81-81 ALGAL CONDITIONS IN THE CALOOSAHATCHEE RIVER (1975-79), LAKE OKEECHOBEE TO FRANKLIN LOCK, FLORIDA

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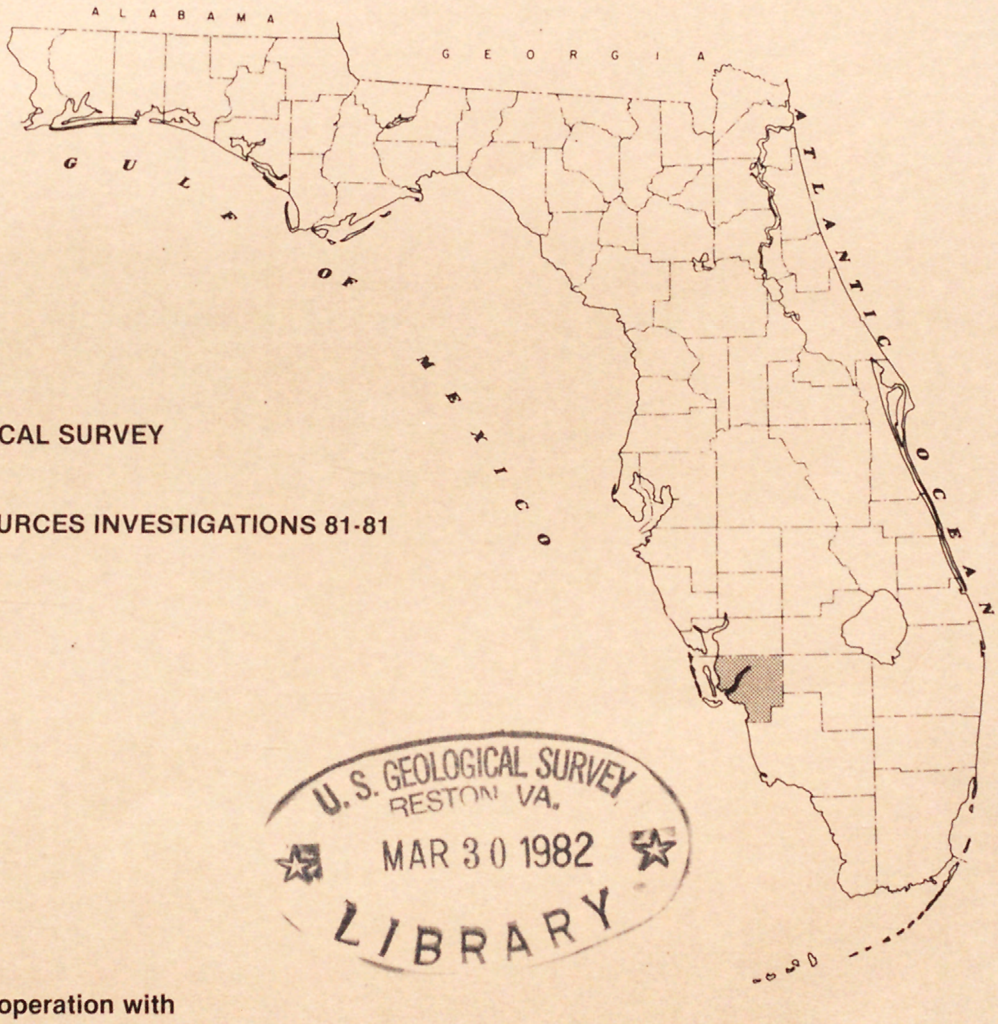

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Blue-green algae were dominant in the river during the summer and at the upstream site throughout the year. The percentage of blue-green algae decreased downstream.

Concentrations of nitrite plus nitrate nitrogen were inversely correlated with concentrations of algae and decreased to near zero during algal blooms. The low concentrations of these forms of inorganic nitrogen relative to other major nutrients probably favor blue-green algae and limit growth of other algae.

Contributions by the basin tributaries to the nutritive condition of the river were small because concentrations of nutrients, algal growth potential, and algae in the tributaries were generally less than those in the river.

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

U.S. Geological Survey
Suite F-240
325 John Knox Road
Tallahassee, Florida 32303

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Factors for converting inch-pound units to International System (SI) metric units and abbreviation of units

Multiply	By	To obtain
foot (ft)	3.048×10^{-1}	meter (m)
inch (in)	2.540×10^{1}	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	2.832×10^{-2}	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	4.381×10^{-2}	cubic meters per second (m^3/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level."

ALGAL CONDITIONS IN THE CALOOSAHATCHEE RIVER (1975-79), LAKE OKEECHOBEE TO FRANKLIN LOCK, FLORIDA

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ABSTRACT

Maximum numbers of suspended algae occurred in late spring and early summer, in each of the years 1975-79, in the Caloosahatchee River. Numbers exceeded 100,000 cells per milliliter at all stations sometime during the study. Concentrations decreased during late summer and autumn and were low during winter, except in January 1979 when numbers at most sites exceeded 100,000 cells per milliliter. The January 1979 bloom coincided with large discharges from Lake Okeechobee. During previous winters, discharges and algal numbers were lower. During other seasons, algal blooms occurred most frequently under low-flow or stagnant conditions. The upstream site at Moore Haven, which had the least discharge and was most stagnant, had consistently higher algal concentrations than downstream sites.

Blue-green algae were dominant in the river during the summer and at the upstream site throughout the year. The percentage of blue-green algae decreased downstream.

Concentrations of nitrite plus nitrate nitrogen were inversely correlated with concentrations of algae and decreased to near zero during algal blooms. The low concentrations of these forms of inorganic nitrogen relative to other major nutrients probably favor blue-green algae and limit growth of other algae.

Contributions by the basin tributaries to the nutritive condition of the river were small because concentrations of nutrients, algal growth potential, and algae in the tributaries were generally less than those in the river.

INTRODUCTION

The Caloosahatchee River is a 42-mile long waterway that connects Lake Okeechobee with the Caloosahatchee River estuary in southwest Florida (fig. 1). Over the years, the river has been extensively modified. Most of the upstream half is a canal dug to connect the river with Lake Okeechobee. Downstream, the river has been straightened, widened, and deepened. At present the river is 150 to 390 feet wide and 18 to 27 feet deep (South Florida Water Management District, 1980). The term "Caloosahatchee River" in this report refers to the freshwater reach of the river-canal system.

