.0	65	25.5	14	347	3.6	(180)	2.7	(135)	8.5
	MC-2	7.0	75	26.0	12	342	3.6	(180)	2.8	(140)	8.6
	LO-W	1.4	60	26.7	14	328	3.3	(165)	2.5	(125)	8.6
	LO-E	1.6	60	26.5	11	282	2.8	(140)	2.0	(100)	8.0
8/4	MC-1	4.0	75	26.8	12	398	2.0	(100)	1.5	(75)	8.6
	MC-2	7.0	70	26.8	17	412	2.1	(105)	1.5	(75)	8.7
	LO-W	1.6	80	26.5	15	299	1.9	(95)	1.1	(55)	8.1
	LO-E	1.6	100	27.0	6	197	1.1	(55)	0.6	(30)	7.5
8/14	MC-1	3.5	75	22.0	14	427	2.1	(105)	1.5	(75)	8.8
	MC-2	6.5	55	22.5	12	425	2.1	(105)	1.5	(75)	8.9
	LO-W	1.6	75	22.0	15	410	2.1	(105)	1.3	(65)	8.8
	LO-E	1.6	90	22.0	13	460	2.1	(105)	1.6	(80)	8.7
9/4	MC-1	4.0	70	20.0	16	380	3.3	(165)	1.3	(65)	8.6
	MC-2	9.0	55	21.0	16	395	3.4	(170)	1.4	(70)	8.7
	LO-W	1.7	50	20.0	15	270	2.1	(105)	0.9	(45)	8.0
	LO-E	1.6	50	19.5	4	225	1.7	(85)	0.8	(40)	8.6
9/18	MC-1	9.0	50	16.0	19	300	2.5	(125)	1.0	(50)	7.7
	MC-2	4.0	55	16.0	16	316	2.6	(130)	1.1	(55)	7.7
	LO-W	1.6	75	15.5	11	231	1.6	(80)	0.7	(35)	7.4
	LO-E	1.7	55	15.0	14	228	1.6	(80)	0.7	(35)	7.2
10/2	MC-1	4.0	80	14.5	14	361	3.0	(150)	1.2	(60)	8.1
	MC-2	7.0	80	14.5	14	365	3.0	(150)	1.2	(60)	8.1
	LO-W	1.7	80	14.5	10	339	2.8	(140)	1.2	(60)	8.0
	LO-E	1.7	80	14.5	14	332	2.6	(130)	1.1	(55)	7.9

Appendix I. (Continued)

Date	Site	Nitrate + Nitrite mg N/L	Total N mg N/L	Ortho-P mg P/L	Total-P mg P/L	N:P	Silica mg SiO^2/L
5/21	MC-1	--	--	0.06	0.09	--	--
	MC-2	--	--	0.08	0.10	--	--
	LO-W	--	--	0.10	0.10	--	--
	LO-E	--	--	0.08	0.13	--	--
5/30	MC-1	--	--	0.12	0.12	--	11.1
	MC-2	--	--	0.13	0.13	--	11.5
	LO-W	--	--	0.11	0.12	--	11.7
	LO-E	--	--	0.10	0.12	--	11.2
6/8	MC-1	0.30	3.27	0.05	0.08	91:1	13.0
	MC-2	0.31	3.46	0.04	0.05	153:1	12.0
	LO-W	0.24	3.67	0.07	0.10	86:1	11.0
	LO-E	0.22	3.89	0.04	0.05	172:1	12.5
6/22	MC-1	0.32	2.34	0.10	0.14	36:1	13.8
	MC-2	0.45	3.09	0.10	0.14	51:1	13.5
	LO-W	0.40	2.55	0.09	0.14	40:1	13.1
	LO-E	0.32	2.76	0.08	0.12	49:1	12.4
7/1	MC-1	0.80	1.89	0.09	0.11	38:1	13.8
	MC-2	0.82	1.99	0.08	0.12	38:1	13.1
	LO-W	0.92	2.22	0.13	0.19	26:1	13.0
	LO-E	0.78	2.34	0.16	0.20	26:1	12.9
7/10	MC-1	0.85	2.47	0.06	0.10	56:1	9.5
	MC-2	0.82	2.61	0.06	0.09	64:1	9.5
	LO-W	0.87	2.34	0.06	0.09	57:1	9.7
	LO-E	0.65	1.99	0.08	0.11	40:1	9.5
7/22	MC-1	0.83	2.72	0.09	0.17	36:1	9.4
	MC-2	0.80	2.72	0.08	0.16	37:1	9.4
	LO-W	0.88	2.58	0.11	0.19	31:1	9.6
	LO-E	0.64	2.20	0.12	0.18	26:1	10.1
8/4	MC-1	1.11	5.09	0.15	0.19	61:1	18.3
	MC-2	0.93	3.99	0.13	0.18	50:1	17.3
	LO-W	0.79	4.69	0.17	0.19	55:1	16.3
	LO-E	0.41	5.09	0.20	0.21	55:1	13.5
8/14	MC-1	0.59	2.47	0.16	0.18	31:1	14.8
	MC-2	0.37	1.79	0.16	0.17	23:1	14.4
	LO-W	0.43	1.99	0.15	0.17	27:1	14.8
	LO-E	0.44	1.89	0.15	0.17	25:1	14.8
9/4	MC-1	0.24	2.22	0.15	0.20	24:1	15.2
	MC-2	0.17	1.62	0.13	0.20	18:1	15.2
	LO-W	0.33	1.79	0.16	0.18	21:1	14.3
	LO-E	0.08	1.70	0.12	0.13	29:1	15.0
9/18	MC-1	0.68	--	0.20	0.20	--	15.2
	MC-2	0.64	--	0.19	0.20	--	15.2
	LO-W	0.42	--	0.19	0.19	--	14.6
	LO-F	0.43	--	0.21	0.21	--	15.0
10/2	MC-1	0.55	1.83	0.14	0.17	24:1	15.0
	MC-2	--	--	--	--	--	--
	LO-W	0.50	1.67	0.14	0.17	21:1	14.8
	LO-E	0.43	1.67	0.16	0.19	19:1	15.0

