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Phytoplankton Water Quality Relationships in U.S. Lakes, Part VI:

The Common Phytoplankton Genera From Eastern and Southeastern Lakes

Working Paper 710

PHYTOPLANKTON WATER QUALITY RELATIONSHIPS IN U.S. LAKES, PART VI: The Common Phytoplankton Genera From Eastern and Southeastern Lakes

by

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FOREWORD

The National Eutrophication Survey (NES) was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs. The survey was designed to develop, in conjunction with State environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and State management practices relating to point-source discharge reduction and nonpoint-source pollution abatement in lake watersheds.

This survey collected physical, chemical, and biological data from 815 lakes and reservoirs throughout the contiguous United States. To date, the Survey has yielded more than two million data points. In-depth analyses are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes.

SUMMARY

The purpose of this report is to identify environmental conditions associated with more common phytoplankton genera and to evaluate their use as indicator organisms for monitoring water quality and/or trophic condition of lakes. Such indicators are highly desirable to aid states in meeting lake classification requirements under Section 305b and monitoring the success of Clean Lakes restoration efforts under Section 314 of the Water Bill (PL92-500). The study follows the basic premise that identification of the environmental conditions surrounding the occurrence of phytoplankton is implicit in their development for, and application to, advanced biological monitoring of lakes. To determine the conditions associated with the absence, presence and dominance of the 57 most common algae genera identified from 250 lakes in 17 eastern and southeastern states during 1973, approximately 25,000 phytoplankton records and 750,000 physical and chemical data points were analyzed and compared.

An ideal indicator organism for a given set of environmental conditions would always be present when all conditions in the set were within established tolerances and never be present when any or all conditions were outside these ranges. The results of this study clearly indicate that the more common phytoplankton genera are found to thrive over such a broad range of environmental conditions that no one genus emerges as a dependable indicator of water quality or trophic condition in lakes. As a result of this finding it is recommended that individual phytoplankton genera not be used as sole or primary indicators of water quality/trophic state in lakes. However, tendencies of some of the genera toward high or low ends of specific parameter ranges suggest an opportunity for development of community-based trophic classification indices which effectively "sum the individual probabilities" of the genera in a community to increase the resolution of trophic state estimates. Preliminary evaluations of tentative community-based indices suggest that these indices offer higher potential for water quality assessment than any of the commonly-used phytoplankton-based water quality indicators and that further development and refinement of their potential is warranted.

Most phytoplankton genera showed no distinct seasonality to their general occurrence, although some forms achieved numerical importance only during certain seasons. Flagellates and diatoms tend to dominate the spring plankton while blue-green and coccoid green genera are most common in summer and fall. The high nutrient levels in the spring were not, in our study findings, accompanied by high phytoplankton populations, probably as a result of seasonal sub-optimal light and temperature conditions.

Blue-green algae, both nitrogen-fixing genera and non-, represented 9 of the 10 common genera which attained numerical dominance in waters with mean inorganic nitrogen/total phosphorus ratio (N/P) of less than 10 (usually suggestive of nitrogen limitation). Note that low N/P in the study lakes was invariably associated with high "P" rather than low "N" values.

The physical and chemical lake data associated with the various occurrence categories of common phytoplankton genera (non-occurrence, non-dominance and dominance) are summarized. These summaries indicate the environmental "requirements" for each taxon and can be used to develop biological tools for monitoring and predicting lake water quality or trophic state (e.g., community-based indices, above) and to suggest environmental control methodologies for problem algal forms.

The information on phytoplankton environmental relationships derived by this study constitutes valuable input for the development and periodic update of water quality criteria required by the Agency under Section 304 and for prediction of biological responses to nutrient and other environmental parameters to aid areawide planners responding to Section 208 of PL92-500.

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LIST OF ABBREVIATIONS AND SYMBOLS

SPRING - data collected during the first sampling round (March 7 - July 1, 1973)

SUMMER - data collected during the second sampling round (July 5 - September 18, 1973)

FALL - data collected during the third sampling round (September 19 - November 14, 1973)

ANNUAL - cumulative data collected through the three sampling rounds

DOM - (numerical dominance) - genus constituted 10 percent or more of the numerical total cell concentration of each lake-date* sample in this category.

NONDOM - (non-dominance) - genus was detected but constituted less than 10 percent of the numerical total cell concentration of each lake-date sample in this category

OCC - (occurrence) - genus was detected in each lake-date sample represented in this category

NONOCC - (non-occurrence) - genus was not detected in any of the lake-date samples represented in this category

MIN - minimum value of a given parameter for the nature of occurrence indicated

MAX - maximum value of a given parameter for the nature of occurrence indicated

MEAN - mean value of a given parameter for the nature of occurrence indicated

STDV - standard deviation of the mean

CHLA - chlorophyll a (μg/l)

TURB - turbidity (% transmission)

*Lake-date (sample, value, information, etc.) denotes specificity for a given lake on a single sampling date.

SECCHI - Secchi disc (inches)

PH - standard pH units

DO - dissolved oxygen (mg/l)

TEMP - temperature (degrees Celsius)

TOTALP - total phosphorus (μg/l)

ORTHOP - dissolved orthophosphorus (μg/l)

NO2NO3 - nitrite-nitrate nitrogen (μg/l)

NH3 - ammonia nitrogen (μg/l)

KJEL - total Kjeldahl nitrogen (μg/l)

ALK - total alkalinity (expressed as $CaCO_3$, mg/l)

N/P - inorganic nitrogen (NO2NO3 + NH3)/total phosphorus (TOTALP)

CONC - number of cells, colonies, or filaments/ml

PERC - percent composition of numerical total

INTRODUCTION

During the spring, summer, and fall of 1973, the National Eutrophication Survey (NES) sampled 250 lakes in 17 states, and collected approximately 750,000 physical and chemical data points. About 180 genera and over 700 phytoplankton species and varieties were observed in the 692 water samples examined, resulting in nearly 25,000 phytoplankton occurrence records. To determine phytoplankton water quality relationships in eastern and southeastern lakes, the physical, chemical, and biological data collected were merged. From this merger it has been possible to establish the ranges of environmental conditions determining the occurrence and relative importance of phytoplankton taxa.

The physical and chemical lake data were summarized on a seasonal basis and organized according to phytoplankton numerical dominance or non-dominance and occurrence or non-occurrence. The summaries provide knowledge of the specific environmental requirements for each taxon and are useful for the development of biological tools for monitoring and predicting of water quality or trophic status.

Summaries of these data were published as a series. Part I (Taylor et al., 1978) was the first publication of the series "Phytoplankton Water Quality Relationships in U.S. Lakes." It presents the methods used, rationale under which the study was carried out, and limitations of the data. Parts II-V (Williams et al., 1978; Hern et al., 1978a; Lambou et al., 1978; Morris et al., 1978) present environmental conditions associated with absence, occurrence, and dominance of specific genera in lakes sampled by the NES in 1973. The purpose of this report is to analyze and summarize the environmental relationships of the 57 most common phytoplankton genera presented in Parts II-V of this series. A future report, Part VII, will investigate the utility of information presented here in the development of biological trophic state indices. Additional interpretative reports and water quality relationships by species will be published later.

CONCLUSIONS

1. Phytoplankton genera thrive over such a broad range of environmental conditions that they cannot be used as indicator organisms.

2. No phytoplankton genera emerged as dependable indicators of <u>any one</u> or combination of the environmental parameters measured. Some taxa, however, showed mean values for a number of parameters which consistently reflected either nutrient-enriched or nutrient-poor conditions.

3. Tentative trophic classification indices based upon phytoplankton community composition show strong early promise for trophic state assessment. Preliminary analyses suggest that these new phytoplankton community-based indices provide more dependable water quality assessment than any of the commonly-used biological water quality indicators.

4. Some taxa, e.g. *Pediastrum* and *Euglena*, were very frequent components of phytoplankton communities, but rarely achieved high relative numerical importance within those communities.

5. Most phytoplankton genera were found in samples from all three seasons and showed no distinct seasonal preference to their occurrence. The attainment of numerical dominance by a few genera <u>did</u> show strong seasonality.

6. Flagellates and diatoms were the most common springtime plankton genera, while the blue-green and coccoid green genera were most common in the summer and fall.

7. High spring nutrient levels are generally not accompanied by high phytoplankton populations. Light and temperature conditions in spring are suboptimal for most phytoplankters encountered, and are probably responsible for this unfulfilled potential.

8. Blue-green algal forms, including several not known to fix elemental nitrogen, contributed 9 of the 10 genera which attained numerical dominance in water with a mean inorganic nitrogen/total phosphorus ratio (N/P) of less than 10 (generally suggestive of nitrogen-limitation).

RECOMMENDATIONS

1. The occurrence of specific phytoplankton genera, even in high relative concentration, should not be used as a sole or primary criterion in water quality assessment or trophic classification of lakes.

2. The potential of phytoplankton community-based trophic indices should be actively explored, developed and refined. Relationships between phytoplankton community structure and composition and environmental conditions should be examined to determine if they can provide useful indices for water quality prediction and trophic state characterization.

MATERIALS AND METHODS

GENERAL

This report is based entirely on the information presented in Parts II-V of the report series Phytoplankton Water Quality Relationships in U.S. Lakes, which contain data collected during the 1973 NES sampling year from 250 lakes in 17 states. The states include Alabama, Delaware, Florida, Georgia, Illinois, Indiana, Kentucky, Maryland, Mississippi, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. For a more complete description of NES methods and the process by which the summary reports (Parts II-V) were developed see Taylor et al., 1978. Parts II-V summarize in tabular form the range of physical and chemical conditions associated with the occurrence of each genus. Four occurrence categories were established for each genus to allow for comparison between numerical dominance, non-dominance and total occurrence, as well as a non-occurrence category which summarizes data associated with all samples where the genus was not found. Numerical dominance was assigned to a genus when it constituted 10 percent or more of the numerical total cell concentration in a lake sample. Non-dominance was assigned to a genus when it constituted less than 10 percent of the numerical total cell concentration in a lake sample. Total occurrence is a category which included all occurrences of each genus whether they be dominant or non-dominant.

DATA SELECTION

Fifty-seven genera were selected for comparative analysis in this report (Table 1). Their inclusion and designation as "common" is based upon their occurrence in at least 10 percent of the 692 samples obtained during 1973.

This report relies primarily on "ANNUAL" data (all data from all seasons), from the photic zone. Using data restricted to the photic zone effectively eliminates extreme conditions from greater depths which have uncertain short-term effects on the phytoplankton community structure.

TABLE 1. COMMON PHYTOPLANKTON GENERA BY DIVISION

CHLOROPHYTA
- Chlorococcales
  - *Actinastrum*
  - *Ankistrodesmus*
  - *Coelastrum*
  - *Crucigenia*
  - *Dictyosphaerium*
  - *Golenkinia*
  - *Kirchneriella*
  - *Lagerheimia*
  - *Oocystis*
  - *Pediastrum*
  - *Scenedesmus*
  - *Schroederia*
  - *Tetraëdron*
  - *Treubaria*
- Volvocales
  - *Chlamydomonas*
  - *Chlorogonium*
  - *Pandorina*
- Zygnematales
  - *Closterium*
  - *Cosmarium*
  - *Euastrum*
  - *Staurastrum*

CHRYSOPHYTA
- Centrales
  - *Cylotella*
  - *Melosira*
  - *Stephanodiscus*
- Pennales
  - *Achnanthes*
  - *Asterionella*
  - *Cocconeis*
  - *Cymbella*
  - *Fragilaria*
  - *Gomphonema*
  - *Gyrosigma*
  - *Navicula*
  - *Nitzschia*
  - *Surirella*
  - *Synedra*
  - *Tabellaria*
- Ochromonadales
  - *Dinobryon*
  - *Mallomonas*

CYANOPHYTA
- Oscillatoriales
  - *Lyngbya*
  - *Oscillatoria*
- Nostocales
  - *Anabaena*
  - *Anabaenopsis*
  - *Aphanizomenon*
  - *Raphidiopsis*
- Chroococcales
  - *Chroococcus*
  - *Coelosphaerium*
  - *Dactylococcopsis*
  - *Merismopedia*
  - *Microcystis*

PYRROPHYTA
  - *Ceratium*
  - *Glenodinium*
  - *Gymnodinium*
  - *Peridinium*

EUGLENOPHYTA
  - *Euglena*
  - *Phacus*
  - *Trachelomonas*

CRYPTOPHYTA
  - *Cryptomonas*

RESULTS

COMMON PHYTOPLANKTON GENERA

Table 1 lists the 57 common phytoplankton genera by taxonomic division which were selected for discussion in this report. Figures 1-3 provide illustrated examples of representative species of each genus. That green algae (Chlorophyta) contributed the most genera of any division is not surprising, as it is a large and diverse grouping. Most of the genera, however, were from one order, the Chlorococcales, widely recognized for its contribution to planktonic communities. Several flagellated and desmid genera were also common planktonic green algae.

The pennate diatoms are much more diverse than the freshwater centric diatoms at the generic level as well as the species level, hence, the seemingly disproportionate number of pennate diatom genera on the list. It should be noted, however, that *Melosira*, a centric diatom, was the most common genus encountered in the survey. It occurred in 88 percent of the samples examined (Table 2). Other Chrysophyta included the flagellated genera *Dinobryon* and *Mallomonas*.

The blue-green algae (Cyanophyta) were also widely distributed, often forming dominant constituents in the phytoplankton community structure. Several genera from each of three major orders (Oscillatoriales, Nostocales, and Chroococcales) were represented in the lake samples.

The two remaining algal divisions, Euglenophyta and Cryptophyta, were represented by just four genera between them. *Euglena* and *Cryptomonas*, however, were among the ten genera most commonly encountered (Table 2).

Table 2 is an alphabetical list of the 57 genera under discussion including the number of samples within which each occurred. It is organized by season (spring, summer, and fall) with an additional catetory (annual) listing the total number of sample occurrences. Each seasonal category is subdivided to show the number of times a given genus occurred as a dominant, a non-dominant, and without regard to dominance. The category OCC RANK denotes the taxon's relative position in a ranking of the 57 genera from highest frequency of total occurrence to lowest.

Melosira was the most common genus encountered in NES lakes sampled in 1973 (Table 2). Other genera of importance, in descending order of total sample occurrences are *Scenedesmus, Synedra, Cyclotella, Oscillatoria, Euglena, Cryptomonas, Navicula, Nitzschia, Anabaena,* and *Microcystis*. All occurred in 50 percent or more of the samples examined. *Pediastrum, Merismopedia, Tetraëdron, Coelastrum, Dactylococcopsis* and *Lyngbya* occurred in 40 to 50 percent of the samples examined.

Figure 1. Illustrations of the common phytoplankton genera observed in NES samples.