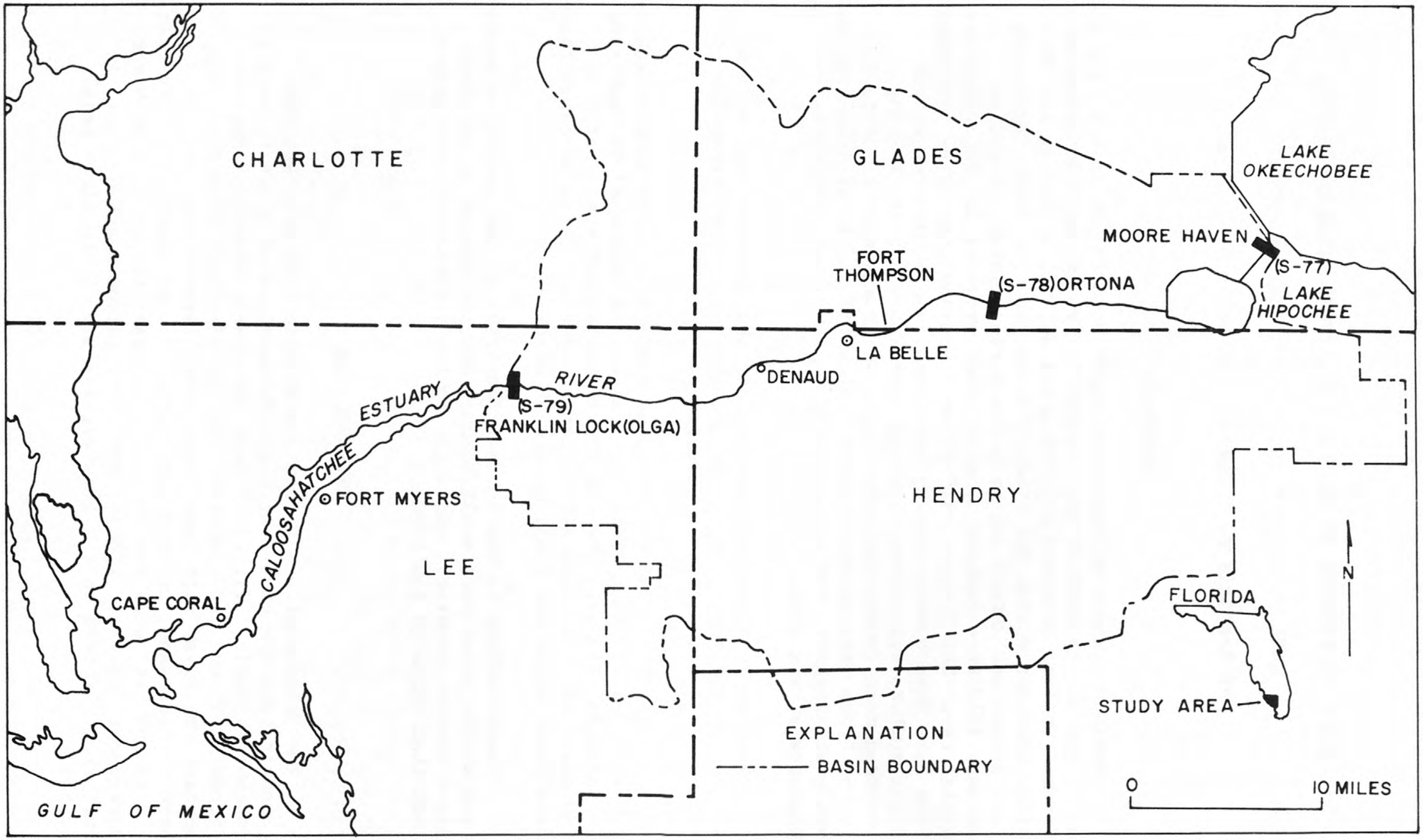

Figure 1.--Caloosahatchee River basin, Lake Okeechobee to Franklin Lock, and surrounding area (Western part of the basin, Franklin Lock to the Gulf of Mexico is not delineated).

Water flow in the Caloosahatchee River is controlled by three locks and dams: (1) Moore Haven Lock (S-77) at the upstream end of the river at Lake Okeechobee; (2) Ortona Lock (S-78) about 15 river miles downstream; and (3) Franklin Lock (S-79) at the downstream end of the river where it becomes estuarine (fig. 1).

The Caloosahatchee River drains a basin of about 850 square miles in area (fig. 1a). The basin contains a maze of tributaries, canals, and ditches. Parts of some tributaries have been channeled, and in some places the direction and period of natural runoff have been altered by interconnected canals and pumping activities.

The Caloosahatchee River is used for navigation and recreation, and as an agricultural and municipal water supply. Large quantities of water are withdrawn from the river system primarily for irrigating citrus and other crops. The river is the source of water for the Lee County water system and for the city of Fort Myers, which collectively serve an estimated population of 70,000. The river supplies about 50 percent of the municipal water for Lee County. In 1978, this amounted to 3,907 Mgal compared with 3,740 Mgal pumped from ground water. Use of the river as a source of water for public supply is presently under consideration by the city of La Belle in Hendry County.

Large concentrations of algae, or algal blooms, occur at times in the Caloosahatchee River and are detrimental to the quality of the river. Blooms are esthetically unpleasing. They can damage fish and other aquatic life by depletion of oxygen or release of toxins, and can create problems in the treatment of drinking water.

Algae are the major primary producers in many aquatic environments. Some algae live on, in, or attached to substrate; others float or swim. Attached algae (periphyton) can be important producers in shallow, flowing waters, but are usually restricted in deeper water bodies where floating or swimming algae (phytoplankton) predominate. Phytoplankton are the dominant algae in the Caloosahatchee River because water depth and low light penetration inhibit growth of algae on the bottom. In this report, "algae" refers to the suspended algae or phytoplankton.

Purpose and Scope

The purpose of this investigation was to gather information on water quality and water flow in the Caloosahatchee River and its tributaries, with emphasis on information that would help define the character of the algal population. The investigation was conducted by the U.S. Geological Survey in cooperation with Lee County, Florida.

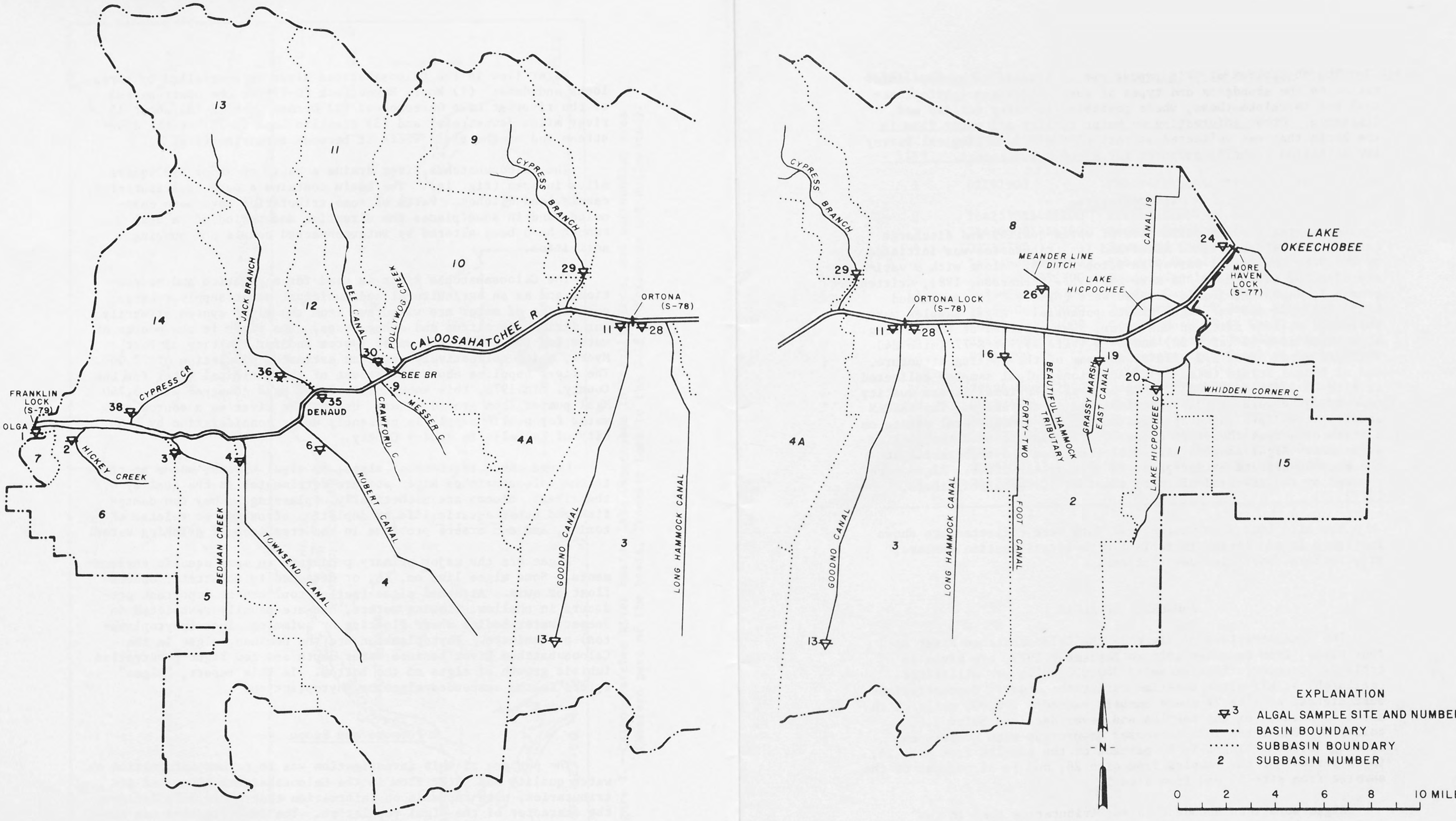

Figure 1a.--Caloosahatchee River and tributaries, sampling sites, and subbasins, Lake Okeechobee to Franklin Lock.

The objectives of this report are to provide background information on the abundance and types of suspended algae (phytoplankton) and to relate these, where possible, to water quality and discharge. Other information on water quality and water flow in the basin that was collected as part of the U.S. Geological Survey investigation is being prepared for a companion report.