A hyphen denotes that data is missing.

Appendix II. Taxanomic composition and frequency of occurrence (%) of phytoplankton found in samples from Navigation Pool No. 7 of the Upper Mississippi River, 21 May-2 October 1982.

Taxa	Frequency of Occurrence MC-1	MC-2	LO-W	LO-E
Division Chlorophyta				
Achnathosphaera zacheriasi Lemm.	8	8	0	0
Actinastrum hantzschii Lagerh.	58	67	58	50
Ankistrodesmus falcatus (Corda) Ralfs	92	92	83	67
Golenkinia maxima Tiffany and Ahlstrom	0	8	0	0
Golenkinia radiata Chod.	0	8	8	0
green coccoid	100	100	100	100
Kirchneriella lunaris (Kirch.) Moebius	92	75	100	58
Mallomonas caudata Iwanoff.	0	17	8	0
Pediastrum boryanum (Turp.) Menegh.	8	17	8	17
P. duplex var. clathratum (A. Braun) Lagerh.	17	17	8	8
P. duplex var. gracillum West and West	17	58	42	17
P. obtusa Lucks	0	0	17	8
P. simplex var. duodenarium (Bailey) Rab.	0	0	8	0
P. tetras (Ehr.) Ralfs	8	8	8	0
Scenedesmus arcuatus Lemm.	0	8	8	8
S. dimorphus (Turp.) Kutz.	83	67	58	58
S. quadricauda var. longispina (Chod.) G.M. Smith	75	83	75	83
Staurastrum paradoxum Meyen.	33	25	25	0
Synura spp.	8	8	17	17
Tetraedron caudatum (Corda) Hansg.	25	0	17	25
T. hastatum var. palatinum (Schmidle) Lemm.	0	0	0	8
T. regularae Kutz.	25	0	0	8
T. trigonum (Naeg.) Hansg.	17	17	0	0
Ulothrix subconstricta G.S. West	92	100	92	75
Division Chrysophyta				
Achnanthes haukiana Grun.	0	8	0	8
A. lanceolata Breb. ex. Kutz.	0	0	0	8
Amphiprora ornata Bailey	8	0	0	0
Amphora ovalis var. affinis (Kutz.) V.H. ex DeT.	8	0	17	8
Asterionella formosa Hass.	42	42	50	33
A. formosa var. gracillima (Hantz.) Grun.	0	8	0	0
Caloneis lewisii Patr.	0	0	0	8
Cocconeis placentula Ehr.	50	42	58	67
Cyclotella spp.	100	100	100	92
C. meneghiana Kutz.	100	92	100	92
Cymatopluera eleptica (Breb.) W. Smith	0	8	8	0
C. solea (Breb.) W. Smith	42	25	25	33
Cymbella minuta Hilse ex. Rabh.	8	0	17	0
Diatoma anceps (Ehr.) Kirch.	0	8	0	0
D. tenue var. elongatum Lyngb.	17	0	8	0
D. vulgarae Bory	8	0	0	0
Epithemia sp.	0	0	8	0
Fragilaria sp.	0	8	0	0
F. brevistriata Grun.	0	8	17	8
F. construens (Chr.) Grun.	25	0	8	0
F. crotenesis Kitton	25	25	42	33
F. leptosauron (Ehr.) Hust.	0	8	8	8
Gomphonema acuminatum Ehr.	0	0	8	0
G. angustatum (Kutz.) Rabh.	0	0	0	17
G. olivaceum (Lyngb.) Kutz.	8	8	17	8
G. parvulum Kutz.	0	0	8	8
Melosira ambigua (Grun.) O. Mull.	0	0	0	17
M. binderana Kutz.	0	8	8	8
M. distans (Ehr.) Grun.	75	67	83	58
M. granulata (Ehr.) Ralfs	100	92	100	100
M. italica (Ehr.) Kutz.	92	100	100	92
M. varians Ag.	42	25	42	33
Navicula capitata Ehr.	25	17	8	0
N. cryptocephala Kutz.	58	50	25	50