1. *Actinastrum*
2. *Ankistrodesmus*
3. *Coelastrum*
4. *Crucigenia*
5. *Dictyosphaerium*
6. *Golenkinia*
7. *Kirchneriella*
8. *Lagerheimia*
9. *Oocystis*
10. *Pediastrum*
11. *Scenedesmus*
12. *Schroederia*
13. *Tetraëdron*
14. *Treubaria*
15. *Chlamydomonas*
16. *Chlorogonium*
17. *Pandorina*
18. *Closterium*
19. *Cosmarium*
20. *Euastrum*
21. *Staurastrum*

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2, 5, 7-9, and 19 from Taylor (in press).

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20 from "A Synopsis of North American Desmids" by G. W. Prescott, H. T. Croasdale, and W. C. Vinyard. Copyright 1977 by University of Nebraska Press. Used with permission of the author.

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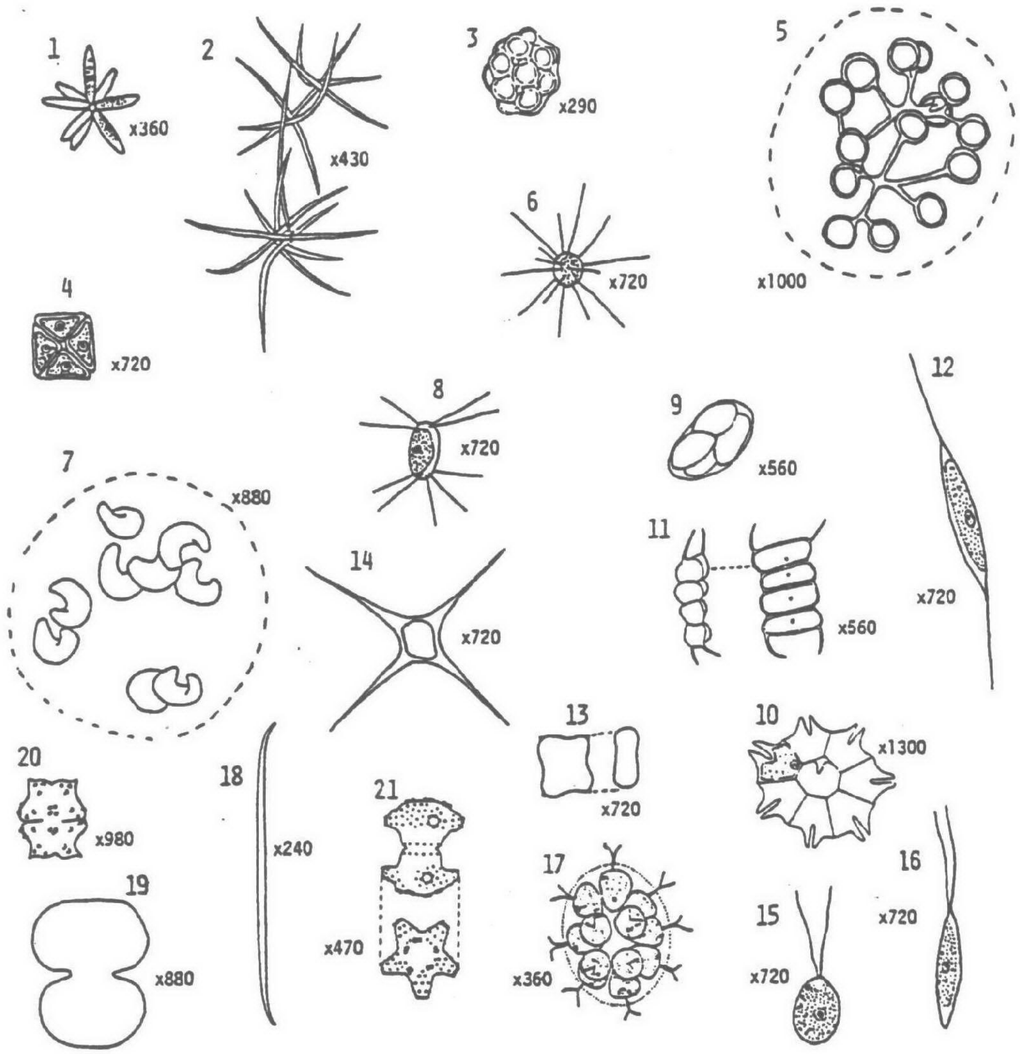
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13
x720
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x240
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x470
17
x360
16
x720
15
x720
19
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Figure 2. Illustrations of the common phytoplankton genera observed in NES samples.

1. *Cyclotella*
2. *Melosira*
3. *Stephanodiscus*
4. *Achnanthes*
5. *Asterionella*
6. *Cocconeis*
7. *Cymbella*
8. *Fragilaria*
9. *Gomphonema*
10. *Gyrosigma*
11. *Navicula*
12. *Nitzschia*
13. *Surirella*
14. *Synedra*
15. *Tabellaria*

1, 2, 8, and 11-13 from Weber 1966.

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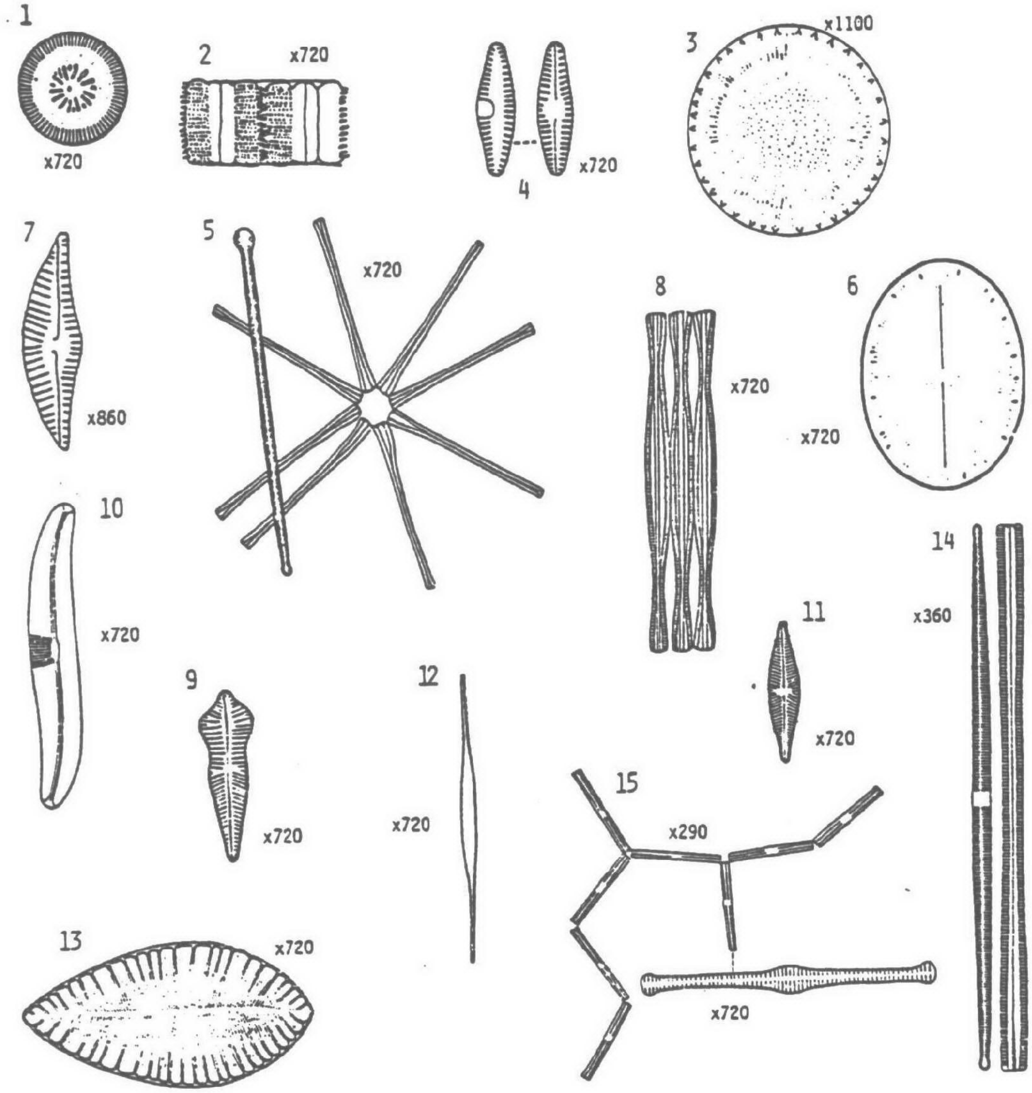
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11
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9
x720
12
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15
x290
x720
13
x720

Figure 3 Illustrations of the common phytoplankton genera observed in NES samples.

1. *Dinobryon*
2. *Mallomonas*
3. *Anabaenopsis*
4. *Raphidiopsis*
5. *Oscillatoria*
6. *Anabaena*
7. *Aphanizomenon*
8. *Lyngbya*
9. *Chroococcus*
10. *Coelosphaerium*
11. *Dactylococcopsis*
12. *Microcystis*
13. *Merismopedia*
14. *Ceratium*
15. *Glenodinium*
16. *Gymnodinium*
17. *Trachelomonas*
18. *Peridinium*
19. *Cryptomonas*
20. *Phacus*
21. *Euglena*

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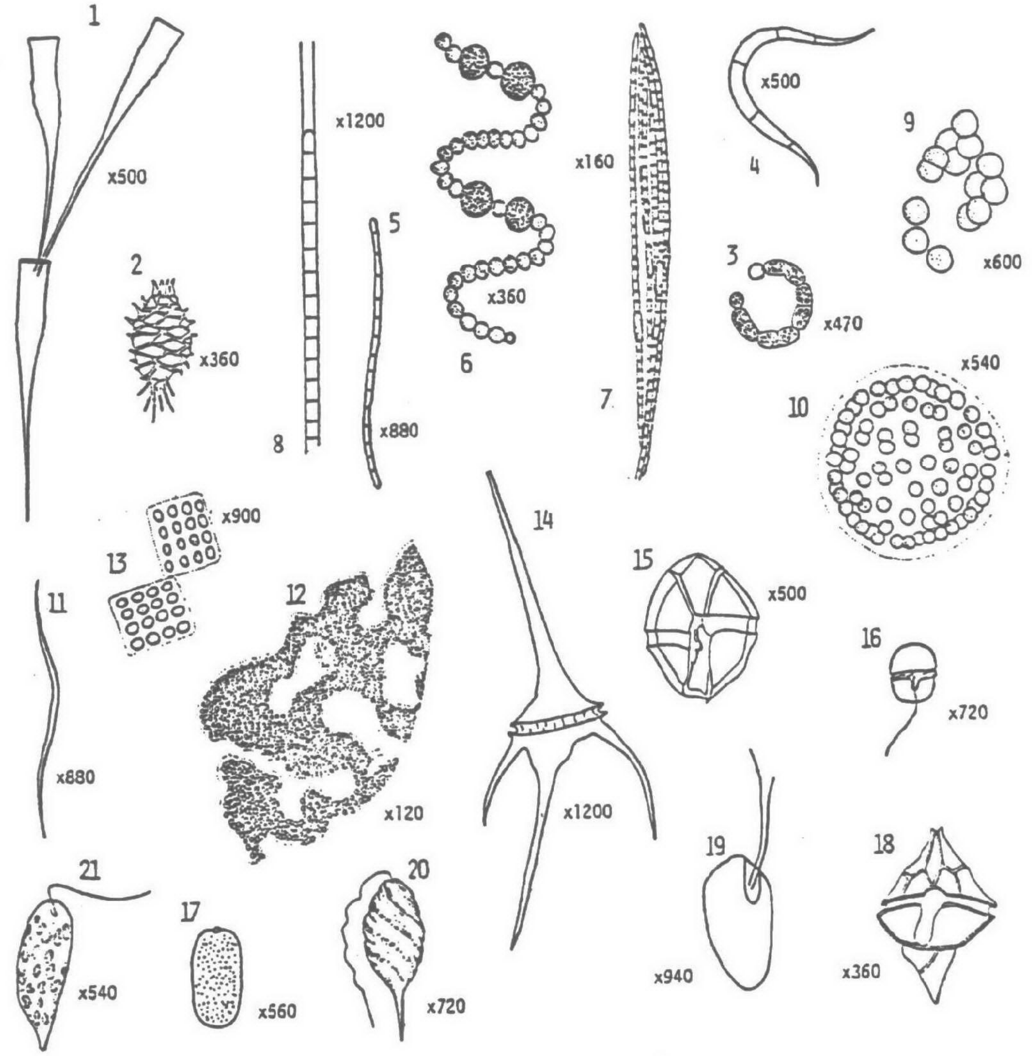
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x900
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x880
12
x120
14
x1200
15
x500
16
x720
21
x540
17
x560
20
x720
19
x940
18
x360

TABLE 2. THE NUMBER OF LAKE-DATE COMPOSITE SAMPLES IN WHICH A GENUS OCCURRED AS A DOMINANT (DOM), NON-DOMINANT (NONDOM), AND IRRESPECTIVE OF DOMINANCE (OCC) DURING 3 SAMPLING SEASONS AND CUMULATIVELY (ANNUAL). A RANKING (OCC RANK) OF THE GENERA BY OCC, HIGHEST TO LOWEST, IS PRESENTED FOR EACH SEASONAL GROUPING.