Data Collection

A program for the collection of water-quality and discharge data on the Caloosahatchee River and its tributaries was initiated by the U.S. Geological Survey in October 1976. Along with a variety of other data (H. R. La Rose and B. F. McPherson, 1981, written commun.), depth-integrated samples were collected for suspended algal analysis and for algal growth potential. Algal samples were collected at four sites on the river, just upstream of the locking structures at S-78 (site 28) and S-79 (site 1), at S-77 (site 24) at Moore Haven about 1/2 mile downstream of the locking structure, and at Denaud Bridge (site 35). Additional algal samples collected at site 28 in 1975-76 and 1979 as part of a National Stream Quality Accounting Network (NASQAN) are included in the study. The NASQAN samples were depth integrated and composited from several points on a transect across the river about 300 feet upstream of the locking structure. Algal samples were collected from the tributaries at the most downstream bridge prior to joining the river. Algae were counted by the inverted microscope method (Greeson and others, 1977).

The site locations where algal data were collected are shown in figure 1a and listed in table 1 with identification numbers, site numbers, and brief descriptions.

ABUNDANCE OF ALGAE

The concentrations of algae in the Caloosahatchee River at four sites, from December 1976 to September 1979, are given in table 2. Concentrations exceeded 100,000 cells per milliliter (cells/mL) at all sites sometime during the study. Concentrations were highest at site 24 where numbers exceeded 100,000 cells/mL in about 40 percent of the samples and never declined below 1,000 cells/mL. Concentrations decreased downstream with numbers exceeding 10,000 cells/mL in 82 percent of the samples from site 24, in 40 percent of the samples from site 28, and in 32 percent of the samples from site 35 and from site 1.

Algae were less abundant in the tributaries than in the Caloosahatchee River (table 3). Numbers in the tributaries ranged from less than 10 to 130,000 cells/mL, but only 12 percent of the samples exceeded 10,000 cells/mL. Highest concentrations occurred in spring and summer.

Table 1.--U.S. Geological Survey sites in the Caloosahatchee River basin.

Site	Identification No.	Description
1	02292900	Caloosahatchee River at Franklin Lock (S-79).
2	264253081402200	Hickey Creek at SR-80.
3	264230081355800	Bedman Creek at SR-80.
4	02292780	Townsend Canal at SR-80.
6	264346081301700	Roberts Canal at SR-80.
11	264715081181700	Goodno Canal at Ortona Locks.
13	263607081204700	Goodno Canal at SR-832.
16	264604081140000	Forty-two Foot Canal at SR-80.
19	264602081102000	Grassy Marsh East Canal at SR-80.
20	264508081074800	Lake Hicpochee Canal at SR-80.
24	02292000	Caloosahatchee Canal at Moore Haven (S-77).
26	264844081122200	Meander Line Ditch at SR-78.
28	02292480	Caloosahatchee Canal at Ortona (S-78).
29	264846081201000	Cypress Branch at SR-78.
30	264529081284000	Bee Branch at SR-78.
35	02292700	Caloosahatchee River at Denaud.
36	264510081313100	Jacks Branch at Norris Road.
38	264332081373800	Cypress Creek at SR-78.

Table 2.--Numbers of algal cells per milliliter at four stations on the Caloosahatchee River, December 1976 to September 1979.

Date	Site 24 (S-77) (Moore Haven)	Site 28 (S-78) (Ortona)	Site 35 (Denaud)	Site 1 (S-79) (Franklin Lock)
12/76	63,000	210	75	14,000
01/77	57,000	1,200	270	3,300
02/77	18,000	110	1,900	3,700
03/77	1,700	--	550	370
04/77	270,000	--	260	860
05/77	200,000	52,000	84,000	--
06/77	190,000	50,000	250,000	140,000
07/77	130,000	18,000	20,000	150,000
08/77	240,000	7,400	19,000	15,000
09/77	72,000	740	6,800	--
10/77	10,000	1,300	2,000	980
11/77	17,000	150	310	6,500
12/77	1,700	--	79	71
01/78	44,000	--	740	640
02/78	120,000	--	3,000	350
03/78	2,300	8,300	220	460
04/78	20,000	--	5,300	2,000
05/78	68,000	18,000	1,600	990
06/78	340,000	53,000	16,000	14,000
07/78	370,000	5,700	96,000	13,000
08/78	85,000	21,000	29,000	18,000
09/78	24,000	1,600	9,800	4,800
10/78	--	--	--	--
11/78	--	430	--	--
12/78	--	--	--	--
01/79	170,000	200,000	290,000	1,600
02/79	--	--	--	--
03/79	--	83,000	--	--
04/79	22,000	4,000	14,000	1,300,000
05/79	510,000	1/7,600	1,200	1,500
06/79	330,000	1/2,000	310	--
07/79	310,000	1/145,000	6,400	9,900
08/79	--	62,000	--	--
09/79	3,800	1/1,260	310	160

1/ Average of two values in a month.

Table 3.--Numbers of algal cells per milliliter in the tributaries of the Caloosahatchee River.

Name	Site No.	1976-77										1978			
		Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Feb	May	July	Sept
Bedman Creek at SR-80.	3	--	--	--	--	--	--	--	--	--	--	500	16	130	120
Bee Branch at SR-78.	30	900	450	820	86	1,600	99	2,200	600	970	790	--	--	--	--
Cypress Branch at SR-78.	29	850	--	840	--	--	--	--	--	2,000	3,700	--	--	--	--
Cypress Creek at SR-78.	38	180	--	21	4	150	630	810	5,900	2,200	1,100	160	0	470	9
Forty-Two Foot Canal at SR-80.	16	--	--	--	--	--	--	--	--	--	--	6,600	470	270	--
Goodno Canal at Ortona Locks.	11	--	--	--	--	--	--	--	--	--	--	200	32	220	230
Grassy Marsh Canal at SR-80.	19	1,400	1,000	850	1,000	45,000	4,900	130,000	93,000	4,100	4,700	--	--	--	--
Hickey Creek at SR-80.	2	350	1,000	420	4,400	890	50,000	55,000	18,000	22,000	1,700	--	--	--	--
Jacks Branch at Norris Road.	36	--	--	--	--	--	--	--	--	--	--	820	0	110	46
Lake Hic-pochee Canal at SR-80.	20	--	--	--	--	--	--	--	--	--	--	--	8,800	85,000	660
Meander Line Ditch at SR-78.	26	--	--	--	--	--	--	--	--	--	--	2,000	7,600	34,000	3,700
Roberts Canal at SR-80.	6	77	1,200	340	470	1,600	450	4,600	8,700	7,200	2,600	1,100	15,000	3,700	1,100
Townsend Canal at SR-80.	4	--	--	--	--	--	--	--	--	--	--	220	260	1,400	1,100

The relatively unaltered and natural flowing tributaries on the north side of the Caloosahatchee River, such as Cypress Branch, Bee Branch, Jacks Branch, and Cypress Creek, had consistently low numbers of algae (less than 6,000 cells/mL). In these tributaries, shade from trees and other plants, and flowing water did not favor growth of suspended algae.

Other tributaries, particularly those on the south side of the river, sometimes had high concentrations of algae (table 3). These high concentrations are attributed to ponding and direct sunlight, both which favor algal growth, or to input of algae from the river by pumping or from backwater.

Algae attached to substrata were visible in some tributaries. Attached (periphytic) algae may add significantly to algal biomass in unshaded tributaries.

MAJOR GROUPS AND GENERA OF ALGAE

Blue-green algae were dominant in number in the phytoplankton of the river during much of the study (fig. 2). The percentage of blue-green algae, relative to other forms, decreased downstream. At site 24, blue-green algae were dominant throughout the study, but downstream green algae and euglenoids made up sizable percentages of the phytoplankton at times. Blue-green algae were dominant along the entire reach of the river during the summer of 1977 and 1978 and in the eastern reach (site 24 to site 28) throughout 1979. Green algae dominated the lower reach, site 35 to site 1, in the summer of 1979. Diatoms were present throughout the years, but accounted for only small percentages of the phytoplankton.

A summary of the numerically dominant genera of algae identified at the four river sites, December 1976 to September 1979, is given in table 4. Anacystis was dominant most frequently, followed by Oscillatoria.

The algal genera which accounted for at least 0.2 percent of the total cell count of all samples at each of the four river sites are given in tables 5-5C. At the three upstream sites, Anacystis and Oscillatoria were the most abundant genera. Anacystis accounted for 35 percent of the total cell count at site 24; 22 percent at site 28; 27 percent at site 35; and 15 percent at site 1. Highest numbers of Anacystis occurred in late spring or summer (fig. 3). Numbers exceeded 100,000 cells/mL at site 24 at these times. Oscillatoria accounted for 28 percent of the total cell count at site 24; 58 percent at site 28 and site 35; and 4 percent at site 1. Oscillatoria became increasingly abundant in 1979 and was dominant on January 15, 1979, with 150,000 cells/mL at site 28.