Appendix II. (Continued)

Taxa	Frequency of Occurrence MC-1	MC-2	LO-W	LO-E
Division Chrysophyta (Continued)				
N. cryptocephala var. veneta (Kutz.) Rabh.	0	8	0	0
N. cuspidata var. major Meist.	0	0	8	0
N. elginensis (Greg.) Ralfs	17	17	33	17
N. exigua var. capitata Patr.	17	17	17	17
N. gastrum (Ehr.) Kutz.	0	0	8	0
N. huerfleri Grun.	0	0	8	0
N. menisculus var. upsaliensis (Grun.) Grun.	0	0	8	0
N. peregrina (Ehr.) Kutz.	0	0	0	8
N. reinhartii (Grun.) Grun.	8	8	17	0
N. ryncocephala Kutz.	8	0	0	0
N. secreta var. apiculata Patr.	0	0	8	0
N. tripunctata (O. Mull.) Bory	0	8	8	8
N. vanheurchii Patr.	0	0	0	8
N. viridula (Kutz.) Kutz. emend. V.H.	0	8	0	0
N. viridula var. rostellata (Kutz.) Cl.	0	0	8	0
Nedium bisulcatum var. subundulatum (Grun.) Reim.	0	0	0	8
Nitzschia sp. a	33	42	42	25
N. sp. b	8	8	8	17
N. sp. c	0	17	8	0
N. sp. d	0	0	8	0
N. sp. e	8	0	0	0
N. dissapata	0	0	8	0
N. holsatica	58	58	58	67
N. palea	58	92	92	83
N. tryblionella	0	0	0	8
Opephora martyi Herib.	0	17	25	8
Pinnularia sp.	0	0	8	0
Rhoicosphenia curvata (Kutz.) Grun. ex Rabh.	17	25	33	33
Stauroneis crucicula (Grun. ex Cl.) Ross	0	0	8	0
Stephanodiscus astrea (Ehr.) Grun.	67	75	33	67
S. hantzschii Grun.	100	100	100	92
S. niagarae Ehr.	42	42	50	33
Suriella sp.	0	8	8	8
S. ovata	0	8	8	8
S. patella	0	0	0	8
Synedra actinastroides Lemm.	0	8	0	8
S. acus Kutz.	0	0	0	8
S. ulna (Nitz.) Ehr.	58	67	58	33
S. vaucheria (Kutz.) Peters.	0	0	8	0
Division Cyanophyta				
Anabaena flos-aquae (Lyngb.) DeB.	17	25	50	25
A. spiroides var. crassa Lemm.	42	58	33	33
Aphanizomenon flos-aquae (L.) Ralfs	100	92	100	92
Aphanocapsa sp.	8	0	0	0
A. pulchra (Kutz.) Rabh.	8	0	0	0
Aphanothece gelatinosa (Henn.) Lemm.	17	8	0	0
A. nidulans P. Richter	8	0	8	0
Chroococcus dispersus (Keissl.) Lemm.	17	0	0	0
Merismopedia tenuissima Lemm.	17	50	42	25
Microcystis aeruginosa Kutz. emend. Elekin	100	100	92	100
M. incerta Lemm.	42	17	33	17
Oscillatoria prolifica (Grev.) Gomont	0	8	8	0
Spirulina major Kutz.	0	0	8	0
Division Euglenophyta				
Euglena sp.	8	17	33	33
Division Pyrrophyta				
Ceratium hirundinella (O. Mull.) Dujardin	67	42	33	25
Cryptomonas ovata Ehr.	92	100	100	100
Rhodomonas sp.	75	83	75	92