	SPRING (202 samples)				SUMMER (243 samples)				FALL (247 samples)				ANNUAL (692 samples)			
GENUS	DOM	NON DOM	OCC	OCC RANK	DOM	NON DOM	OCC	OCC RANK	DOM	NON DOM	OCC	OCC RANK	DOM	NON DOM	OCC	OCC RANK
Achnanthes	0	41	41	31	5	44	49	40	1	53	54	38	6	138	144	40
Actinastrum	2	26	28	47	0	29	29	51	0	38	38	46	2	93	95	47
Anabaena	5	62	67	17	14	133	147	8	14	128	142	7	33	323	356	10
Anabaenopsis	2	8	10	56	4	36	40	46	1	32	33	49	7	76	83	51
Ankistrodesmus	5	71	76	14	1	84	85	24	3	91	94	24	9	246	255	20
Aphanizomenon	7	19	26	48	19	45	64	34	15	49	64	34	41	113	154	38
Asterionella	27	87	114	9	6	38	44	43	2	38	40	42	35	163	198	28
Ceratium	0	16	16	52	0	77	77	28	2	63	65	33	2	156	158	37
Chlamydomonas	0	33	33	42	2	44	46	41	2	59	61	36	4	136	140	41
Chlorogonium	0	11	11	53	0	29	29	52	0	36	36	48	0	76	76	55
Chroococcus	0	30	30	45	7	67	74	31	12	63	75	28	19	160	179	32
Closterium	1	44	45	28	1	90	91	22	2	100	102	20	4	234	238	23
Cocconeis	0	45	45	29	0	39	39	47	0	31	31	53	0	115	115	45
Coelastrum	0	47	47	26	5	118	123	14	1	116	117	16	6	281	287	15
Coelosphaerium	0	11	11	54	2	32	34	49	4	35	39	45	6	78	84	52
Cosmarium	1	34	35	40	1	103	104	18	1	96	97	22	3	233	236	24
Crucigenia	1	38	39	35	0	104	104	19	1	98	99	21	2	240	242	22
Cryptomonas	36	100	136	4	16	112	128	12	19	110	129	13	71	322	393	7
Cyclotella	18	105	123	6	38	130	168	3	27	123	150	5	83	358	441	4
Cymbella	0	77	77	13	0	42	42	44	0	51	51	39	0	170	170	33
Dactylococcopsis	7	69	76	15	20	72	92	21	31	88	119	15	58	229	287	16
Dictyosphaerium	0	41	41	32	1	66	67	33	0	77	77	26	1	184	185	29
Dinobryon	15	71	86	12	7	53	60	35	9	66	75	28	31	190	221	26
Euastrum	0	11	11	55	0	26	26	54	0	40	40	43	0	77	77	56
Euglena	3	103	106	10	2	142	144	9	3	155	158	3	8	400	408	6
Fragilaria	15	61	76	16	16	61	77	29	14	48	62	35	45	170	215	27
Glenodinium	0	33	33	43	3	43	46	42	1	31	32	51	4	107	111	46
Golenkinia	2	20	22	50	0	59	59	36	0	45	45	40	2	124	126	42
Gomphonema	0	38	38	36	1	18	19	57	0	20	20	57	1	76	77	57
Gymnodinium	2	34	36	38	0	22	22	55	0	29	29	55	2	85	87	50
Gyrosigma	0	30	30	46	0	28	28	53	0	22	22	56	0	79	80	54
Kirchneriella	1	31	32	44	2	54	56	37	5	70	75	29	8	155	163	34
Lagerheimia	0	21	21	51	0	31	31	50	0	32	32	52	0	84	84	53
Lyngbya	15	39	54	21	49	70	119	15	35	78	113	17	99	187	286	17
Mallomonas	2	49	51	23	1	51	52	38	3	56	59	37	6	156	162	36
Melosira	92	87	179	1	74	132	206	1	89	133	222	1	255	352	607	1
Merismopedia	1	46	47	27	10	138	148	6	11	122	133	12	22	306	328	13
Microcystis	6	43	49	24	22	126	148	7	25	124	149	6	53	293	346	11
Navicula	3	134	137	3	2	115	117	16	1	136	137	10	6	385	391	8
Nitzschia	4	119	123	7	11	117	128	13	13	108	121	14	28	344	372	9
Oocystis	2	38	40	34	2	71	73	32	1	68	69	31	5	177	182	35
Oscillatoria	21	99	120	8	51	103	154	5	33	121	154	4	105	323	428	5
Pandorina	0	38	38	37	0	41	41	45	0	37	37	47	0	116	116	44
Pediastrum	0	61	61	19	0	130	130	11	0	142	142	8	0	333	333	12
Peridinium	2	34	36	39	3	75	78	26	1	39	40	44	6	148	154	39
Phacus	0	44	44	30	0	98	98	20	2	109	111	18	2	251	253	21
Raphidiopsis	2	24	26	49	25	53	78	27	18	55	73	30	45	132	177	30
Scenedesmus	12	124	136	5	17	186	203	2	21	193	214	2	50	503	553	2
Schroederia	1	33	34	41	1	75	76	30	0	69	69	32	2	177	179	33
Staurastrum	0	52	52	22	0	108	108	17	1	110	111	19	1	270	271	19
Stephanodiscus	30	66	96	11	26	56	82	25	17	80	97	23	73	202	275	18
Surirella	0	48	48	25	0	20	20	56	0	31	31	54	0	99	99	48
Synedra	18	137	155	2	22	143	165	4	8	134	142	9	48	414	462	3
Tabellaria	7	34	41	33	10	28	38	48	3	40	43	41	20	102	122	43
Tetraedron	1	56	57	20	1	130	131	10	3	133	136	11	5	319	324	14
Trachelomonas	2	60	62	18	2	84	86	23	0	80	80	25	4	224	228	25
Treubaria	0	10	10	57	0	51	51	39	0	33	33	50	0	94	94	49

The number of samples in which a genus is detected is not necessarily an indication of its ability to attain community dominance. While *Melosira* occurred more frequently than any other genus both as a dominant and non-dominant, *Scenedesmus*, the second most common genus, attained dominance only 9 percent of the time. Several other genera, (*Euglena, Navicula, Pediastrum, Tetraëdron,* and *Coelastrum*), are of special interest because they occurred in more than 40 percent of the samples ($\geq$ 277/692), but were dominant in less than 2 percent of the samples. *Pediastrum* never occurred as a numerical dominant.

SEASONALITY

All 57 genera occurred during each season (Table 2), SPRING (3/7-7/1), SUMMER (7/5-9/18), and FALL (9/19-11/14) of 1973. In fact, many of the genera occurred as dominants in all three of the seasons. The lack of clear seasonal preferences by various genera may be the result of several factors: (1) Data presented at the generic level, in many cases, lumps species with wide differences in environmental requirements, resulting in seasonal occurrence overlap, (2) Because of abnormal weather conditions in the south during 1973, several lakes received their first sampling as late as July 1, (3) Also, the length and nature of seasons vary between states, e.g., Florida versus Pennsylvania, (4) A wide range of lake-types were encountered in the study, varying considerably with respect to morphometry, residence time, turbidity, heat budget, and other lake-type descriptors, and perhaps the most important reason that many forms were less than discriminating with respect to seasonal occurrence is that, (5) The ranges of conditions permitting at least limited growth of most phytoplankton genera are very broad and reflect the range of normal lake conditions encountered in a particular season.

There are, however, some seasonal trends for each genus which are informative when examined closely. To illustrate seasonal preference, percent occurrence and percent dominant occurrence were calculated for each genus by season and are presented in Figures 4 and 5, respectively. The percentages should be interpreted in conjunction with the total number of occurrences (N) since the total number of samples containing specific forms varied considerably, e.g., 76 for *Chlorogonium*, 607 for *Melosira* (Figure 4).

Only 5 genera (*Asterionella, Gomphonema, Surirella, Cymbella,* and *Gymnodinium*) had at least 40 percent of their occurrences in spring samples (Figure 4). This is in sharp contrast with summer and fall samples where 21 and 25 genera, respectively, had at least 40 percent of their occurrences. These data reflect the more restrictive environmental conditions found in spring which are conducive to good growth for a limited range of phytoplankton organisms occupying lake systems. Light conditions during the summer and temperature conditions during summer and fall generally favor a greater variety of forms.

Asterionella and *Raphidiopsis* are the only forms among those showing strong seasonal preferences in their general occurrence (Figure 4) which frequently appeared as dominants. Seventy-seven percent of the *Asterionella* dominant occurrences were in spring samples (Figure 5). By comparison, *Oscillatoria* did not show strong seasonal preference in general occurrence

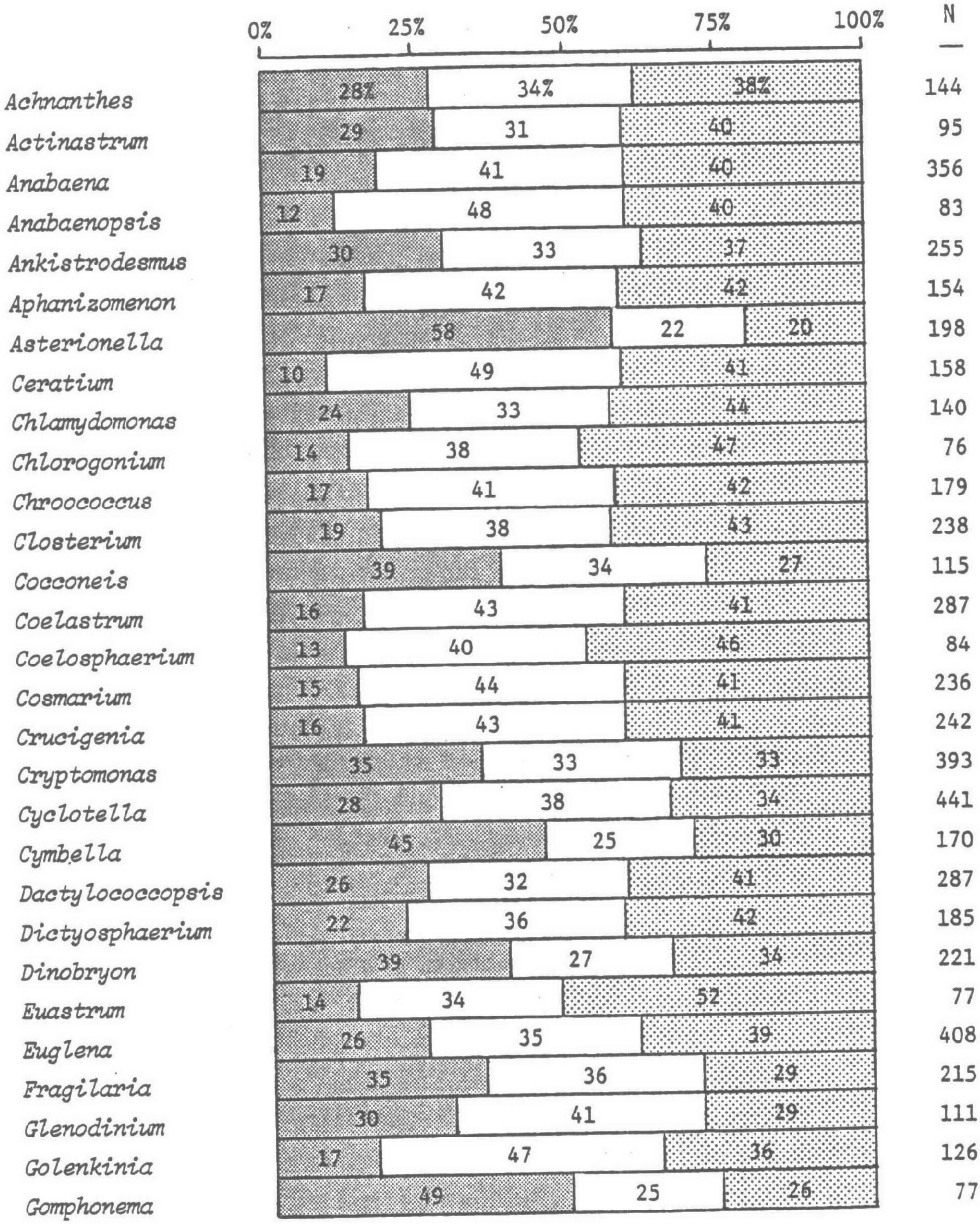


Figure 4. Percent occurrence of each genus by season: SPRING ▒, SUMMER ▭, and FALL ░. N is the total number of samples in which the genus was detected. (Continued on page)

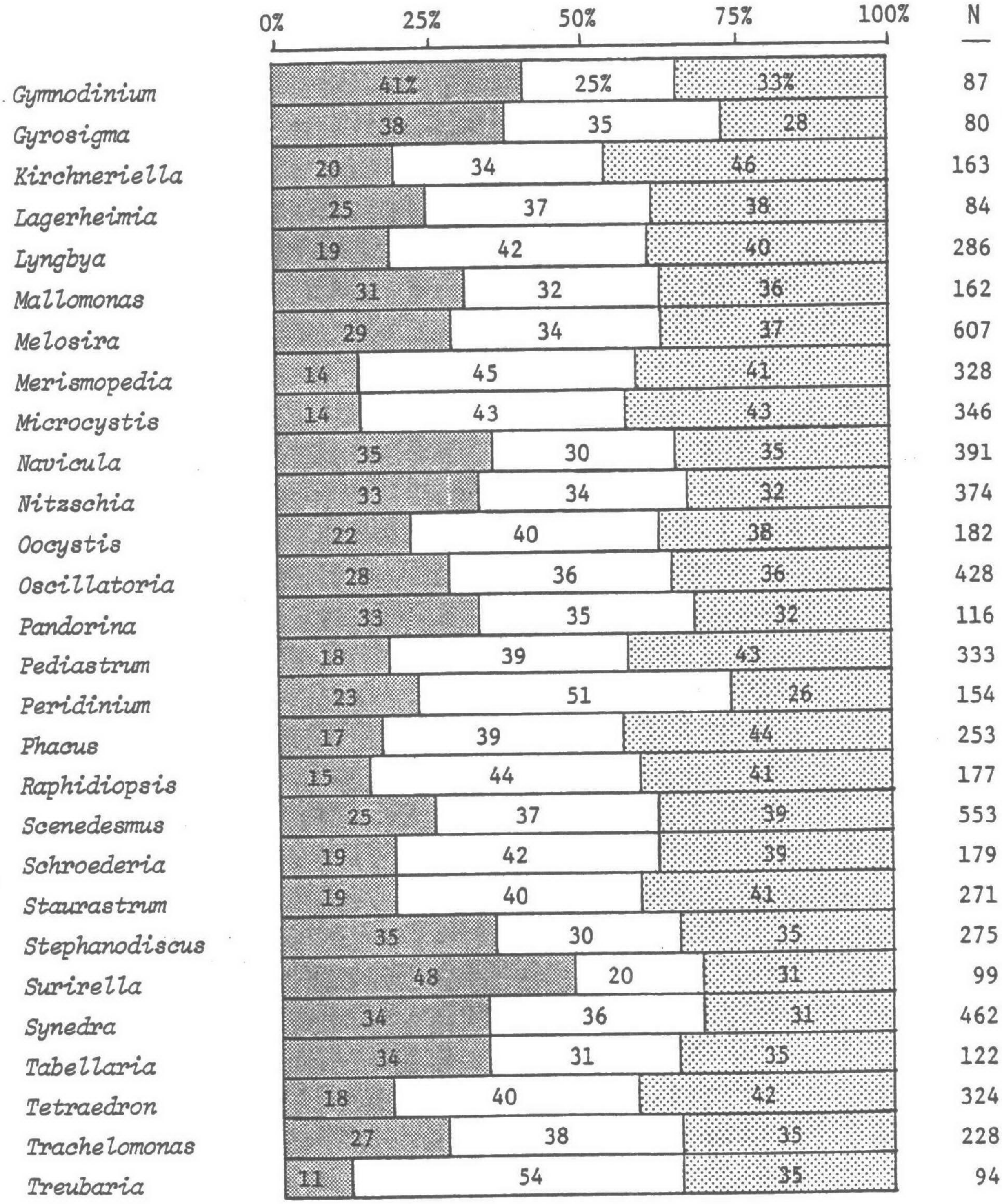


Figure 4. (Continued) Percent occurrence of each genus by season: SPRING ▒, SUMMER ☐, and FALL ░. N is the total number of samples in which the genus was detected.