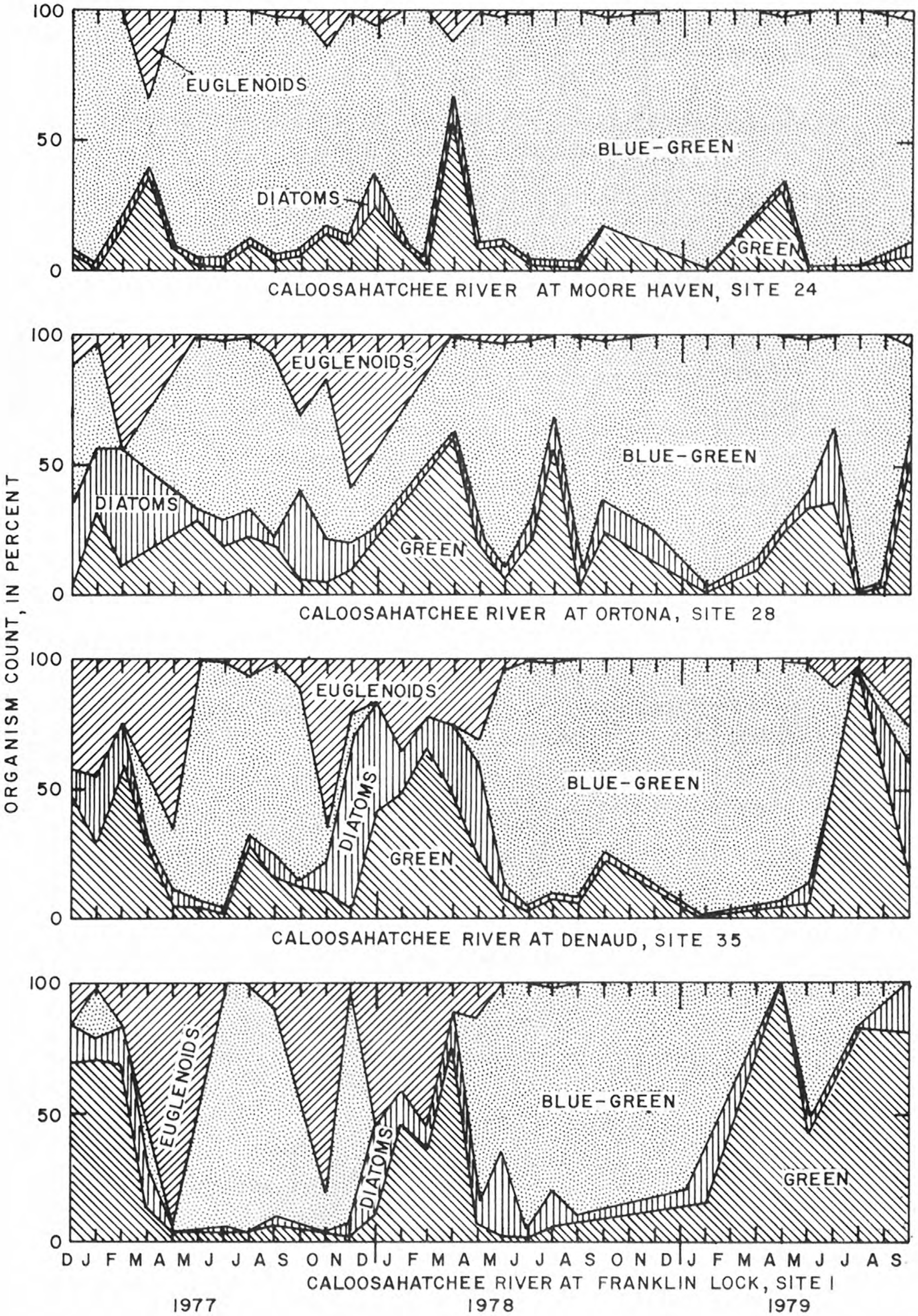

Figure 2.--Percentages of major algal groups in the Caloosahatchee River, December 1976 to September 1979.

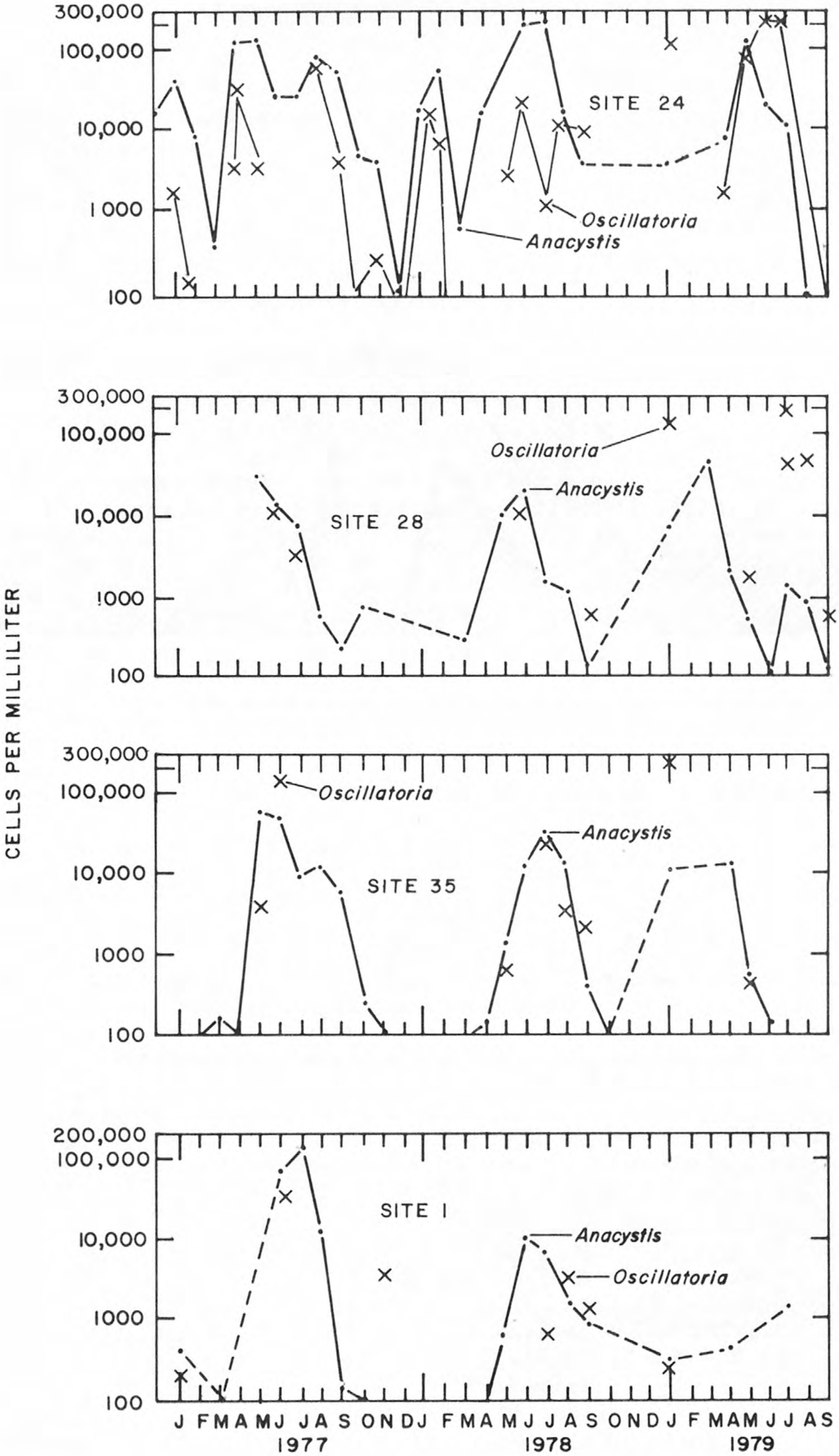

Figure 3.--Concentrations of Anacystis and Oscillatoria in the Caloosahatchee River.

Table 4.--Dominant genera of algae in the Caloosahatchee River, December 1976 to September 1979.