Appendix III. Values of chlorophyll a, total standing crops and major taxa.

Date	Site	Chla $\mu g/m^3$	Total Cell Vol mm^3/L	Dominant Groups - % Total Cell Volume		
5/21	MC-1	13.1	4.19	Chrysophyta 90%	Chlorophyta 8%	Pyrrhophyta 2%
	MC-2	15.0	7.29	Chrysophyta 97%	Chlorophyta 2%	Pyrrhophyta 1%
	LO-W	19.2	5.77	Chrysophyta 88%	Chlorophyta 10%	Pyrrhophyta 2%
	LO-E	11.5	3.60	Chrysophyta 89%	Chlorophyta 5%	Pyrrhophyta 5%
5/30	MC-1	6.1	5.48	Chrysophyta 96%	Chlorophyta 2%	Pyrrhophyta 1%
	MC-2	8.5	2.34	Chrysophyta 82%	Cyanophyta 8%	Chlorophyta 5%
	LO-W	9.0	3.55	Chrysophyta 92%	Cyanophyta 4%	Chlorophyta 3%
	LO-E	6.6	1.98	Chrysophyta 89%	Cyanophyta 5%	Chlorophyta 4%
6/8	MC-1	9.3	7.61	Chrysophyta 96%	Chlorophyta 3%	Cyanophyta 1%
	MC-2	18.0	6.30	Chrysophyta 89%	Chlorophyta 8%	Cyanophyta 2%
	LO-W	16.6	8.47	Chrysophyta 95%	Chlorophyta 3%	Cyanophyta 2%
	LO-E	6.3	5.33	Chrysophyta 89%	Chlorophyta 6%	Cyanophyta 4%
6/22	MC-1	13.6	6.66	Chrysophyta 85%	Chlorophyta 11%	Cyanophyta 3%
	MC-2	13.4	5.03	Chrysophyta 73%	Chlorophyta 19%	Cyanophyta 7%
	LO-W	17.7	4.84	Chrysophyta 61%	Chlorophyta 18%	Cyanophyta 16%
	LO-E	6.2	2.27	Chrysophyta 58%	Chlorophyta 29%	Cyanophyta 7%
7/1	MC-1	13.2	3.03	Chrysophyta 81%	Chlorophyta 10%	Pyrrhophyta 7%
	MC-2	14.2	4.13	Chrysophyta 85%	Cyanophyta 7%	Chlorophyta 7%
	LO-W	10.5	4.15	Chrysophyta 92%	Chlorophyta 6%	Cyanophyta 2%
	LO-E	3.5	2.57	Chrysophyta 78%	Cyanophyta 10%	Chlorophyta 9%
7/10	MC-1	17.6	3.83	Chrysophyta 83%	Cyanophyta 14%	Chlorophyta 2%
	MC-2	32.5	5.03	Chrysophyta 67%	Cyanophyta 20%	Chlorophyta 8%
	LO-W	18.6	3.09	Chrysophyta 73%	Cyanophyta 23%	Chlorophyta 5%
	LO-E	3.6	1.26	Cyanophyta 66%	Chrysophyta 22%	Pyrrhophyta 10%
7/22	MC-1	22.9	3.04	Chrysophyta 61%	Cyanophyta 32%	Chlorophyta 6%
	MC-2	23.8	6.02	Cyanophyta 67%	Chrysophyta 23%	Chlorophyta 9%
	LO-W	6.1	3.38	Chrysophyta 57%	Cyanophyta 28%	Chlorophyta 13%
	LO-E	11.7	1.19	Cyanophyta 60%	Chrysophyta 29%	Chlorophyta 9%
8/4	MC-1	35.0	3.03	Cyanophyta 70%	Chrysophyta 22%	Chlorophyta 7%
	MC-2	45.0	10.10	Cyanophyta 74%	Chrysophyta 24%	Chlorophyta 2%
	LO-W	17.3	1.70	Cyanophyta 65%	Chrysophyta 23%	Chlorophyta 11%
	LO-E	5.1	0.86	Cyanophyta 53%	Chrysophyta 31%	Chlorphyta 15%
8/14	MC-1	33.3	3.58	Chrysophyta 77%	Cyanophyta 17%	Chlorophyta 5%
	MC-2	80.0	10.20	Chrysophyta 61%	Cyanophyta 35%	Chlorophyta 2%
	LO-W	111.0	5.99	Cyanophyta 66%	Chrysophyta 29%	Chlorophyta 5%
	LO-E	128.0	5.69	Chrysophyta 52%	Cyanophyta 41%	Chlorophyta 5%
9/4	MC-1	21.0	1.64	Chrysophyta 58%	Cyanophyta 34%	Chlorophyta 7%
	MC-2	31.7	10.40	Chrysophyta 85%	Cyanophyta 10%	Chlorophyta 3%
	LO-W	9.6	4.16	Chrysophyta 75%	Cyanophyta 21%	Chlorophyta 4%
	LO-E	0.9	0.36	Chrysophyta 49%	Chlorophyta 20%	Cyanophyta 17%
9/18	MC-1	1.7	2.54	Chrysophyta 65%	Cyanophyta 33%	Chlorophyta 2%
	MC-2	5.8	2.68	Chrysophyta 83%	Cyanophyta 12%	Chlorophyta 2%
	LO-W	1.7	2.32	Cyanophyta 66%	Chrysophyta 30%	Chlorophyta 2%
	LO-E	1.8	1.69	Chrysophyta 70%	Cyanophyta 22%	Chlorophyta 3%
10/2	MC-1	10.7	3.08	Chrysophyta 89%	Chlorophyta 5%	Cyanophyta 5%
	MC-2	13.0	4.17	Chrysophyta 81%	Cyanophyta 13%	Chlorophyta 5%
	LO-W	11.0	2.02	Chrysophyta 80%	Chlorophyta 10%	Euglenophyta 6%
	LO-E	8.1	3.07	Chrysophyta 90%	Chlorophyta 5%	Cyanophyta 3%