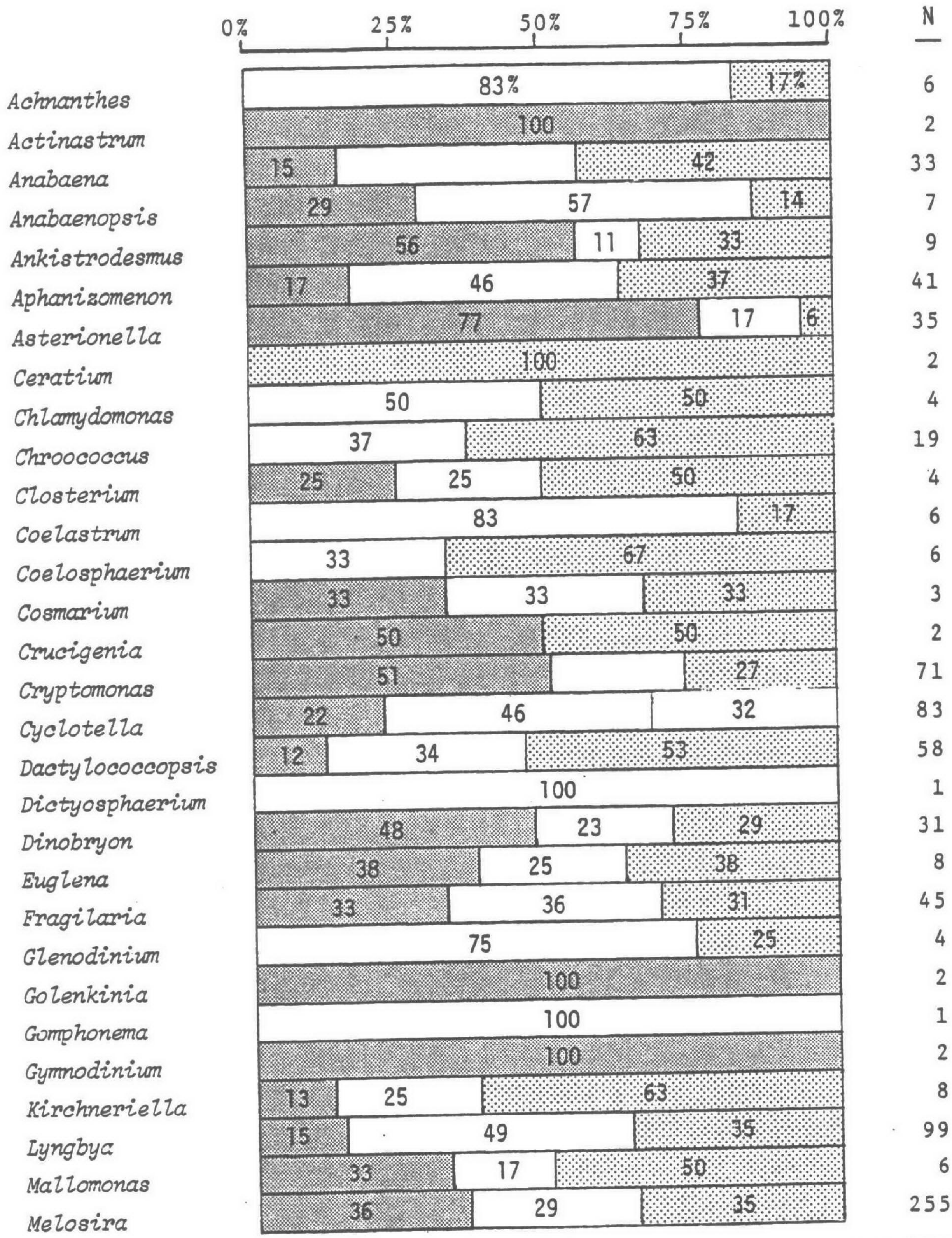


Figure 5. Percent dominant occurrence of each genus by season: SPRING [shaded box], SUMMER [open box], and FALL [dotted box]. N is the total number of samples in which the genus represented 10% or more of the total cell count. (Continued on page)

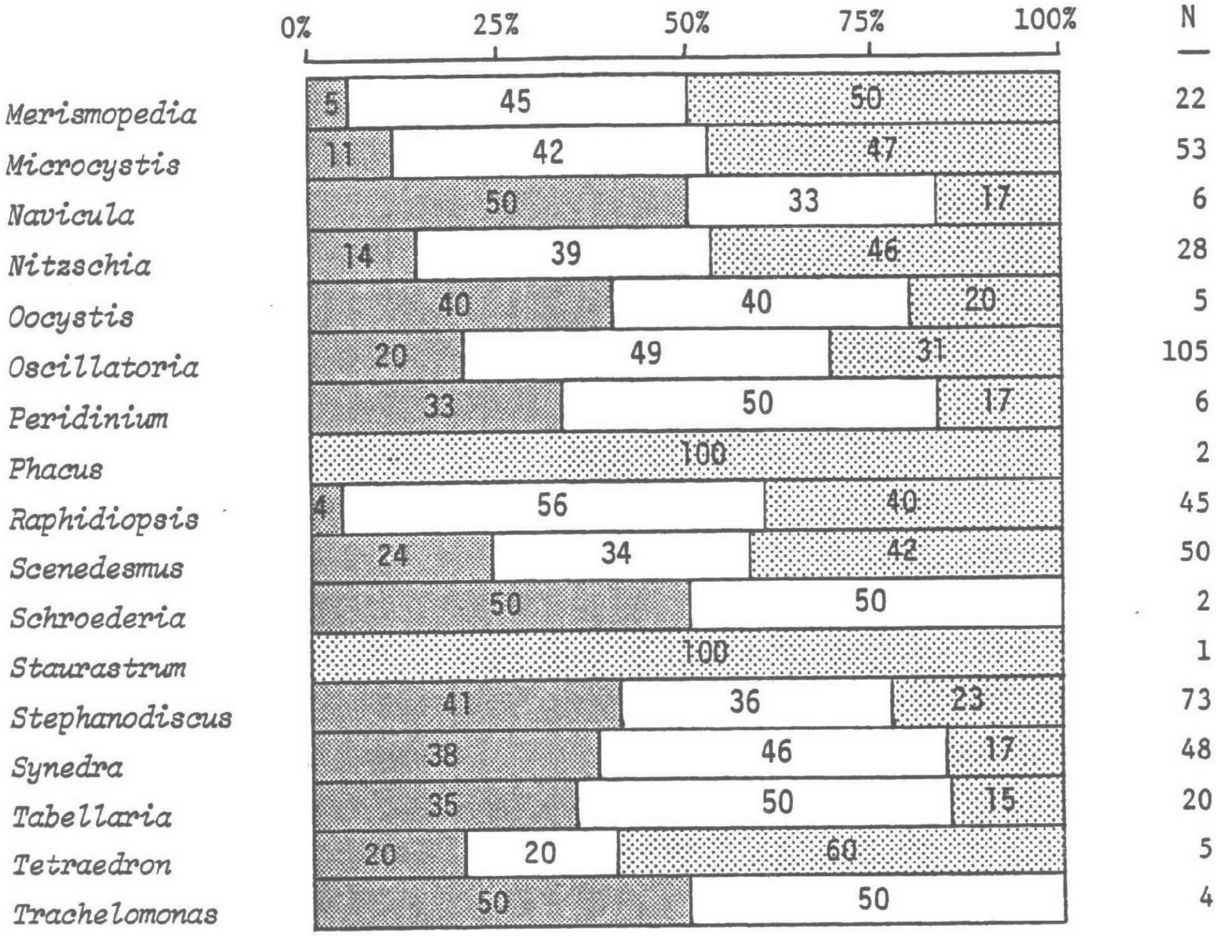


Figure 5. (Continued) Percent dominant occurrence of each genus by season: SPRING, SUMMER, and FALL. N is the total number of samples in which the genus represented 10% or more of the total cell count.

but as a dominant is an important summer form. Similarly, the preference of *Dinobryon* for spring conditions is only apparent in data from it's occurrence as a dominant (Figure 5). It should be noted that little can be inferred from apparent "uniseasonal" relationships (e.g., *Actinastrum* and *Ceratium*) derived from only one or a few occurrences.

Flagellates and diatoms were the most common springtime plankton genera while blue-green and chlorococcalean genera were most common in the summer and fall. Diatoms were quite important in all three seasons. However, their outstanding prevalence over other groups in the spring is most probably due to the relative inability of members of the other groups to grow as well as diatoms under springtime conditions. As mentioned earlier, nutrient levels in the spring would generally support higher phytoplankton populations than were noted.

ENVIRONMENTAL REQUIREMENTS

As would be expected, most genera were found to occur over extremely wide ranges or conditions. To illustrate the point, range diagrams for the respective occurrence categories of each genus have been prepared for the following parameters: total phosphorus (TOTALP), total Kjeldahl nitrogen (KJEL), chlorophyll a (CHLA), and inorganic nitrogen/total phosphorus ratio (N/P) (Appendices A-1 through A-4, respectively). Direct comparisons of the ranges of conditions in which a genus occurred or attained numerical dominance with those conditions under which it was not detected at all, clearly demonstrate the breadth of both the conditions favorable to the phytoplankton genera and the overlap of conditions supporting widely dissimilar genera. In many cases the ranges of conditions supporting a given genus were no different than those under which that genus was not detected. In Appendix B, the range of all available parameter values associated with dominance, non-dominance, and occurrence (general occurrence without respect to dominant status) are presented using *Anabaena, Cryptomonas,* and *Dinobryon* as representative examples.

To illustrate the range overlap typically encountered when making generic comparisons, the two genera having the largest and smallest mean total phosphorus values were examined. *Actinastrum* had the highest mean TOTALP (287 μg/liter) associated with its distribution while *Tabellaria* had the lowest mean TOTALP (42 μg/liter) of the 57 genera considered in this report (Appendix A-1). Even though they represent the extremes in mean total phosphorus, enough overlap occurred in their ranges to substantially reduce their usefulness as general indicators of either high total phosphorus in the case of *Actinastrum* or low total phosphorus in the case of *Tabellaria.*

Considering dominant occurrence, *Scenedesmus* and *Tabellaria* were the genera with the largest and smallest TOTALP values, 351 μg/l and 22 μg/l respectively (Appendix A-1). One might expect ranges to narrow appreciably since attaining dominance presumably requires near optimal conditions for growth and reproduction. What was found, however, is that the range of TOTALP values for the two genera overlapped. Although the upper end of the *Tabellaria* range was well below the mean value of *Scenedusmus*, the entire range of *Tabellaria* was encompassed by the range of *Scenedesmus*.

The wide bands of overlap, even with genera seemingly at opposite ends of the spectrum, practically eliminate the more common phytoplankton genera as effective, stand-alone indicators of environmental conditions. A number of genera appear to have a narrow range of TOTALP values as dominants (e.g., *Achnanthes, Actinastrum,* and *Gymnodinium*). The narrow ranges may have resulted from the small number of dominant occurrences recorded rather than truly restrictive requirements. If an organism has such unique requirements or is only able to outcompete other organisms under very unusual conditions it will generally be quite rare in the "normal" range of lake conditions and therefore relatively useless in classifying most lake waters.

It is desirable to identify trends in the physical and chemical conditions associated with specific genera and to provide means for comparative analysis among genera. To accomplish these, a series of tables were constructed which rank the 57 genera by mean parameter values (Table 3).

The first column in Table 3 presents, in rank order, the total number of occurrences of each of the genera. There is a total of 692 sample possibilities in which each genus could have occurred. In subsequent columns the genera are ranked by their mean values on a parameter-by-parameter basis. Assuming total phosphorus levels to provide a general index of nutrient enrichment, and chlorophyll a levels as a best estimate of the biological manifestations of such nutrients, several interesting trends can be noted. Based upon these criteria two groups of genera, one at each extreme for both parameters, were identified. Each group with few exceptions, retained its integrity for the remaining parameters as well.

The 7 genera associated with levels of TOTALP >200 μg/l (see Table 3) were tracked through the other physical and chemical factor rankings. Note that they represent 7 of the 8 highest CHLA values. Similarly, 5 genera associated with levels of TOTALP <70 μg/l (the same 5 represent the 5 lowest CHLA values) were tracked. These two groups will be referred to as the nutrient-rich and nutrient-poor groups, respectively. The final group specifically tracked through the various rankings of mean parameter values is comprised of the blue-green algal representatives. The blue-greens are well-known in their role as problem algae in lakes and reservoirs.

Among the 7 nutrient-rich genera, *Actinastrum* and *Anabaenopsis* were in the top 10 for 10 of 13 parameters, *Schroederia* and *Raphidiopsis* for 9, *Chlorogonium* for 8, and *Golenkinia* and *Lagerheimia* for 7 of the 13 parameters. *Raphidiopsis* was the only genus among the seven that occurred commonly as a numerical dominant (45 dominant occurrences). The others, although quite common, rarely attained numerical dominance.

The nutrient-rich group consists of 4 chlorococcaleans (Chlorophyta), 1 green flagellate (Chlorophyta) and 2 filamentous blue-green (Cyanophyta) genera. While *Lagerheimia* has about 10 species reported in the United States, the other genera have very few species and not all of these were detected in NES samples. Therefore data trends suggested at the genus level often times may be attributed to the influence of only 1 of 2 species. All 7 genera were summer and fall forms while *Actinastrum* and *Lagerheimia* also occurred equally in spring.