[All genera listed by Palmer (1969; 1977) as pollution tolerant or associated with eutrophic waters, except those with asterisks. Numbers indicate number of samples in which genus was dominant]

Genus	Site 24 (S-77) (Moore Haven)	Site 28 (S-78) (Ortona)	Site 35 (Denaud)	Site 1 (S-79) (Franklin Lock)	Totals
Anacystis	13	9	9	7	38
Agmenellum	6	1	1	2	10
Anabaena	1	--	--	--	1
Chlamydomonas	--	--	4	4	8
Chroomonas*	--	--	3	1	4
Coccochloris*	--	--	--	1	1
Cryptomonas	--	2	4	4	10
Cyclotella	--	--	1	--	1
Eudorina	--	1	--	--	1
Lyngbya	3	1	--	--	4
Oscillatoria	4	13	3	2	22
Pandorina	--	--	--	1	1
Pediastrum	1	--	--	--	1
Scenedesmus	--	--	--	1	1
Schroederia*	--	--	1	--	1
Sphaerocystis*	--	--	--	1	1
Tribonema	--	--	1	--	1
Volvox	--	--	--	1	1
Totals	28	27	27	25	107

Table 5.--Algal genera which accounted for at least 0.2 percent of the total cell count of all samples at site 24, December 1976 to September 1979.

Phylum	Genus	Percent of total count--all samples[1]	Percent of all samples in which genus was reported[2]
Chlorophyta (green algae)	*Coelastrum*	0.2	25
	Ankistrodesmus	.4	86
	Dictyosphaerium	.2	50
	Kirchneriella	.4	64
	Crucigenia	.2	25
	Scenedesmus	1.2	100
	Sphaerocystis	.2	21
	Subtotal	2.8	--
Chrysophyta (Diatoms)	*Cyclotella*	.5	89
	Melosira	.2	57
	Subtotal	.7	--
Cyanophyta (blue-green algae)	*Agmenellum*	18.6	82
	Anacystis	35.2	96
	Coccochloris	.2	21
	Gomphosphaeria	.3	14
	Anabaena	5.6	36
	Aphanizomenon	.2	11
	Lyngbya	5.4	57
	Oscillatoria	27.8	75
	Schizothrix	.3	7
	Raphidiopsis	.4	7
	Subtotal	94.0	--
Euglenophyta (Cryptomonads)	*Cryptomonas*	.2	71
	Total	97.7	--

[1]Total cell count for a genus divided by the total cell count for all genera.

[2]Number of samples in which a genus was reported divided by the total number of samples.

Table 5a.--Algal genera which accounted for at least 0.2 percent of the total cell count of all samples at site 28, October 1976 to September 1979.

Phylum	Genus	Percent of total count--all samples[1]	Percent of all samples in which genus was reported[2]
Chlorophyta (green algae)	*Coelastrum*	0.6	19
	Pediastrum	.2	7
	Ankistrodesmus	.2	74
	Chodatella	.2	22
	Kirchneriella	.4	44
	Quadrigula	.2	4
	Crucigenia	1.9	26
	Scenedesmus	1.7	70
	Chlamydomonas	.3	74
	Eudorina	.5	4
	Subtotal	6.2	--
Chrysophyta (Diatoms)	*Cyclotella*	1.1	85
	Melosira	.4	41
	Gomphonema	.7	15
	Subtotal	3.2	--
Cyanophyta (blue-green algae)	*Agmenellum*	3.1	44
	Anacystis	22.4	81
	Gomphosphaeria	.2	7
	Anabaena	2.4	30
	Aphanizomenon	.9	4
	Arthrospira	.8	4
	Lyngbya	1.3	22
	Oscillatoria	58.0	56
	Subtotal	89.1	--
	Total	98.5	--

[1]Total cell count for a genus divided by the total cell count for all genera.

[2]Number of samples in which a genus was reported divided by the total number of samples.

Table 5b.--Algal genera which accounted for at least 0.2 percent of the total cell count of all samples at site 35, December 1976 to September 1979.

Phylum	Genus	Percent of total count--all samples[1]	Percent of all samples in which genus was reported[2]
Chlorophyta (green algae)	*Schroederia*	0.7	11
	Ankistrodesmus	.2	36
	Dictyospharium	.4	11
	Kirchneriella	.6	36
	Actinastrum	.3	4
	Scenedesmus	.8	58
	Chlamydomonas	.8	79
	Eudorina	.2	4
	Pandorina	.4	7
	Subtotal	4.4	--
Chrysophyta (Diatoms)	*Cyclotella*	.9	75
	Nitzschia	.3	36
	Subtotal	1.2	--
Cyanophyta (blue-green algae)	*Agmenellum*	2.8	21
	Anacystis	27.3	71
	Coccochloris	1.5	21
	Anabaena	.6	14
	Lyngbya	.9	11
	Oscillatoria	57.8	32
	Subtotal	90.9	--
Euglenophyta (Cryptomonads)	*Chroomonas*	.4	61
	Cryptomonas	.6	75
	Subtotal	1.0	--
	Total	97.5	--

[1]Total cell count for a genus divided by the total cell count for all genera.

[2]Number of samples in which a genus was reported divided by the total number of samples.

Table 5c.--Algal genera which accounted for at least 0.2 percent of the total cell count of all samples at site 1, December 1976 to September 1979.

Phylum	Genus	Percent of total count--all samples[1]	Percent of all samples in which genus was reported[2]
Chlorophyta (green algae)	*Schroederia*	0.2	16
	Kirchneriella	.3	24
	Scenedesmus	.2	28
	Sphaerocystis	.3	4
	Chlamydomonas	.4	68
	Eudorina	.2	8
	Pandorina	76.5	8
	Subtotal	78.1	--
Chrysophyta (Diatoms)	*Cyclotella*	.2	68
Cyanophyta (blue-green algae)	*Agmenellum*	.4	16
	Anacystis	15.3	56
	Anabaena	.7	16
	Lyngbya	.2	12
	Oscillatoria	3.7	32
	Subtotal	20.3	--
Euglenophyta (Cryptomonads)	*Chroomonas*	.2	44
	Cryptomonas	.4	76
	Subtotal	.6	--
	Total	99.2	--

[1]Total cell count for a genus divided by the total cell count for all genera.

[2]Number of samples in which a genus was reported divided by the total number of samples.

Maximum numbers of *Oscillatoria* occurred at site 24 in June and July 1979 (290,000 and 260,000 cells/mL, respectively). At the downstream site, site 1, the green algae *Pandorina* dominated the total cell count (77 percent). This dominance resulted from a single bloom in April 1979 of over a million cells/mL. *Pandorina* was only reported in 8 percent of the samples at site 1.

Blue-green algae were also the dominant algal group in most of the tributaries of the Caloosahatchee River (table 6). Diatoms and green algae made up relatively higher percentages of the total algal population in tributaries that had low numbers of algae.

Anacystis and *Oscillatoria* were also the dominant algal genera in most of the tributaries (table 6). Together they accounted for 62 percent of the total cell count. Other common genera included the blue-green algae *Lyngbya*, *Gomphosphaeria*, *Agmenellum*, and *Coccochloris*, and the green algae *Chlamydomonas*.

Most of the dominant algal genera in the Caloosahatchee River and its tributaries were listed by Palmer (1969; 1977) as pollution tolerant or associated with eutrophic waters.

ALGAL GROWTH POTENTIAL

Algal growth potential (AGP) is measured in the laboratory as the growth of the test algae *Selenastrum capricomutum* in autoclaved sample water and is expressed as milligrams dry weight per liter (Greeson and others, 1977). AGP does not duplicate algal growth in the natural environment because the laboratory and natural environment differ in light, temperature, grazing by fish and invertebrates, and toxic substances. AGP does, however, provide an index of the capacity of a water to support growth based on the nutritive and nontoxic condition of the water. AGP determinations provide baseline data and can be used to compare the potential for different water sources, such as tributaries, to support algal growth.

Algal growth potential ranged from 0.4 to 30 milligrams per liter (mg/L) in the Caloosahatchee River, and 0.05 to 19 mg/L in the tributaries (table 7). Mean concentrations were slightly lower in the tributaries than in the river. Goodno Canal at SR-832 (site 13) and Jacks Branch (site 36) had lowest average values, less than 2.0 mg/L. Although AGP values were quite variable, these data indicate that most tributaries add little to the capacity of the river to support algal growth.

Table 6.--Percentages of major algal groups in the Caloosahatchee River tributaries.