Appendix III. (Continued)

Date	Site	Dominant Taxa - % Total Cell Volume			
5/21	MC-1	Melosira italica	41%	Melosira granulata	7%
	MC-2	Synedra ulna	46%	Stephanodiscus hantzschii	11%
	LO-W	Stephanodiscus niagarae	38%	Melosira italica	9%
	LO-E	Melosira italica	23%	Stephanodiscus niagarae	13%
5/30	MC-1	Stephanodiscus niagarae	53%	Stephanodiscus hantzschii	11%
	MC-2	Stephanodiscus niagarae	14%	Synedra ulna	13%
	LO-W	Stephanodiscus niagarae	33%	Navicula cuspidata var. major	24%
	LO-E	Nitschia sps. a	17%	Stephanodiscus niagarae	11%
6/8	MC-1	Stephanodiscus niagarae	32%	Melosira italica	26%
	MC-2	Stephanodiscus niagarae	25%	Synedra ulna	14%
	LO-W	Melosira varians	60%	Stephanodiscus niagarae	14%
	LO-E	Melosira varians	30%	Stephanodiscus niagarae	29%
6/22	MC-1	Stephanodiscus niagarae	35%	Stephanodiscus hantzschii	13%
	MC-2	Stephanodiscus hantzschii	23%	Nitzschia sp. a	15%
	LO-W	Stephanodiscus hantzschii	17%	Stephanodiscus niagarae	16%
	LO-E	Stephanodiscus hantzschii	25%	Ulothrix subconstricta	20%
7/1	MC-1	Stephanodiscus niagarae	27%	Stephanodiscus hantzschii	15%
	MC-2	Stephanodiscus niagarae	38%	Melosira italica	12%
	LO-W	Stephanodiscus niagarae	57%	Melosira italica	11%
	LO-E	Stephanodiscus niagarae	46%	Stephanodiscus astrea	10%
7/10	MC-1	Melosira granulata	43%	Aphanizomenon flos-aquae	9%
	MC-2	Melosira granulata	32%	Microcystis aeruginosa	13%
	LO-W	Melosira granulata	30%	Aphanizomenon flos-aquae	15%
	LO-E	Aphanizomenon flos-aquae	42%	Microcystis aeruginosa	24%
7/22	MC-1	Aphanizomenon flos-aquae	29%	Melosira granulata	29%
	MC-2	Aphanizomenon flos-aquae	59%	Cyclotella spp.	12%
	LO-W	Aphanizomenon flos-aquae	19%	Synedra ulna	16%
	LO-E	Aphanizomenon flos-aquae	44%	Microcystis aeruginosa	13%
8/4	MC-1	Aphanizomenon flos-aquae	53%	Microcystis aeruginosa	16%
	MC-2	Microcystis aeruginosa	39%	Aphanizomenon flos-aquae	33%
	LO-W	Aphanizomenon flos-aquae	28%	Microcystis aeruginosa	27%
	LO-E	Aphanizomenon flos-aquae	25%	Melosira granulata	14%
8/14	MC-1	Melosira granulata	41%	Melosira italica	15%
	MC-2	Melosira granulata	41%	Microcystis aeruginosa	18%
	LO-W	Microcystis aeruginosa	54%	Melosira granulata	13%
	LO-E	Melosira granulata	23%	Microcystis aeruginosa	20%
9/4	MC-1	Melosira granulata	25%	Melosira italica	21%
	MC-2	Melosira italica	42%	Melosira granulata	27%
	LO-W	Melosira granulata	35%	Melosira italica	30%
	LO-E	Cocconeis placentula	17%	green coccoid	16%
9/18	MC-1	Melosira granulata	31%	Microcystis aeruginosa	26%
	MC-2	Stephanodiscus niagarae	25%	Melosira italica	23%
	LO-W	Microcystis aeruginosa	55%	Melosira italica	12%
	LO-E	Melosira italica	38%	Microcystis aeruginosa	17%
10/2	MC-1	Melosira italica	40%	Stephanodiscus hantzschii	11%
	MC-2	Melosira italica	30%	Stephanodiscus niagarae	29%
	LO-W	Melosira italica	36%	Stephanodiscus hantzschii	10%
	LO-E	Melosira italica	49%	Melosira granulata	24%