TABLE 3. PHYTOPLANKTON GENERA RANKED BY FREQUENCY OF OCCURRENCE AND ASSOCIATED MEAN PARAMETER VALUES

GENUS	FREQUENCY OF OCCURRENCE		TOTALP (µg/l)	GENUS	ORTHOP (µg/l)
Melosira	607	⊛ Actinastrum	287	⊛ Actinastrum	149
Scenedesmus	553	⊛ Chlorogonium	271	⊛ Chlorogonium	147
Synedra	462	⊛ Golenkinia	245	⊛ Golenkinia	142
Cyclotella	441	⊛ Lagerheimia	243	⊛ Lagerheimia	126
* Oscillatoria	428	⊛ * Anabaenopsis	238	⊛ Schroederia	115
Euglena	408	⊛ Schroederia	227	⊛ * Anabaenopsis	114
Cryptomonas	393	⊛ * Raphidiopsis	212	⊛ * Raphidiopsis	109
Navicula	391	Chlamydomonas	199	* Chroococcus	107
Nitzschia	374	Dictyosphaerium	197	Chlamydomonas	105
* Anabaena	356	Phacus	192	Dictyosphaerium	105
* Microcystis	346	* Chroococcus	191	Kirchneriella	94
Pediastrum	333	Kirchneriella	184	* Merismopedia	87
* Merismopedia	328	* Merismopedia	176	* Dactylococcopsis	87
Tetraedron	324	* Microcystis	167	* Microcystis	83
Coelastrum	287	Pediastrum	166	Tetraedron	81
* Dactylococcopsis	287	Tetraedron	165	Pediastrum	80
* Lyngbya	286	* Dactylococcopsis	164	Phacus	79
Stephanodiscus	275	Closterium	156	Closterium	71
Staurastrum	271	Euglena	153	Pandorina	70
Ankistrodesmus	255	Treubaria	146	Treubaria	64
Phacus	253	Coelastrum	142	Euglena	63
Crucigenia	242	Pandorina	138	Scenedesmus	63
Closterium	238	Scenedesmus	135	Coelastrum	63
Cosmarium	236	Surirella	135	* Oscillatoria	62
Trachelomonas	228	* Oscillatoria	135	Cyclotella	60
⊕ Dinobryon	221	Crucigenia	133	* Anabaena	58
Fragilaria	215	Ankistrodesmus	129	Surirella	57
⊕ Asterionella	198	Oocystis	129	Crucigenia	57
Dictyosphaerium	185	* Anabaena	127	Ankistrodesmus	56
Oocystis	182	Cyclotella	126	Cosmarium	53
* Chroococcus	179	Stephanodiscus	126	Oocystis	52
⊛ Schroederia	179	Cosmarium	125	* Lyngbya	50
⊛ * Raphidiopsis	177	Trachelomonas	118	Stephanodiscus	49
Cymbella	170	Cryptomonas	116	Cocconeis	49
Kirchneriella	163	Nitzschia	116	Cryptomonas	48
Mallomonas	162	Glenodinium	113	Nitzschia	47
⊕ Ceratium	158	Cocconeis	112	Melosira	45
* Aphanizomenon	154	* Lyngbya	110	Glenodinium	43
⊕ Peridinium	154	Melosira	109	Euastrum	41
Achnanthes	144	* Aphanizomenon	103	Trachelomonas	41
Chlamydomonas	140	Gymnodinium	101	* Coelosphaerium	40
⊛ Golenkinia	126	Synedra	98	* Aphanizomenon	38
⊕ Tabellaria	122	Gyrosigma	95	Staurastrum	35
Pandorina	116	Navicula	94	Navicula	34
Cocconeis	115	* Coelosphaerium	93	Cymbella	34
Glenodinium	111	Staurastrum	91	Synedra	34
Surirella	99	Cymbella	91	Fragilaria	31
⊛ Actinastrum	95	Gomphonema	91	Gyrosigma	30
Treubaria	94	Euastrum	89	Achnanthes	29
Gymnodinium	87	Mallomonas	85	Mallomonas	29
* Coelosphaerium	84	Fragilaria	82	Gomphonema	28
⊛ Lagerheimia	84	Achnanthes	74	Gymnodinium	27
⊛ * Anabaenopis	83	⊕ Peridinium	66	⊕ Peridinium	26
Gyrosigma	80	⊕ Ceratium	62	⊕ Ceratium	24
Euastrum	77	⊕ Dinobryon	60	⊕ Dinobryon	24
Gomphonema	77	⊕ Asterionella	56	⊕ Asterionella	17
⊛ Chlorogonium	76	⊕ Tabellaria	42	⊕ Tabellaria	14

(Continued)

⊛ nutrient-rich group: mean TOTALP > 200 ug/l
⊕ nutrient-poor group: mean TOTALP < 70 ug/l
* blue-green algae

TABLE 3. PHYTOPLANKTON GENERA RANKED BY FREQUENCY OF OCCURRENCE AND ASSOCIATED MEAN PARAMETER VALUES (Continued)

GENUS	NO2NO3 (μg/l)	GENUS	NH3 (μg/l)	GENUS	KJEL (μg/l)
Surirella	1146	⊛ *Actinastrum*	157	⊛ *Lagerheimia*	1717
Gomphonema	963	*Surirella*	154	⊛ * *Anabaenopsis*	1697
Gyrosigma	925	⊛ *Lagerheimia*	149	⊛ *Chlorogonium*	1592
Stephanodiscus	850	⊛ * *Raphidiopsis*	145	* *Chroococcus*	1529
⊛ *Actinastrum*	799	⊛ *Schroederia*	137	⊛ *Schroederia*	1526
Gymnodinium	714	*Pandorina*	136	⊛ *Actinastrum*	1523
Trachelomonas	701	*Coelastrum*	133	⊛ *Golenkinia*	1515
Euglena	693	*Phacus*	132	*Dictyosphaerium*	1398
Cryptomonas	683	*Chlamydomonas*	132	⊛ * *Raphidiopsis*	1386
Synedra	634	*Pediastrum*	130	*Oocystis*	1380
Navicula	634	*Dictyosphaerium*	130	* *Microcystis*	1367
Nitzschia	629	*Trachelomonas*	128	* *Merismopedia*	1363
Cyclotella	611	* *Merismopedia*	128	*Kirchneriella*	1347
⊕ *Asterionella*	605	*Oocystis*	128	*Tetraedron*	1326
Glenodinium	599	*Euglena*	126	*Phacus*	1307
Cymbella	572	⊛ *Golenkinia*	125	*Pediastrum*	1307
Chlamydomonas	568	* *Aphanizomenon*	124	*Treubaria*	1300
Phacus	565	* *Oscillatoria*	124	*Cosmarium*	1285
Pandorina	558	*Gyrosigma*	123	*Closterium*	1279
Melosira	531	*Closterium*	122	*Chlamydomonas*	1232
* *Dactylococcopsis*	523	* *Microcystis*	122	*Coelastrum*	1207
Cocconeis	520	* *Dactylococcopsis*	121	* *Lyngbya*	1202
Closterium	512	* *Anabaena*	119	* *Aphanizomenon*	1175
Ankistrodesmus	508	*Cyclotella*	119	*Crucigenia*	1155
Fragilaria	499	*Tetraedron*	118	* *Coelosphaerium*	1146
* *Oscillatoria*	496	*Cryptomonas*	117	* *Dactylococcopsis*	1141
Coelastrum	492	*Staurastrum*	116	* *Anabaena*	1138
⊛ *Schroederia*	489	* *Chroococcus*	116	*Glenodinium*	1133
Scenedesmus	481	*Navicula*	116	*Scenedesmus*	1125
⊕ *Dinobryon*	478	*Melosira*	116	*Euglena*	1109
* *Aphanizomenon*	464	*Scenedesmus*	116	*Staurastrum*	1104
Achnanthes	456	*Cocconeis*	115	*Ankistrodesmus*	1087
⊛ *Chlorogonium*	453	*Kirchneriella*	115	* *Oscillatoria*	1081
Kirchneriella	434	*Gomphonema*	114	*Gymnodinium*	1032
Crucigenia	425	*Crucigenia*	114	*Cyclotella*	1018
⊛ *Lagerheimia*	423	*Ankistrodesmus*	113	*Stephanodiscus*	1016
Pediastrum	422	*Synedra*	113	*Trachelomonas*	1006
* *Merismopedia*	413	*Cymbella*	113	*Cryptomonas*	1001
Mallomonas	406	*Nitzschia*	113	*Melosira*	999
⊕ *Ceratium*	383	*Glenodinium*	113	*Surirella*	996
Oocystis	379	⊛ * *Anabaenopsis*	112	*Fragilaria*	990
Treubaria	371	*Cosmarium*	111	*Nitzschia*	975
⊕ *Tabellaria*	363	*Fragilaria*	110	*Cocconeis*	958
⊛ * *Raphidiopsis*	361	⊛ *Chlorogonium*	108	*Euastrum*	930
* *Anabaena*	351	*Stephanodiscus*	108	*Gyrosigma*	923
Dictyosphaerium	348	* *Coelosphaerium*	106	*Mallomonas*	923
* *Microcystis*	347	*Mallomonas*	106	*Navicula*	921
Tetraedron	335	* *Lyngbya*	106	*Synedra*	870
⊕ *Peridinium*	334	⊕ *Ceratium*	103	⊕ *Ceratium*	850
⊛ *Golenkinia*	330	*Gymnodinium*	103	*Gomphonema*	845
Staurastrum	325	*Achnanthes*	100	*Pandorina*	830
* *Lyngbya*	310	⊕ *Dinobryon*	100	⊕ *Peridinium*	828
Cosmarium	287	*Treubaria*	99	*Achnanthes*	818
* *Coelosphaerium*	274	⊕ *Asterionella*	96	*Cymbella*	807
* *Chroococcus*	239	⊕ *Tabellaria*	95	⊕ *Dinobryon*	707
⊛ * *Anabaenopsis*	197	*Euastrum*	91	⊕ *Asterionella*	627
Euastrum	145	⊕ *Peridinium*	91	⊕ *Tabellaria*	582

(Continued)

⊛ nutrient-rich group: mean TOTALP > 200 μg/l
⊕ nutrient-poor group: mean TOTALP < 70 μg/l
* blue-green algae

TABLE 3. PHYTOPLANKTON GENERA RANKED BY FREQUENCY OF OCCURRENCE AND ASSOCIATED MEAN PARAMETER VALUES (Continued)

GENUS	CHLA (μg/l)	GENUS	N/P	GENUS	ALK (mg/l as $CaCO_3$)
⊙ Chlorogonium	54.6	⊙ * Anabaenopsis	3.3	* Aphanizomenon	111
⊙ Schroederia	52.8	Euastrum	4.7	Stephanodiscus	101
⊙ Actinastrum	52.3	* Chroococcus	6.0	Cocconeis	95
⊙ Lagerheimia	52.0	⊙ Golenkinia	6.0	Oocystis	94
⊙ * Anabaenopsis	50.6	⊙ * Raphidiopsis	7.1	Closterium	92
⊙ Golenkinia	50.2	Dictyosphaerium	7.1	Phacus	90
Treubaria	44.1	⊙ Lagerheimia	7.6	⊙ Schroederia	90
⊙ * Raphidiopsis	43.6	Treubaria	7.9	⊙ Chlorogonium	87
* Chroococcus	42.4	Tetraedron	7.9	⊙ Actinastrum	86
Dictyosphaerium	39.9	Cosmarium	8.1	Cryptomonas	86
Tetraedron	37.9	⊙ Schroederia	8.3	⊙ Lagerheimia	85
Kirchneriella	37.8	Pediastrum	8.4	⊛ Ceratium	85
* Microcystis	37.5	Kirchneriella	8.6	Gomphonema	85
Phacus	37.5	⊙ Actinastrum	8.9	Gymnodinium	84
* Merismopedia	37.1	Chlamydomonas	9.1	Surirella	84
Pediastrum	37.0	* Merismopedia	9.1	Glenodinium	84
Oocystis	36.9	* Microcystis	9.3	Fragilaria	83
Coelastrum	34.0	* Lyngbya	9.4	Dictyosphaerium	81
Chlamydomonas	33.1	⊙ Chlorogonium	9.7	* Microcystis	80
Cosmarium	33.0	* Anabaena	9.8	Coelastrum	79
Closterium	32.9	* Dactylococcopsis	9.9	* Coelosphaerium	79
Crucigenia	31.1	Staurastrum	9.9	Chlamydomonas	79
Ankistrodesmus	30.7	Oocystis	10.1	Trachelomonas	79
Gymnodinium	30.7	Phacus	10.2	Cymbella	79
* Aphanizomenon	30.2	Closterium	10.3	Euglena	79
Euglena	30.0	Crucigenia	10.6	* Oscillatoria	78
Glenodinium	29.9	Pandorina	10.6	⊙ * Raphidiopsis	78
Stephanodiscus	29.6	* Oscillatoria	10.6	Gyrosigma	77
Scenedesmus	29.6	Cocconeis	10.9	Navicula	76
* Dactylococcopsis	29.4	Scenedesmus	11.1	Crucigenia	76
* Oscillatoria	29.0	Coelastrum	11.3	Mallomonas	75
* Coelosphaerium	28.9	Ankistrodesmus	11.3	* Merismopedia	75
* Anabaena	28.5	Euglena	12.2	Cyclotella	73
* Lyngbya	28.2	* Aphanizomenon	12.2	Scenedesmus	73
Staurastrum	26.9	* Coelosphaerium	12.3	Pediastrum	73
Trachelomonas	26.7	Achnanthes	12.3	⊛ Dinobryon	72
Nitzschia	26.7	Trachelomonas	12.5	Nitzschia	71
surirella	26.2	Nitzschia	12.8	Melosira	71
Cyclotella	25.9	Melosira	13.0	Ankistrodesmus	70
Cryptomonas	25.3	Mallomonas	13.4	⊙ * Anabaenopsis	70
Mallomonas	24.8	Gyrosigma	13.4	Synedra	70
Melosira	24.8	Gymnodinium	14.3	* Dactylococcopsis	69
Navicula	23.3	Fragilaria	14.3	Cosmarium	68
Gyrosigma	22.7	Cryptomonas	14.6	* Anabaena	68
Cocconeis	22.3	Navicula	14.6	Achnanthes	68
Fragilaria	21.8	Cymbella	14.7	* Lyngbya	68
Synedra	21.4	⊛ Perdinium	14.7	Kirchneriella	68
Cymbella	19.8	Stephanodiscus	14.9	Tetraedron	68
Achnanthes	18.5	Cyclotella	14.9	* Chroococcus	65
Gomphonema	18.4	Synedra	15.1	Treubaria	59
Euastrum	18.3	Surirella	15.2	Staurastrum	59
Pandorina	18.0	Glenodinium	15.4	⊛ Asterionella	59
⊛ Peridinium	17.9	⊛ Ceratium	15.7	⊛ Peridinium	56
⊛ Ceratium	16.6	Gomphonema	16.3	⊙ Golenkinia	54
⊛ Asterionella	13.4	⊛ Asterionella	16.9	Pandorina	52
⊛ Dincbryon	12.9	⊛ Tabellaria	18.0	Euastrum	39
⊛ Tabellaria	10.5	⊛ Dinobryon	19.2	⊛ Tabellaria	34

(Continued)

⊙ nutrient-rich group: mean TOTALP > 200 ug/l
⊛ nutrient-poor group: mean TOTALP < 70 ug/l
* blue-green algae

TABLE 3. PHYTOPLANKTON GENERA RANKED BY FREQUENCY OF OCCURRENCE AND ASSOCIATED MEAN PARAMETER VALUES (Continued)