Name	Site	Number of samples	Total cells	Average number of cells	Percentage of total: Green algae	Percentage of total: Diatoms	Percentage of total: Englenoids	Percentage of total: Blue-green algae	Percentage of blue greens: *Anacystis*	Percentage of blue greens: *Oscillatoria*	Other common genera
Bedman Creek.	3	4	766	194	11	14	9	66	34	32	
Bee Branch.	30	10	8,515	850	4	6	2	88	35	36	*Lyngbya*.
Cypress Branch.	29	4	7,390	1,850	22	13	4	61	43	7	*Chlamydomonas*,
Cypress Creek.	38	13	11,634	895	9	4	6	80	59	15	
Forty-Two Foot Canal.	16	3	7,340	2,447	21	13	3	63	--	16	*Gomphosphaeria*.
Goodno Canal, Ortona.	11	3	462	154	30	45	1	24	--	5	
Grassy Marsh Canal.	19	10	286,000	28,600	6	3	1	90	42	11	*Lyngbya*.
Hickey Creek.	2	10	153,760	15,376	6	3	5	86	50	31	
Jacks Branch.	36	4	980	245	22	1	18	60	20	40	
Lake Hicpochee.	20	3	94,460	31,487	9	2	1	88	28	54	
Meander Line	26	4	47,300	11,825	8	8	1	83	5	76	*Gomphosphaeria*,
Roberts Canal.	6	13	44,437	3,420	10	6	3	81	55	10	*Chlamydomonas*,
Townsend Canal.	4	4	2,980	745	20	8	4	68	4	39	*Agmenellum*.

Table 7.--Algal growth potential (AGP) in the Caloosahatchee River and tributaries.

[Milligram dry weight per liter]

Name	Site	February 13-14, 1978	May 4, 1978	January 15-18, 1979	April 17-18, 1979	June 14-16, 1979	September 19-21, 1979	Average
Caloosahatchee River at:								
Moore Haven.	24	7.8	2.2	--	--	4.4	30	11
Ortona.	28	13	14	--	--	13	16	14
Denaud.	35	9.9	13	--	--	9.6	14	12
Franklin Lock (S-79).	1	.4	10	--	--	--	28	13
Bedman Creek, SR-80.	3	--	9.8	0.5	1.1	1.0	.5	2.6
Bee Branch, SR-78.	30	--	--	6.0	.05	4.2	2.9	3.3
Cypress Branch, SR-78.	29	--	--	--	--	13	--	--
Cypress Creek, SR-78.	38	--	--	4.5	9.2	1.6	.4	3.9
Forty-Two Foot Canal, SR-80.	16	--	--	8.8	.4	1.8	6.0	4.2
Goodno Canal at Ortona.	11	--	--	15	2.2	3.1	3.0	5.8
Goodno Canal at SR-832.	13	--	--	2.4	.9	1.5	.6	1.4
Jacks Branch at Norris.	36	--	--	.4	.4	.2	2.3	.8
Lake Hicpochee, SR-80.	20	--	--	14	4.5	12	18	12
Meander Line Ditch, SR-78.	26	--	--	4.7	1.8	--	8.6	5.0
Roberts Canal, SR-80.	6	--	--	16	.8	.5	11	7.1
Townsend Canal, SR-80.	4	--	--	.08	8.6	6.4	19	8.5

RELATIONS OF ALGAE TO SEASON, FLOW, NUTRIENTS, AND RUNOFF

The abundance and the kind of algae varied seasonally in the Caloosahatchee River. The number of algae and the percentage of blue-green algae increased in late spring and summer as light and water temperature increased. Light penetration, as measured by Secchi disk, tended to decrease during summer. Maximum numbers of algae usually occurred in early or midsummer, and then decreased in late summer to low concentrations in autumn and winter. Blue-green algae were dominant in summer, whereas other groups were better represented in autumn and winter (fig. 2).

Generally, the seasonal pattern in the algal population coincided with the seasonal pattern of discharge in the river (fig. 4). The increase in algae in late spring and early summer occurred at about the same time flow increased in the river at the beginning of the rainy season. However, the seasonal decrease in algae in late summer usually occurred a month or two before flow decreased.

Flow of water in the river affected the magnitude of the algal population, though not in an entirely consistent way. Algal blooms occurred most frequently under stagnant, no-flow conditions. Such conditions were most prevalent at site 24, where algal numbers were consistently higher than at downstream sites (figs 5-7). For example, in the summers of 1978 and 1979, algae exceeded 250,000 cells/mL at site 24 under stagnant conditions. Downstream, during the same periods, where basin runoff and flushing increased, numbers of algae were significantly lower (figs. 5 and 6).

On the other hand, a bloom of the blue-green algae, Oscillatoria, occurred in the river in January 1979 during a high discharge from Lake Okeechobee (fig. 5). During the previous winters, 1977-78, discharges and algal numbers were lower. The high discharge from the lake in the winter of 1979 transported algae throughout the river. The numbers of algae in the 1979 winter bloom, however, were less than numbers in blooms the following summer (fig. 5).

Nutrients are those elements or compounds required by algae (or other organisms) for growth. Although any nutrient can limit growth, carbon, nitrogen, or phosphorus are most often limiting. This is because the inorganic forms of these elements are required by algae in relatively large amounts and are sometimes not readily available.

A comparison between the ratios of carbon to nitrogen to phosphorus (C:N:P) in water and the ratio in algal cells can indicate which of these nutrients is in low supply in the water compared with algal growth needs. A commonly quoted C:N:P ratio in algal cells, based on work by Redfield (1934), is 106:16:1 (Strumm and Morgan, 1970; Odum, 1971). The ratio has since been found to be quite variable and dependent on environmental and nutritive conditions of the algae. James and Lee (1974), for example, reported a ratio of 40:7:1 for blue-green algae.

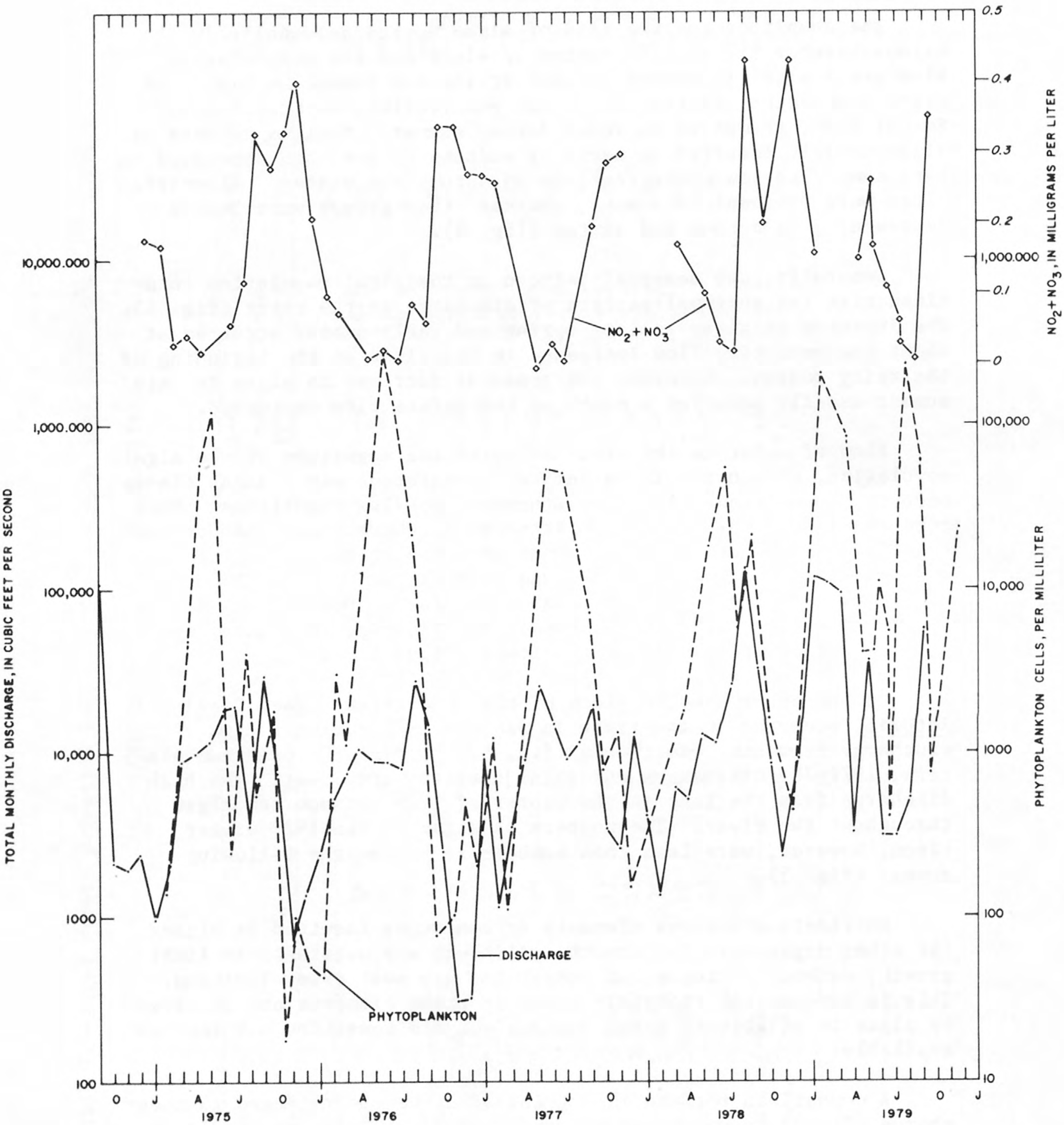

Figure 4.--Total monthly discharge and concentrations of algal cells and NO_2 and NO_3 as N, at site 28, 1975-79.