Appendix III. (Continued)

Date	Site	Dominant Taxa - % Total Cell Volume			
5/21	MC-1	Stephanodiscus niagarae	6%	Synedra ulna	6%
	MC-2	Stephanodiscus astrea	8%	Melosira italica	7%
	LO-W	Stephanodiscus hantzschii	8%	green coccoid	7%
	LO-E	Stephanodiscus hantzschii	11%	Cyclotella meneghiana	7%
5/30	MC-1	Melosira italica	10%	Asterionella formosa	7%
	MC-2	Stephanodiscus hantzschii	12%	Melosira italica	8%
	LO-W	Melosira italica	8%	Melosira varians	8%
	LO-E	Stephanodiscus hantzschii	10%	Melosira italica	9%
6/8	MC-1	Melosira granulata	14%	Nitzschia sp. a	7%
	MC-2	Stephanodiscus hantzschii	10%	Melosira varians	10%
	LO-W	Synedra ulna	6%	Melosira italica	4%
	LO-E	Melosira italica	7%	Stephanodiscus hantzschii	5%
6/22	MC-1	Cyclotella spp.	10%	Ulothrix subconstricta	8%
	MC-2	Ulothrix subconstricta	15%	Melosira italica	9%
	LO-W	Ulothrix subconstricta	13%	Aphanizomenon flos-aquae	13%
	LO-E	Cyclotella spp.	10%	Synedra ulna	8%
7/1	MC-1	Stephanodiscus astrea	10%	Melosira italica	8%
	MC-2	Stephanodiscus hantzschii	6%	Cyclotella meneghiana	6%
	LO-W	Melosira distans	5%	Cyclotella meneghiana	4%
	LO-E	Microcystis aeruginosa	8%	green coccoid	6%
7/10	MC-1	Melosira varians	9%	Stephanodiscus hantzschii	8%
	MC-2	Cyclotella spp.	9%	Aphanizomenon flos-aquae	6%
	LO-W	Cyclotella spp.	10%	Microcystis aeruginosa	8%
	LO-E	Rhodomonas sp.	8%	Melosira granulata	8%
7/22	MC-1	Melosira italica	10%	Cyclotella spp.	9%
	MC-2	Cyclotella meneghiania	5%	Anabaena spiroides var. crassa	4%
	LO-W	Stephanodiscus niagarae	13%	green coccoid	9%
	LO-E	Melosira granulata	13%	green coccoid	7%
8/4	MC-1	Melosira granulata	10%	Synedra ulna	5%
	MC-2	Stephanodiscus niagarae	10%	Melosira granulata	8%
	LO-W	green coccoid	9%	Anaphanizomenon flos-aquae	9%
	LO-E	Aphanothece gelatinosa	14%	green coccoid	12%
8/14	MC-1	Synedra ulna	10%	Aphanizomenon flos-aquae	8%
	MC-2	Aphanizomenon flos-aquae	10%	Melosira italica	8%
	LO-W	Aphanizomenon flos-aquae	8%	Cyclotella spp.	6%
	LO-E	Aphanizomenon flos-aquae	19%	Melosira italica	13%
9/4	MC-1	Aphanizomenon flos-aquae	21%	Microcystis aeruginosa	9%
	MC-2	Apahnizomenon flos-aquae	8%	Cyclotella meneghiana	6%
	LO-W	Aphanizomenon flos-aquae	11%	Microcystis aeruginosa	8%
	LO-E	Melosira granulata	13%	Aphanizomenon flos-aquae	13%
9/18	MC-1	Nitschia palea	11%	Melosira italica	11%
	MC-2	Melosira granulata	21%	Aphanizomenon flos-aquae	6%
	LO-W	Aphanizomenon flos-aquae	11%	Melosira granulata	8%
	LO-E	Stephanodiscus astrea	9%	Melosira varians	5%
10/2	MC-1	Melosira granulata	8%	Aphanizomenon flos-aquae	7%
	MC-2	Melosira granulata	8%	Stephanodiscus hantzschii	6%
	LO-W	Stephanodiscus astrea	10%	green coccoid	7%
	LO-E	Stephanodiscus hantzschii	5%	green coccoid	4%