GENUS	TEMP (°C)	GENUS	PH	GENUS	DO (mg/l)
Treubaria	25.0	⊛Lagerheimia	8.3	Euastrum	6.9
⊛*Anabaenopsis	24.9	⊛*Anabaenopsis	8.2	⊙Ceratium	7.1
⊛Golenkinia	24.8	⊛Chlorogonium	8.1	⊛*Raphidiopsis	7.3
Euastrum	24.1	⊛Golenkinia	8.0	⊛*Anabaenopsis	7.3
*Merismopedia	24.0	*Aphanizomenon	8.0	*Merismopedia	7.3
*Chroococcus	24.0	⊛Actinastrum	8.0	*Anabaena	7.4
Cosmarium	23.8	Fragilaria	8.0	Trachelomonas	7.4
⊙Peridinium	23.7	*Microcystis	8.0	⊙Peridinium	7.4
⊛*Raphidiopsis	23.7	⊛Schroederia	8.0	*Lyngbya	7.4
*Lyngbya	23.6	Oocystis	8.0	Crucigenia	7.4
*Anabaena	23.4	Coelastrum	7.9	Phacus	7.4
Tetraedron	23.4	Phacus	7.9	Staurastrum	7.4
Pediastrum	23.2	Stephanodiscus	7.9	Treubaria	7.5
Coelastrum	23.2	*Coelosphaerium	7.9	Cosmarium	7.5
*Microcystis	23.2	Chlamydomonas	7.9	Achnanthes	7.5
⊛Schroederia	23.2	Treubaria	7.9	Coelastrum	7.5
Kirchneriella	23.1	*Merismopedia	7.9	Closterium	7.5
Crucigenia	23.1	⊛*Raphidiopsis	7.9	Gyrosigma	7.5
Staurastrum	23.0	Pediastrum	7.9	⊛Chlorogonium	7.5
⊙Ceratium	23.0	*Chroococcus	7.9	*Dactylococcopsis	7.5
⊛Chlorogonium	23.0	Dictyosphaerium	7.9	Pandorina	7.5
⊛Lagerheimia	22.8	Cosmarium	7.9	*Aphanizomenon	7.5
Pandorina	22.8	Tetraedron	7.9	*Chroococcus	7.6
*Dactylococcopsis	22.7	Kirchneriella	7.8	Cyclotella	7.6
Closterium	22.5	Euglena	7.8	Euglena	7.6
Dictyosphaerium	22.4	Ankistrodesmus	7.8	Tetraedron	7.6
Phacus	22.4	Navicula	7.8	*Oscillatoria	7.6
Scenedesmus	22.3	Achnanthes	7.8	Scenedesmus	7.6
Oocystis	22.3	Nitzschia	7.8	Pediastrum	7.6
Chlamydomonas	22.2	Closterium	7.8	*Microcystis	7.6
Cyclotella	22.2	*Anabaena	7.8	Kirchneriella	7.6
⊛Actinastrum	22.1	⊙Ceratium	7.8	*Coelosphaerium	7.7
*Oscillatoria	22.1	Cocconeis	7.8	Dictyosphaerium	7.7
Euglena	22.0	Scenedesmus	7.8	Synedra	7.7
*Aphanizomenon	21.8	*Dactylococcopsis	7.8	Melosira	7.7
Glenodinium	21.8	Cryptomonas	7.8	⊛Schroederia	7.7
Trachelomonas	21.7	*Lyngbya	7.8	Chlamydomonas	7.7
Melosira	21.7	*Oscillatoria	7.8	Cryptomonas	7.7
Nitzschia	21.6	Gymnodinium	7.8	Navicula	7.8
Achnanthes	21.6	Glenodinium	7.8	Gymnodinium	7.8
Synedra	21.4	Gomphonema	7.8	Glenodinium	7.8
*Coelosphaerium	21.4	Synedra	7.7	Ankistrodesmus	7.8
Ankistrodesmus	21.4	Surirella	7.7	Mallomonas	7.8
Mallomonas	21.3	Pandorina	7.7	Nitzschia	7.8
Cryptomonas	21.1	Mallomonas	7.7	⊛Golenkinia	7.9
Gyrosigma	20.9	Staurastrum	7.7	Oocystis	7.9
Navicula	20.8	Crucigenia	7.7	⊙Tabellaria	8.0
⊙Tabellaria	20.7	Trachelomonas	7.7	Stephanodiscus	8.0
Fragilaria	20.4	Cymbella	7.7	⊙Dinobryon	8.1
Gymnodinium	20.4	Gyrosigma	7.7	Cocconeis	8.1
Stephanodiscus	20.4	Melosira	7.7	⊛Actinastrum	8.1
Cocconeis	20.2	Cyclotella	7.7	⊛Lagerheimia	8.2
⊙Dinobryon	19.8	⊙Dinobryon	7.6	Fragilaria	8.3
Cymbella	19.3	⊙Peridinium	7.6	Gomphonema	8.3
Gomphonema	19.0	Euastrum	7.5	Cymbella	8.3
Surirella	18.6	⊙Asterionella	7.5	Surirella	8.4
⊙Asterionella	18.5	⊙Tabellaria	7.1	⊙Asterionella	8.6

(Continued)

⊛ nutrient-rich group: mean TOTALP > 200 μg/l
⊙ nutrient-poor group: mean TOTALP < 70 μg/l
* blue-green algae

TABLE 3. PHYTOPLANKTON GENERA RANKED BY FREQUENCY OF OCCURRENCE AND ASSOCIATED MEAN PARAMETER VALUES (Continued)

GENUS	SECCHI (inches)	GENUS	TURB (% transmission)
⊛ *Actinastrum*	30	⊛ *Chlorogonium*	62
⊛ *Chlorogonium*	32	⊛ *Actinastrum*	62
Surirella	33	*Surirella*	63
⊛ * *Anabaenopsis*	33	*Phacus*	63
Gyrosigma	34	⊛ * *Anabaenopsis*	63
Trachelomonas	35	⊛ *Schroederia*	64
⊛ *Schroederia*	35	*Trachelomonas*	64
Gomphonema	36	*Gyrosigma*	64
⊛ * *Raphidiopsis*	36	*Gomphonema*	65
Phacus	36	*Stephanodiscus*	66
Euglena	37	*Euglena*	67
Kirchneriella	37	⊛ * *Raphidiopsis*	67
⊛ *Lagerheimia*	37	*Gymnodinium*	67
Euastrum	38	⊛ *Lagerheimia*	68
* *Merismopedia*	38	*Closterium*	69
Pediastrum	39	*Kirchneriella*	69
* *Dactylococcopsis*	39	* *Merismopedia*	69
Closterium	40	*Glenodinium*	69
⊛ *Golenkinia*	40	*Ankistrodesmus*	69
Chlamydomonas	40	* *Oscillatoria*	70
Treubaria	40	*Dictyosphaerium*	70
Ankistrodesmus	40	*Pediastrum*	70
Dictyosphaerium	40	*Nitzschia*	70
* *Oscillatoria*	41	*Tetraedron*	71
Nitzschia	41	*Cryptomonas*	71
Stephanodiscus	42	*Cymbella*	71
Coelastrum	42	* *Microcystis*	71
Crucigenia	42	* *Dactylococcopsis*	71
* *Microcystis*	42	*Chlamydomonas*	71
Cosmarium	42	*Cocconeis*	71
Tetraedron	42	*Treubaria*	71
Pandorina	42	*Navicula*	71
Scenedesmus	44	*Oocystis*	72
Glenodinium	44	* *Chroococcus*	72
Oocystis	44	*Crucigenia*	72
* *Chroococcus*	44	*Cyclotella*	72
Navicula	44	*Scenedesmus*	72
Cryptomonas	45	*Coelastrum*	72
Cocconeis	46	*Cosmarium*	73
* *Lyngbya*	46	* *Aphanizomenon*	73
Achnanthes	46	*Melosira*	73
Melosira	46	*Synedra*	73
Cymbella	47	*Achnanthes*	74
Gymnodinium	47	⊛ *Golenkinia*	74
Cyclotella	48	*Mallomonas*	75
Synedra	48	*Staurastrum*	75
Staurastrum	48	* *Anabaena*	75
* *Anabaena*	49	* *Lyngbya*	76
* *Aphanizomenon*	51	⊕ *Asterionella*	76
⊕ *Asterionella*	57	*Pandorina*	76
Fragilaria	57	*Fragilaria*	76
Mallomonas	57	* *Coelosphaerium*	78
⊕ *Peridinium*	62	*Euastrum*	79
⊕ *Ceratium*	62	⊕ *Peridinium*	80
* *Coelosphaerium*	65	⊕ *Dinobryon*	81
⊕ *Dinobryon*	66	⊕ *Ceratium*	82
⊕ *Tabellaria*	69	⊕ *Tabellaria*	83

⊛ nutrient-rich group: mean TOTALP > 200 µg/l
⊕ nutrient-poor group: mean TOTALP < 70 µg/l
* blue-green algae

There is a strong tendency for the group to cluster at or near the top of the nutrient parameter lists. The outstanding exception was with nitrite-nitrate-nitrogen (NO2NO3) where the genera scatter from top to bottom. Lake NO2NO3 concentrations were found to be considerably higher in spring than in summer or fall. This may explain the scatter of the nutrient-rich group for this parameter since they were primarily summer and fall forms. The association with high CHLA values is interesting since all of the genera are small forms and, with the possible exception of *Raphidiopsis*, a fairly common dominant, they were not responsible in themselves for the high CHLA levels associated with their distribution. As such, these genera must be associates of bloom formers during times of high production.

Algae responsible for high CHLA concentrations exhibit periodic population fluctuations resulting in short-term high production periods where CHLA values may be quite high. Usually these same common algal forms are found as relatively low "maintenance" populations not associated with extreme CHLA values. Therefore mean CHLA values resulting from a random collection of these algae will often be lower than that associated with forms only encountered during high production periods even if the latter forms are not themselves responsible for the high CHLA levels. Attempts to correlate combinations of up to 7 of the nutrient-rich genera in a sample with visible algal blooms reported by field limnologists at the time of collection were unsuccessful (unpublished data). The 7 genera were less clustered with respect to the physical parameters. In the case of ALK and DO they were spread throughout the full range of mean values.

Of the five genera composing the nutrient-poor group, *Asterionella* was among the lowest 10 genera for 12 of 13 parameters. *Dinobryon, Tabellaria,* and *Peridinium* fell in this select category 10 times, while *Ceratium* occurred 7 times among the lowest 10 genera. *Asterionella* was the only genus with primarily spring occurrences. The two dinoflagellates, *Peridinium* and *Ceratium*, were summer and fall forms, while *Dinobryon* and *Tabellaria* occurred equally through the seasons.

The genera in this group remained tightly packed at the lower mean values for all of the nutrient series parameters except NO2NO3 where, as with the group at the high end, they generally scattered throughout the range. The association of *Asterionella* with particularly high NO2NO3 levels appears to be a consequence of its seasonal "preference."

The nutrient-poor group elements retained position among the lower values for the physical and chemical parameters more consistently than was found with the nutrient-rich genera. A notable exception is the association of *Ceratium* and particularly *Peridinium* with high temperature (TEMP) and dissolved oxygen (DO). The TEMP and DO values were consistent with the seasonal preference (summer and fall) of the two genera. These data suggest that *Ceratium* and *Peridinium* compete successfully in a low nutrient, higher temperature niche.

Certain of the blue-green algae are notorious for creating periodic problem blooms manifested in the formation of thick surface scums, DO depletion, and production of toxic substances, either metabolically or in the course of decay. Eleven blue-green algal genera were quite common in the study (Table 3). Nine of these were important dominants (genera achieved dominance at least 10 times in samples from eastern and southeastern lakes) (Table 4). All can be classified as summer and fall forms except *Dactylococcopsis* and *Oscillatoria*, which occurred equally in spring as well.

As a group, the blue-green algae are scattered throughout the upper and middle range of mean values for all the parameters (Table 3). Except for NO2NO3, SECCHI, and TURB they never appear at the extreme low end. The blue-green algae completely reversed their trend for NO2NO3 with most of the genera falling into the lower half of the list. The phenomenon cannot be readily explained on the basis of nitrogen fixation since only 1 of 5 blue-green genera associated with the lowest mean NO2NO3 values is an acknowledged nitrogen-fixer (*Anabaenopsis*).

The 3 genera listed which have heterocysts and are known to contain species which fix nitrogen are *Anabaena*, *Aphanizomenon*, and *Anabaenopsis* (Fogg, 1974). Nitrogen fixation, an extremely important physiological process [in algae associated uniquely with the blue-greens (Fogg et al., 1973)] is a characteristic which might be expected to form a natural group having similar environmental requirements. These data do <u>not</u> support that premise. In fact, scatter among the 3 genera is great, with mean values differing commonly by a factor of 2 (Table 3). Nor is there a clear relationship with N/P ratio, since 5 non-heterocystous genera have lower N/P ratio values than *Anabaena* and 7 show lower values than *Aphanizomenon*. Similar N/P ratio trends occurred with dominance (Table 4).

Most of the common planktonic blue-green algae have been reported as hard water forms (e.g., Hutchinson, 1967 and Prescott, 1962). In fact, Prescott indicated that *Aphanizomenon* is so consistently related to hard water lakes that it may be used as an index organism for high pH. Many species of *Oscillatoria*, *Anabaena*, *Lyngbya*, and *Microcystis* were cited by Prescott as associates of hard water while species of *Merismopedia* and *Dactylococcopsis* (where indicated), were soft water forms. The common planktonic species of *Chroococcus* are reportedly found under both conditions (Prescott, 1962) while such information on *Raphidiopsis* is generally unavailable from the literature.

A test of hard water requirements can be made by comparing total alkalinity (ALK) values among the occurrence categories for each of the blue-green algae genera (Table 5). *Aphanizomenon*, *Oscillatoria*, and *Merismopedia* showed upward trends in ALK from non-occurrence to non-dominance to dominance. Notably high alkalinities corresponded to the dominance of *Aphanizomenon* and *Merismopedia*. Recall that the literature indicated a soft water preference for *Merismopedia*. *Microcystis*, another very common problem form, showed no difference in ALK values between dominance and non-dominance, though both exceeded the mean level associated with non-occurrence. *Microcystis*, as a dominant, did have the highest pH value among the genera presented in this report. All of the other blue-green algae genera showed <u>lower</u> ALK values with dominance than non-dominance or non-occurrence. The merit of including non-occurrence values (values associated with the sampled waters in which the genus was <u>not</u> detected) becomes readily apparent in attempting to interpret trends in conditions "favoring" or discriminating against a specific genus.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE

GENUS	Frequency of Dominant Occurrence	GENUS	TOTALP (μg/l)	GENUS	ORTHOP (μg/l)
Melosira	255	*Scenedesmus*	351	*Scenedesmus*	194
Oscillatoria	105	*Cyclotella*	185	*Cyclotella*	110
Lyngbya	99	*Anabaena*	183	*Dactylococcopsis*	108
Cyclotella	83	*Merismopedia*	183	*Anabaena*	92
Stephanodiscus	73	*Dactylococcopsis*	178	*Merismopedia*	89
Cryptomonas	72	*Stephanodiscus*	166	*Chroococcus*	76
Dactylococcopsis	58	*Chroococcus*	163	*Stephanodiscus*	66
Microcystis	53	*Microcystis*	148	*Aphanizomenon*	63
Scenedesmus	50	*Aphanizomenon*	147	*Microcystis*	62
Synedra	48	*Oscillatoria*	125	*Cryptomonas*	53
Raphidiopsis	45	*Cryptomonas*	115	*Synedra*	43
Fragilaria	45	*Raphidiopsis*	106	*Oscillatoria*	41
Aphanizomenon	41	*Lyngbya*	99	*Melosira*	38
Asterionella	36	*Melosira*	94	*Lyngbya*	38
Anabaena	33	*Nitzschia*	92	*Raphidiopsis*	27
Dinobryon	31	*Synedra*	82	*Fragilaria*	26
Nitzschia	29	*Fragilaria*	64	*Nitzschia*	25
Merismopedia	22	*Asterionella*	36	*Dinobryon*	11
Tabellaria	20	*Dinobryon*	27	*Asterionella*	11
Chroococcus	19	*Tabellaria*	22	*Tabellaria*	5