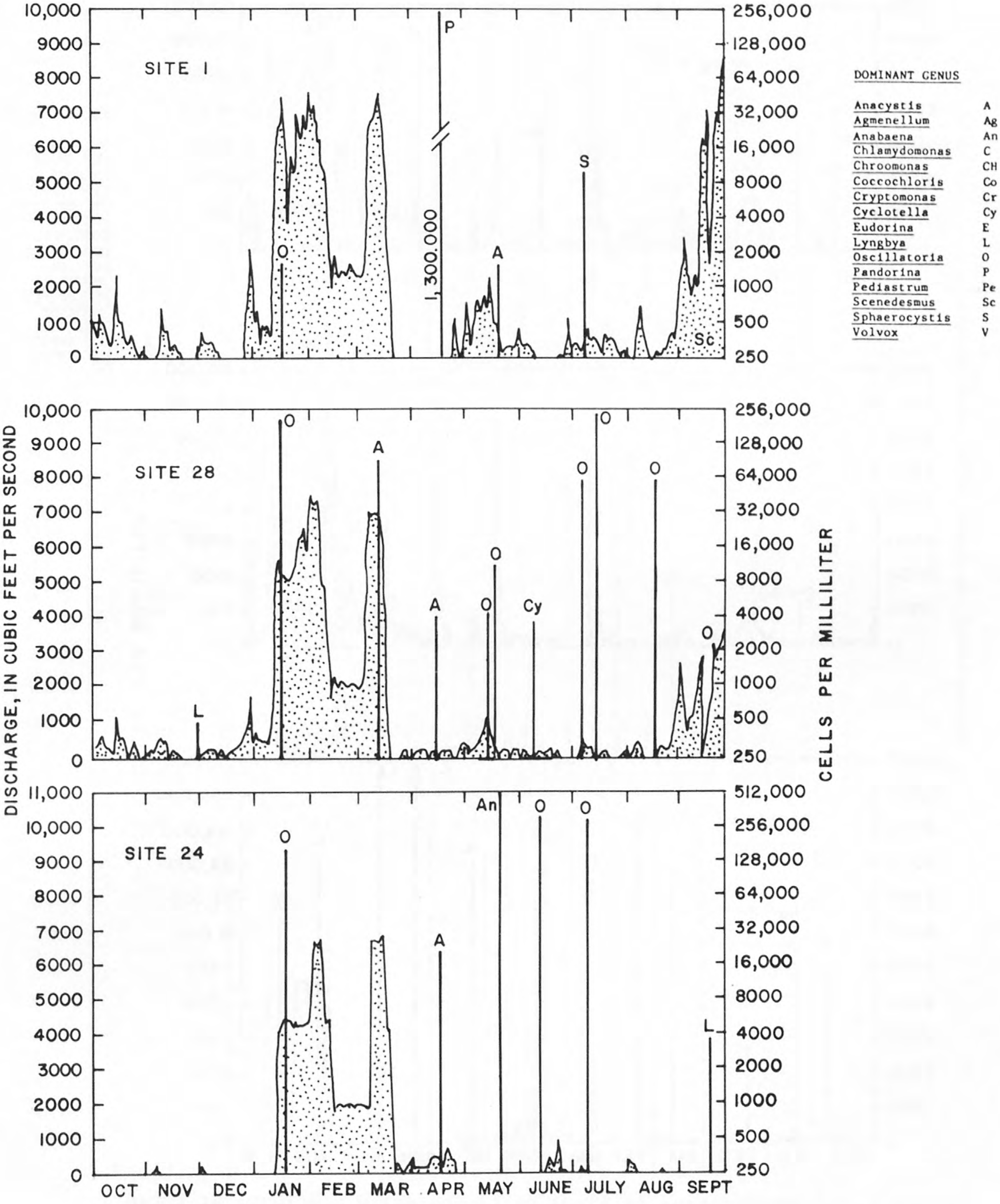

Figure 5.--Concentrations of algal cells and daily discharge at three sites on the Caloosahatchee River, 1979 water year.

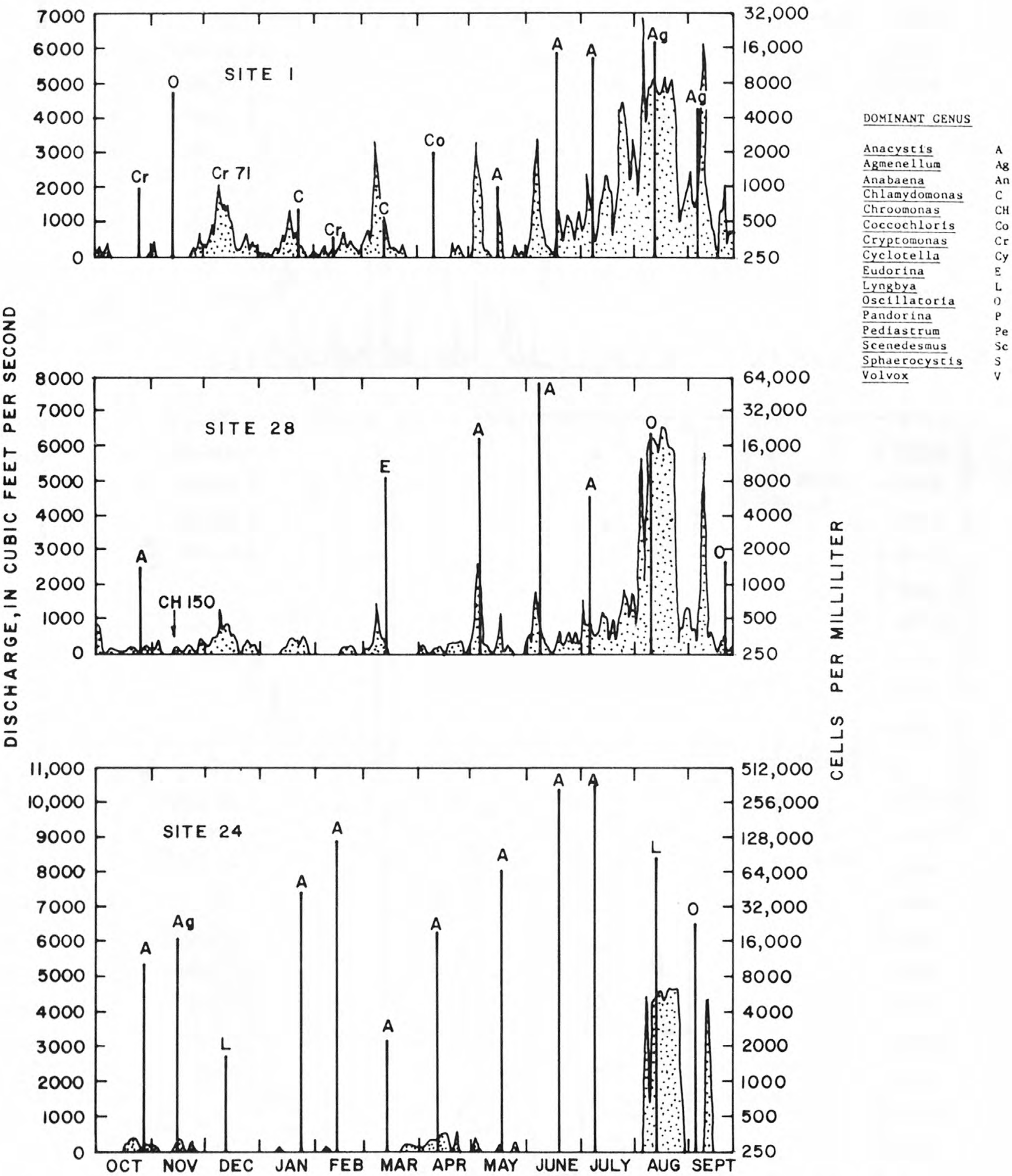

Figure 6.--Concentrations of algal cells and daily discharge at three sites on the Caloosahatchee River, 1978 water year.