Appendix III. (Continued)

Date	Site	Dominant Taxa - Total Cell Volume	
5/21	MC-1	Stephanodiscus hantschii	5%
	MC-2	Suriella ovata	6%
	LO-W	Melosira varians	4%
	LO-E	Asterionella formosa	7%
5/30	MC-1	Melosira varians	4%
	MC-2	Asterionella formosa	6%
	LO-W	Stephanodiscus hantzschii	5%
	LO-E	Asterionella formosa	8%
6/8	MC-1	Stephanodiscus hantzschii	6%
	MC-2	Nitzschia sp. a	7%
	LO-W	Stephanodiscus hantzschii	3%
	LO-E	Nitzschia sp. a	4%
6/22	MC-1	Melosira italica	8%
	MC-2	Cyclotella spp.	5%
	LO-W	Melosira italica	9%
	LO-E	Melosira granulata	8%
7/1	MC-1	Cyclotella meneghiana	5%
	MC-2	Microcystis aeruginosa	6%
	LO-W	Cyclotella spp.	4%
	LO-E	Cyclotella spp.	5%
7/10	MC-1	Stephanodiscus astrea	7%
	MC-2	Melosira italica	6%
	LO-W	Melosira italica	6%
	LO-E	Melosira italica	5%
7/22	MC-1	Cyclotella meneghiana	4%
	MC-2	Microcystis aeruginosa	3%
	LO-W	Microcystis aeruginosa	5%
	LO-E	Mleosira italica	6%
8/4	MC-1	green coccoid	4%
	MC-2	Melosira italica	2%
	LO-W	Melosira granulata	7%
	LO-E	Microcystis aeruginosa	11%
8/14	MC-1	Cyclotella meneghiana	7%
	MC-2	Aphanothece gelatinosa	5%
	LO-W	Melosira italica	6%
	LO-E	Cyclotella meneghiana	7%
9/4	MC-1	Cyclotella meneghiana	5%
	MC-2	Stephanodiscus hantzschii	5%
	LO-W	Cyclotella meneghiana	5%
	LO-E	Melosira varians	11%
9/18	MC-1	Aphanizomenon flos-aquae	6%
	MC-2	Stephanodiscus astrea	6%
	LO-W	Cyclotella meneghiana	3%
	LO-E	Melosira granulata	5%
10/2	MC-1	Synedra ulna	6%
	MC-2	Nitzschia sp. a	5%
	LO-W	Melosira granulata	7%
	LO-E	Cyclotella meneghiana	3%