(Continued)

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE (Continued)

GENUS	NO2NO3 (µg/l)	GENUS	NH3 (µg/l)	GENUS	KJEL (µg/l)
Stephanodiscus	1201	*Anabaena*	208	*Scenedesmus*	1826
Cryptomonas	970	*Oscillatoria*	127	*Chroococcus*	1630
Synedra	905	*Cyclotella*	120	*Lyngbya*	1488
Melosira	715	*Stephanodiscus*	120	*Microcystis*	1457
Asterionella	621	*Synedra*	120	*Aphanizomenon*	1437
Fragilaria	601	*Raphidiopsis*	119	*Merismopedia*	1387
Nitzschia	592	*Scenedesmus*	117	*Oscillatoria*	1356
Cyclotella	587	*Fragilaria*	115	*Stephanodiscus*	1112
Merismopedia	510	*Cryptomonas*	112	*Raphidiopsis*	1073
Scenedesmus	502	*Aphanizomenon*	112	*Cyclotella*	1053
Oscillatoria	381	*Lyngbya*	110	*Dactylococcopsis*	1041
Aphanizomenon	311	*Merismopedia*	110	*Anabaena*	1015
Raphidiopsis	303	*Melosira*	103	*Nitzschia*	883
Microcystis	302	*Nitzschia*	101	*Fragilaria*	843
Dinobryon	298	*Microcystis*	98	*Cryptomonas*	798
Anabaena	252	*Chroococcus*	90	*Synedra*	797
Dactylococcopsis	186	*Tabellaria*	86	*Melosira*	774
Chroococcus	161	*Dactylococcopsis*	82	*Dinobryon*	594
Tabellaria	133	*Asterionella*	74	*Asterionella*	491
Lyngbya	107	*Dinobryon*	65	*Tabellaria*	455

(Continued)

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE (Continued)

GENUS	CHLA (µg/l)	GENUS	N/P	GENUS	ALK (mg/l as $CaCO_3$)
Scenedesmus	60.4	*Chroococcus*	4.3	*Aphanizomenon*	138
Chroococcus	46.6	*Lyngbya*	4.6	*Stephanodiscus*	125
Oscillatoria	39.2	*Merismopedia*	6.1	*Merismopedia*	103
Aphanizomenon	37.6	*Dactylococcopsis*	6.9	*Oscillatoria*	89
Microcystis	37.5	*Anabaena*	7.1	*Microcystis*	80
Stephanodiscus	37.0	*Aphanizomenon*	7.5	*Nitzschia*	80
Merismopedia	33.6	*Scenedesmus*	8.5	*Fragilaria*	78
Raphidiopsis	30.5	*Oscillatoria*	9.0	*Cyclotella*	76
Cyclotella	29.9	*Microcystis*	9.7	*Cryptomonas*	75
Lyngbya	29.5	*Raphidiopsis*	9.8	*Melosira*	71
Nitzschia	26.5	*Nitzschia*	10.4	*Dinobryon*	71
Dactylococcopsis	25.0	*Tabellaria*	11.3	*Synedra*	67
Anabaena	19.7	*Cryptomonas*	14.2	*Asterionella*	65
Synedra	19.0	*Melosira*	14.4	*Scenedesmus*	64
Melosira	18.1	*Cyclotella*	17.7	*Lyngbya*	62
Fragilaria	17.5	*Stephanodiscus*	17.8	*Raphidiopsis*	57
Cryptomonas	16.5	*Synedra*	21.0	*Dactylococcopsis*	52
Asterionella	9.6	*Asterionella*	22.4	*Anabaena*	50
Dinobryon	8.1	*Fragilaria*	22.9	*Chroococcus*	47
Tabellaria	7.7	*Dinobryon*	28.5	*Tabellaria*	21

(Continued)

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE (Continued)

GENUS	TEMP (°C)	GENUS	PH	GENUS	DO (mg/l)
Raphidiopsis	25.4	*Microcystis*	8.2	*Merismopedia*	6.6
Lyngbya	25.1	*Scenedesmus*	8.1	*Raphidiopsis*	7.0
Chroococcus	24.2	*Aphanizomenon*	8.1	*Anabaena*	7.1
Dactylococcopsis	24.0	*Stephanodiscus*	8.1	*Dactylococcopsis*	7.2
Anabaena	23.9	*Oscillatoria*	8.0	*Cyclotella*	7.2
Microcystis	23.5	*Chroococcus*	8.0	*Nitzschia*	7.4
Scenedesmus	23.3	*Lyngbya*	7.9	*Aphanizomenon*	7.4
Oscillatoria	23.2	*Nitzschia*	7.9	*Lyngbya*	7.4
Cyclotella	23.1	*Merismopedia*	7.9	*Oscillatoria*	7.4
Merismopedia	23.1	*Dactylococcopsis*	7.8	*Melosira*	7.7
Nitzschia	22.4	*Raphidiopsis*	7.8	*Synedra*	7.8
Tabellaria	22.1	*Fragilaria*	7.8	*Scenedesmus*	7.8
Aphanizomenon	21.5	*Synedra*	7.7	*Tabellaria*	7.9
Synedra	21.1	*Asterionella*	7.7	*Cryptomonas*	7.9
Melosira	21.0	*Melosira*	7.6	*Microcystis*	8.0
Fragilaria	19.8	*Cryptomonas*	7.6	*Fragilaria*	8.1
Cryptomonas	19.7	*Dinobryon*	7.6	*Chroococcus*	8.2
Stephanodiscus	19.6	*Cyclotella*	7.5	*Stephanodiscus*	8.5
Dinobryon	18.3	*Anabaena*	7.5	*Dinobryon*	8.7
Asterionella	15.1	*Tabellaria*	6.9	*Asterionella*	9.5

(Continued)

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE (Continued)

GENUS	SECCHI (inches)	GENUS	TURB (% transmission)	GENUS	ALGAL UNITS PER ml
Oscillatoria	36	*Stephanodiscus*	56	*Lyngbya*	12,948
Nitzschia	36	*Merismopedia*	58	*Raphidiopsis*	11,019
Stephanodiscus	37	*Nitzschia*	64	*Oscillatoria*	9,070
Scenedesmus	38	*Oscillatoria*	66	*Dactylococcopsis*	6,814
Merismopedia	39	*Scenedesmus*	67	*Scenedesmus*	6,029
Dactylococcopsis	41	*Aphanizomenon*	71	*Chroococcus*	5,751
Chroococcus	42	*Melosira*	72	*Stephanodiscus*	3,662
Microcystis	43	*Synedra*	73	*Fragilaria*	3,413
Melosira	43	*Cyclotella*	73	*Merismopedia*	3,127
Lyngbya	46	*Raphidiopsis*	75	*Synedra*	3,051
Raphidiopsis	46	*Microcystis*	75	*Melosira*	2,793
Cryptomonas	46	*Dactylococcopsis*	75	*Microcystis*	2,663
Synedra	47	*Cryptomonas*	75	*Aphanizomenon*	2,527
Aphanizomenon	53	*Lyngbya*	75	*Cyclotella*	2,519
Cyclotella	54	*Chroococcus*	76	*Nitzschia*	2,198
Anabaena	55	*Fragilaria*	80	*Anabaena*	1,863
Fragilaria	70	*Anabaena*	81	*Asterionella*	1,583
Asterionella	71	*Asterionella*	81	*Tabellaria*	1,483
Dinobryon	90	*Dinobryon*	88	*Cryptomonas*	1,123
Tabellaria	106	*Tabellaria*	90	*Dinobryon*	633

(Continued)

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 4. SELECTED GENERA* RANKED BY THEIR FREQUENCY OF DOMINANT OCCURRENCE AND THE MEAN PARAMETER VALUES ASSOCIATED WITH THEIR DOMINANCE (Continued)

GENUS	PERC
Raphidiopsis	38.9
Aphanizomenon	32.2
Melosira	32.1
Lyngbya	31.0
Asterionella	30.9
Fragilaria	30.9
Tabellaria	30.8
Oscillatoria	29.0
Dinobryon	26.1
Stephanodiscus	24.8
Anabaena	23.8
Cryptomonas	23.1
Cyclotella	23.1
Dactylococcopsis	21.9
Microcystis	20.4
Nitzschia	20.4
Scenedesmus	19.6
Synedra	19.6
Chroococcus	18.7
Merismopedia	16.2

*Each genus selected achieved dominance at least 10 times in samples from eastern and southeastern lakes.

TABLE 5. COMPARISON OF DOMINANT, NON-DOMINANT, AND NON-OCCURRENCE MEAN PARAMETER VALUES FOR THE 20 MOST COMMON DOMINANT GENERA

	Anabaena			*Aphanizomenon*			*Asterionella*			*Chroococcus*			*Cryptomonas*			*Cyclotella*			*Dactylococcopsis*		
Parameter	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC
TOTALP (µg/liter)	183	121	147	147	87	146	36	61	167	163	194	120	115	116	161	185	112	154	178	161	120
ORTHOP (µg/liter)	92	55	62	63	29	66	11	19	75	76	111	45	53	47	74	110	48	60	108	82	43
NO2NO3 (µg/liter)	252	362	769	311	517	597	621	602	556	161	248	675	970	619	441	587	617	508	186	608	599
NH3 (µg/liter)	208	110	114	112	129	114	74	101	123	90	119	116	112	118	115	120	119	111	82	131	113
KJEL (µg/liter)	1015	1151	956	1437	1082	1009	491	657	1194	1630	1517	888	798	1046	1090	1053	1010	1079	1041	1166	981
N/P	7.1	10.1	18	7.5	13.8	14.6	22.4	15.7	13.1	4.3	6.2	16.7	14.2	14.6	13.6	17.7	14.2	13.0	6.9	10.6	16.8
CHLA (µg/liter)	19.7	29.4	24.1	37.6	27.6	25.1	9.6	14.2	30.9	46.6	41.9	21.0	16.5	27.2	27.2	29.9	25.0	26.6	25.0	30.5	24.2
TURB (% trans-mission)	81	74	70	71	73	72	81	75	71	76	71	73	75	70	74	73	72	72	75	70	78
SECCHI (inches)	55	48	46	53	50	47	71	54	44	42	42	49	46	45	50	54	46	47	41	38	53
PH	7.5	7.8	7.7	8.1	7.9	7.7	7.7	7.5	7.8	8.0	7.9	7.7	7.6	7.9	7.7	7.5	7.8	7.8	7.8	7.8	77
DO (mg/liter)	7.1	7.4	8.1	7.4	7.5	7.9	9.5	8.4	7.5	8.2	7.5	7.8	7.9	7.7	7.8	7.2	7.6	8.1	7.2	7.5	8.0
TEMP (°C)	23.9	23.4	19.7	21.5	21.9	21.4	15.1	19.2	22.6	24.2	24.0	20.7	19.7	21.4	22.0	23.1	22.0	20.4	24.0	22.4	20.7
ALK (mg/liter as CaCO3)	50	69	76	138	101	62	65	58	77	47	67	74	75	88	57	76	72	71	52	74	74
PERC	23.8	1.7	-	32.2	2.3	-	30.9	1.8	-	18.7	2.0	-	23.1	3.2	-	23.1	2.6	-	21.9	2.9	-

(Continued)

TABLE 5. COMPARISON OF DOMINANT, NON-DOMINANT, AND NON-OCCURRENCE MEAN PARAMETER VALUES FOR THE 20 MOST COMMON DOMINANT GENERA (Continued)

	Dinobryon			*Fragilaria*			*Lyngbya*			*Melosira*			*Merismopedia*			*Microcystis*			*Nitzschia*		
Parameter	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC
TOTALP (µg/liter)	27	66	170	64	87	160	99	116	154	94	122	256	183	176	106	148	170	111	92	118	159
ORTHOP (µg/liter)	11	26	75	26	32	72	38	56	66	38	52	121	89	87	38	62	87	40	25	48	73
NO2NO3 (µg/liter)	298	507	608	601	472	598	107	418	732	715	429	731	510	406	693	302	355	763	592	632	509
NH3 (µg/liter)	65	106	123	115	108	119	110	104	123	103	125	118	110	129	107	98	127	111	101	114	119
KJEL (µg/liter)	594	726	1185	843	1029	1064	1488	1051	943	774	1162	1228	1387	1362	789	1457	1350	761	883	983	112
N/P	28.5	17.7	12.0	22.9	12.0	14.0	4.6	12.5	17.1	14.4	12.4	18.8	6.1	9.3	18.1	9.7	9.3	18.3	10.4	13.0	15.4
CHLA (µg/liter)	8.1	13.6	31.8	17.5	22.9	28.0	29.5	27.5	24.9	18.1	29.5	32.3	33.6	37.4	17.5	37.5	37.4	16.3	26.5	26.7	25.7
TURB (% trans-mission)	88	80	69	80	75	71	75	77	70	72	72	71	58	70	75	75	71	73	64	71	75
SECCHI (inches)	90	62	40	70	53	44	46	46	48	43	48	54	39	38	55	43	42	52	36	41	55
PH	7.6	7.6	7.8	7.8	8.0	7.7	7.9	7.7	7.7	7.6	7.8	7.9	7.9	7.9	7.6	8.2	8.0	7.5	7.9	7.8	7.7
DO (mg/liter)	8.7	8.0	7.6	8.1	8.3	7.6	7.4	7.3	8.0	7.7	7.6	8.3	6.6	7.4	8.1	8.0	7.5	7.9	7.4	7.8	7.8
TEMP (°C)	18.3	20.0	22.2	19.8	20.6	21.9	25.1	22.8	20.2	21.0	22.2	20.7	23.1	24.1	19.5	23.5	23.2	20.0	22.4	21.6	21.4
ALK (mg/liter as $CaCO_3$)	71	72	72	78	85	67	62	71	75	71	73	76	103	72	70	80	80	65	80	70	73
PERC	26.1	1.4	-	30.9	1.7	-	31.0	2.7	-	32.1	2.7	-	16.2	2.4	-	20.4	2.5	-	20.4	1.7	-

(Continued)

TABLE 5. COMPARISON OF DOMINANT, NON-DOMINANT, AND NON-OCCURRENCE MEAN PARAMETER VALUES FOR THE 20 MOST COMMON DOMINANT GENERA (Continued)