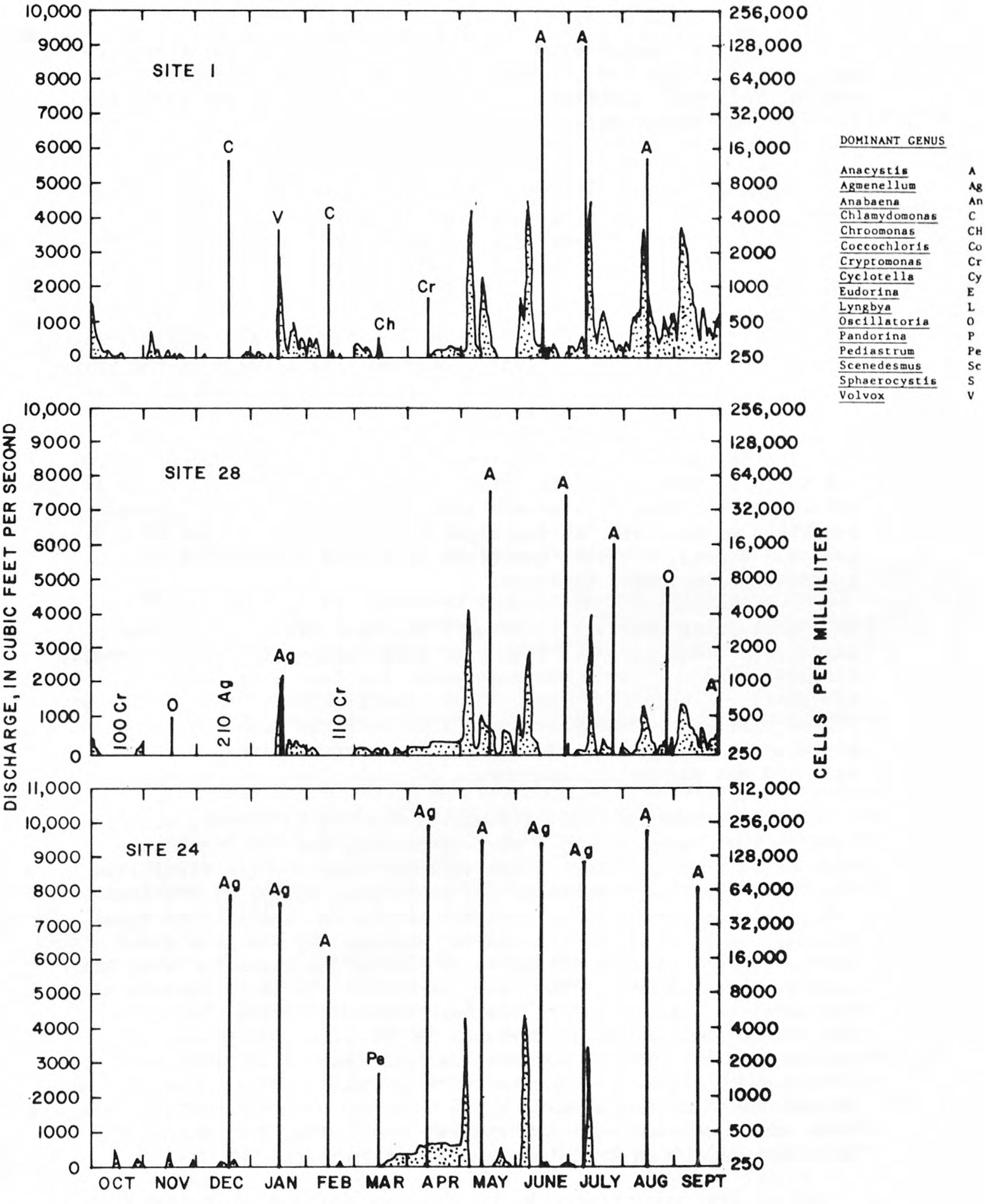

Figure 7.--Concentrations of algal cells and daily discharge at three sites on the Caloosahatchee River, 1977 water year.

The average molar ratio of the total inorganic forms of carbon, nitrogen (NO_2, NO_3, and NH_3), and phosphorus from data collected in the Caloosahatchee River from 1976-79, are given below for the four river sites:

	C:N:P
site 24 -	1,900: 13: 1
site 28 -	400: 5: 1
site 35 -	1,100: 7: 1
site 1 -	1,200: 7: 1

These ratios indicate that inorganic nitrogen in the river was low compared with the amount of nitrogen common in algae. Of the three nutrients, nitrogen was, on the average, in shortest supply in relation to algal growth needs.

The concentration of the two forms of inorganic nitrogen, NO_2 and NO_3, was inversely correlated with concentrations of algae in the river, as shown in figure 4 for site 28. $NO_2 + NO_3$ nitrogen decreased to near zero during algal blooms because it was used for growth. Blooms, however, sometimes persisted despite low concentrations of inorganic nitrogen.

A limiting supply of inorganic nitrogen favors blue-green algae over other groups. Some blue-green algae utilize atmospheric nitrogen (N_2), and thus can compensate for low concentrations of inorganic nitrogen (NO_2, NO_3, NH_3). The ability to utilize atmospheric nitrogen probably accounts for the large number of blue-green algae that persisted at site 24, where at times inorganic nitrogen was virtually depleted.

An input-output loading analysis for the 1979 water year indicated that loads of $NO_2 + NO_3$, inorganic, and total nitrogen discharged from the river exceeded loads input to the river from the basin and Lake Okeechobee (H. R. La Rose and B. F. McPherson, 1981, written commun.). A possible source for the gain in total nitrogen is fixation of atmospheric nitrogen by the blue-green algae. Annual nitrogen fixation by blue-green algae in lakes has been reported to range from less than 1 percent to 43 percent of the total nitrogen input to the lake (Wetzel, 1975). Gains in NO_2 and NO_3 and inorganic nitrogen in the river are probably due to oxidation of organic material and ammonia in addition to the nitrogen fixation. The increases in inorganic nitrogen generated downstream would favor other algae over the blue-green algae, and this was consistent with the general trend of an increase in the relative numbers of nonblue-green algae downstream.

Several things indicate that input of nutrients, including inorganic nitrogen, from the basin and from Lake Okeechobee have a limited effect on enrichment and algal growth in the river. These are as follows: (1) the short water renewal time during large discharges (in the order of a few days or weeks) results in loss of nutrients and algae downstream; (2) numbers of algae tended to decrease downstream, whereas basin runoff increased downstream; (3) nutrients, including inorganic nitrogen and the algal growth potential in tributary input, tended to be less than concentrations in the river (H. R. La Rose and B. F. McPherson, 1981, written commun.), and thus would not add to the nutritive condition of the river; and (4) large algal blooms occurred primarily during stagnant and low-flow conditions and sometimes persisted despite low concentrations of inorganic nitrogen.

SUMMARY AND CONCLUSIONS

1. Maximum concentrations of algae in the Caloosahatchee River and its tributaries occurred in late spring or summer. Concentrations exceeded 100,000 cells per mL at all river sites sometime during 1976-79. Concentrations were highest in the river at site 24 and generally decreased downstream.

2. Blue-green algae, primarily Anacystis or Oscillatoria, were dominant in the river during much of 1976-79. The percentage of blue-green algae decreased downstream.

3. Algal blooms occurred in the river under different flow regimes, but were most common under low-flow stagnant conditions.

4. Concentrations of $NO_2 + NO_3$ nitrogen were inversely correlated with concentrations of algae and decreased to near zero during algal blooms. The relatively low amounts of inorganic nitrogen probably favored blue-green algae and limited growth of other types of algae. Blooms sometimes persisted despite low concentrations of inorganic nitrogen.

5. Input of nutrients from the basin and from Lake Okeechobee probably have a limited effect on algal growth in the river. This is indicated by several lines of evidence. First, large algal blooms occurred primarily during stagnant and low-flow conditions when input of nutrients from the lake and basin was minimal. Second, the number of algae tended to decrease downstream with increasing runoff from the basin. Algal blooms were largest and most persistent at the upstream site. Third, except during large algal blooms, nutrients in the basin tributaries were in lower concentrations than those in the river. Fourth, even when input of nutrients from the lake or basin was substantial, the short water renewal time during large discharges (days or weeks) results in loss of nutrients and algae downstream.

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