	Oscillatoria			*Raphidiopsis*			*Scenedesmus*			*Stephanodiscus*			*Synedra*			*Tabellaria*		
Parameter	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC	DOM	NON DOM	NON OCC
TOTALP (µg/liter)	125	139	140	106	248	114	351	114	142	166	111	144	82	100	202	22	46	156
ORTHOP (µg/liter)	41	69	57	27	136	45	194	50	50	66	43	66	43	33	102	5	15	69
NO2NO3 (µg/liter)	381	534	669	303	380	635	502	479	827	1201	724	404	905	602	464	133	408	610
NH3 (µg/liter)	127	122	106	119	153	107	117	116	116	120	103	121	120	112	122	86	97	120
KJEL (µg/liter)	1356	992	991	1073	1492	936	1826	1055	805	1112	981	1059	797	879	1326	455	606	1134
N/P	9.0	11.1	19.0	9.8	6.2	16.3	8.5	11.3	23.0	17.8	13.8	13.7	21.0	14.4	12.5	11.3	19.3	13.3
CHLA (µg/liter)	39.2	25.6	22.4	30.5	48.0	20.7	60.4	26.5	16.2	37.0	26.9	24.2	19.0	21.6	34.1	7.7	11.1	29.3
TURB (% trans-mission)	66	71	76	75	64	74	67	72	75	56	70	76	73	73	71	90	81	70
SECCHI (inches)	36	43	56	46	33	51	38	44	59	37	44	51	47	48	46	106	62	43
PH	8.0	7.8	7.6	7.8	8.0	7.7	8.1	7.8	7.6	8.1	7.9	7.6	7.7	7.7	7.9	6.9	7.2	7.9
DO (mg/liter)	7.4	7.6	8.0	7.0	7.4	7.9	7.8	7.6	8.2	8.5	7.8	7.6	7.8	7.7	7.8	7.9	8.0	7.7
TEMP (°C)	23.2	21.8	20.6	25.4	23.2	20.8	23.3	22.2	19.0	19.6	20.6	22.2	21.1	21.5	21.6	22.1	20.5	21.6
ALK (mg/liter as CaCO3)	89	74	65	57	85	70	64	73	70	125	92	55	67	70	76	21	37	80
PERC	29.0	2.0	-	38.9	3.0	-	19.6	2.1	-	24.8	2.6	-	19.6	2.0	-	30.8	1.2	-

In an attempt to determine the major constituents within phytoplankton communities, dominant status was attached to those genera which accounted for 10 percent or more of the numerical total cell count in a given sample. The 10 percent cut-off point is arbitrary and resulted in an average of about 3 dominant genera in each sample. Dominance as defined here often includes each of multiple forms in "codominance" within a single sample. With this approach every sample had dominant members regardless of the total cell count. One advantage to this approach is that it recognizes forms of relative importance in each sample. Several problems are inherent in the interpretation of data using this scheme. Equivalent weight in the environmental requirements summary is given to an *Asterionella* representing 10 percent or more in a sample of 100 cells per milliliter (ml) as one representing an equivalent percentage in a sample containing 10,000 cells per ml. It is the relative importance, based upon cell count, which characterizes the dominant forms. It should be noted that large forms (e.g., *Pediastrum*) which might constitute a substantial fraction of the biomass, often fell short of numerical dominance.

In Table 4, each genus which achieved dominance at least ten times is ranked by its frequency of dominant occurrence and the mean level for each of the parameters addressed, found associated with the occurrence of the genus as a dominant. The "flagellates," a general category which crosses broad taxonomic lines, had about 300 dominant occurrences associated with it. This group, the members of which are often difficult to accurately identify, was not included among the Table 4 entries but was obviously an important component of many communities.

The genera represented in Table 4 include 9 blue-greens (Myxophyceae), 8 diatoms (Chrysophyta), 2 flagellates (1 Cryptophyta and 1 Chrysophyta), and one chlorococcalean (Chlorophyta). Obviously blue-green and diatom genera numerically dominated a majority of the samples. *Melosira* was by far the most common dominant genus followed by *Oscillatoria* and *Lyngbya*. *Scenedesmus*, second only to *Melosira* in total occurrences, was considerably less important among dominant forms.

Asterionella can be considered a spring dominant, while *Stephanodiscus*, *Synedra*, and *Tabellaria* are spring and summer dominants. *Cryptomonas* and *Dinobryon* are spring and fall dominants. *Fragilaria* occurred equally throughout the seasons as a dominant. The remaining genera were summer and fall dominants.

As expected, the dominance category tended to narrow the ranges of associated environmental conditions for most of the genera (Appendices A1-4) by eliminating data associated with passive or chance occurrences of genera within a given sample, and by using data associated with "healthy" populations. It should be noted that a dominant population at the time of sampling may have been in growth, stationary, or decline phases. Naturally, "environmental requirements" would vary accordingly. Therefore there is no assurance that the conditions detected at the time of sampling were, in fact, optimal for growth of that genus.

DOMINANT GENERA

This section summarizes our findings for the 20 phytoplankton genera most frequently recorded as numerical dominants in our samples. Although, within the literature, a great deal of data are available describing environmental conditions associated with the presence of a large variety of freshwater algae, the data are scattered, inconsistent, and difficult to extract and summarize. Several authors have begun the arduous review process (Reimer, 1965; Palmer, 1969; Lowe, 1974) and their findings are used here where possible, in conjunction with our results. Reimer presented detailed physical and chemical ranges for 5 common diatom species, while Lowe's summaries were more subjective in nature, and again done at the species levels which limits their usefulness here. Palmer addressed both genera and species and provides the most directly comparable information.

Genus-by-genus discussions found in this section elaborate further on the summary Table 5. The emphasis on dominant/non-dominant comparisons is based upon the assumption that those conditions under which a genus achieves high numerical importance are more reflective of "optimal" environmental ranges than those conditions under which that genus is merely detected at relatively low levels. Attention is also called to substantive differences noted between conditions of dominant/non-dominant occurrence and those associated with waters in which specific genera were not detected.

Anabaena

Anabaena was the 10th most common phytoplankton genus encountered in the NES lakes sampled during 1973 (Table 2). It was considered dominant in 33 (9 percent) of the 356 samples in which it occurred. Most of the dominant occurrences were recorded from summer and fall samples. According to Hutchinson (1967), *Anabaena* is most often found in abundance during the warmest time of the year in eutrophic localities. A positive relationship between occurrence of *Anabaena* and temperature is supported by our data (Table 5). Palmer (1969), ranked *Anabaena* 22nd in ability to tolerate organic pollution.

Relative to the other dominant genera, *Anabaena* was associated with a high mean TOTALP value, the highest NH3 value (207 µg/liter) and a low mean N/P ratio (Table 4). For the remaining parameters, *Anabaena* was not associated with extremes.

Occurrence of *Anabaena* as a dominant was associated with distinctly higher mean TOTALP, ORTHOP, and NH3 than non-dominant occurrence or waters in which *Anabaena* was not detected (non-occurrence). However, the strong downward trend in NO2NO3 noted in comparing conditions associated with non-occurrence (769 μg/l), non-dominance (362 μg/l) and dominance (252 μg/l) (Table 5) suggests that *Anabaena* competes more successfully in waters containing lower nitrite/nitrate levels. This finding supports information previously reported (e.g., Williams, 1975). The high levels of NH3 associated with dominance are not sufficient to offset the impact of the combined effects of lower NO2NO3 and higher TOTALP of the N/P ratio (quite low at 7.1 for dominance). The natural inclination to ascribe competitive advantage to *Anabaena,* at low N/P ratios (or just low NO2NO3 levels, for that matter), as a function of nitrogen fixation must be approached with care, however. Other blue-greens, heterocystous and non-heterocystous alike, showed modest to dramatic reductions in N/P associated with their general occurrence and still greater reductions associated with their dominance, e.g., *Chroococcus,* relative to waters in which they were not detected. It should be noted that in the lakes sampled in 1973 low N/P ratios were usually a consequence of high phosphorus levels rather than of low nitrogen levels.

Additional trends noted in comparing dominance, non-dominance, and non-occurrence conditions (Table 5) for DO (7.1, 7.4, and 8.1 mg/l, respectively) and ALK (50, 69 and 76 mg/l, respectively) suggest that *Anabaena* is "favored" by conditions of lower dissolved oxygen and "softer" waters.

Productivity, as measured by Kjeldahl nitrogen and particularly chlorophyll a, showed a relative decrease where *Anabaena* achieved dominance. Keep in mind that dominance, as defined here, is not necessarily synonymous with "bloom" conditions.

Aphanizomenon

While only the 38th most common genus encountered in the NES lakes sampled during 1973, 41 (27 percent) of the 154 sample occurrences of *Aphanizomenon* were classified as dominant (Table 2). *A. flos-aquae* was by far the most common species of *Aphanizomenon* in the study. *Aphanizomenon* was numerically one of the most important constituents with a mean percent composition (PERC) of 32.2 percent as a dominant. For the nutrient series and remaining parameters, *Aphanizomenon* was not associated with the extremes of the ranges (Table 4).

Aphanizomenon is a well-known bloom-former in productive lakes of temperature regions during the warmest months and can be considered an indicator of eutrophy (Hutchinson, 1967). Prescott (1962) indicates that *Aphanizomenon* is hardly ever found unless in eutrophic waters or polluted streams, and is so consistently related to hard water lakes that it may be used as an index organism for high pH and usually high nitrogen as well. These reports of conditions associated with the occurrence of *Aphanizomenon* received mixed support from our data. Most dominant occurrences do coincide with the warm water periods (summer and fall) but *Aphanizomenon* achieved dominance in colder waters, on an average, than any of the other blue-green algae (Table 4). Indeed, extensive *Aphanizomenon* growths have been recorded on the under-surface of ice in lakes (F. B. Trama, personal communication). If eutrophy is considered roughly synonymous with high levels of TOTALP and inorganic nitrogen (NO2NO3 + NH3), the broad range of nutrient conditions (Figure A-1) under which it was found and trends in conditions associated with the categories of occurrence do not support *Aphanizomenon* as a reliable indicator of eutrophy. Mean TOTALP for general occurrence (103 µg/l, Table 3) is well below the average level for those lakes in which it was not detected (146 µg/l, Table 5). And while the TOTALP level associated with dominance (147 µg/l) is substantially higher than non-dominance (87 µg/l), it is virtually indistinguishable from the non-occurrence value. The inorganic nitrogen mean value for *Aphanizomenon* dominance is approximately 40 percent lower than that for lakes in which it was not detected. The NH3 levels are essentially constant across the occurrence categories, while the NO2NO3 component ranges from 597 µg/l to 517 µg/l to 311 µg/l for non-occurrence, non-dominance and dominance, respectively. This trend clearly suggests that *Aphanizomenon* is "favored" at lower NO2NO3 levels (as we also noted for *Anabaena*, another heterocystous blue-green) rather than higher, as previously reported. The low N/P ratio (7.5, Table 5) associated with dominance of *Aphanizomenon* reflects the differences in NO2NO3 and TOTALP noted. The relationships of *Aphanizomenon* to "hard" waters and high pH, suggested by Prescott (1962), are supported by trends in ALK (138, 101, and 62 mg/l) and pH (8.1, 7.9, and 7.7) for dominance, non-dominance, and non-occurrence, respectively. The ALK value of 138 mg/l with dominance was the highest such value recorded among the 20 dominant genera.

Productivity, as estimated by CHLA, and standing crop, as reflected by both CHLA and KJEL, are both considerably higher in association with *Aphanizomenon* dominance than with non-dominance or non-occurrence. While Hutchinson (1967) indicated that *Aphanizomenon* is favored by low turbidity (high light transmission) neither absolute values of TURB and SECCHI nor trends across the occurrence categories (Table 5) support that relationship.

Asterionella

Asterionella was the 28th most common genus encountered in the NES lakes sampled during 1973 (Table 2). It was considered dominant in 35 (18 percent) of the 198 samples in which it occurred. Most of the occurrences were of one species (*A. formosa*). Among the very common genera, *Asterionella* was the most seasonally restricted, with 58 percent of its total sample occurrences and 77 percent of its dominant occurrences in spring.

Asterionella was one of the few genera consistently associated with lower nutrient and productivity parameter values for general occurrence as well as dominance (Table 4). Most of the mean parameter values for *Asterionella* were still within the mesotrophic range. This is not inconsistent with the findings of other workers (Patrick and Reimer, 1966; Lowe, 1974; Pearsall, 1932), in which *Asterionella* was reported to prefer mesotrophic and eutrophic waters. It is highly likely that mean nutrient values associated with the occurrence (Table 3) and particularly the dominance (Table 4) of this genus would have been considerably lower in a test set of lakes containing truly oligotrophic representatives (virtually absent among the 273 lakes sampled in 1973) considering the data trends (Table 5) and apparent affinity of the genus for the lowest nutrient waters in our study group. Indeed, Rawson (1956) demonstrated a strong preference for the genus in Canada's western oligotrophic lakes. *Asterionella* occurred in samples with low values of TOTALP, ORTHOP, NH3, KJEL, and CHLA. For all of these parameters distinct trends are noted (Table 5) in which the lowest mean values are associated with the dominance of *Asterionella* while the highest values are associated with those waters in which the genus was not detected. Non-dominant occurrence values are intermediate in all cases.

Also consistent with a preference for more "pristine" water conditions are the trends (see Table 5) in DO (9.5, 8.4, and 7.5 mg/l), SECCHI (71, 54, and 44 inches), TURB (81, 75, and 71 percent transmission), N/P (22.4, 15.7, and 13.1), and TEMP (15.1, 19.2, and 22.6) for the respective occurrence categories (dominance, non-dominance, and non-occurrence). The high NO2NO3 value associated with dominance of *Asterionella* may, in part, reflect spring lake conditions when NO2NO3 concentrations were found to be significantly higher than in other seasons. It also suggests a competitive advantage for *Asterionella* under high N/P conditions. That *Asterionella* has a low temperature optimum for high relative success is evidenced by the mean TEMP at dominance (15.1°C, lowest among the algae presented) and the greater than 4°C difference between that value and the mean TEMP for non-dominance (19.2°C). The TEMP mean for lakes in which *Asterionella* was <u>not</u> detected was 22.6°C.

Chroococcus

Chroococcus was the 32nd most common genus encountered in the NES lakes sampled during 1973. Although it was identified in 179 samples, it was found to be a dominant in only 19 (11 percent) of the samples (Table 2).

Chroococcus is a common phytoplankton genus with species exhibiting requirements ranging from soft to hard water, while some species do well under both conditions (Prescott, 1962). Values for ALK across the occurrence categories (Table 5) suggest some preference for "softer" waters, particularly with dominance. Palmer (1969) ranked *Anacystis* (*Chroococcus*, in part) 19th in ability to tolerate organic pollution. There is however, no way to determine if his results were based on data associated with the *Chroococcus* form or not.

Chroococcus was associated with several extreme conditions as a dominant (Table 4). Both CHLA and KJEL values were among the highest while the NO2NO3 value was at the low end. *Chroococcus* was associated with relatively high mean phosphorus values and had the smallest N/P ratio, as a dominant, (4.3) of the 20 genera under discussion. *Chroococcus* was associated with high TEMP (24.2°C) and low ALK (47 µg/l).

TOTALP, ORTHOP, NO2NO3, and NH3 levels were lower with dominance than non-dominance (Table 5). The NO2NO3 levels associated with both non-dominance and dominance are far lower than those found for the waters in which *Chroococcus* was not detected. These findings are further reflected in the extremely low N/P value calculated for this genus (note that *Chroococcus* is <u>not</u> a known nitrogen-fixer). Productivity and standing crop, as estimated by CHLA and KJEL, showed similar patterns when evaluated across the occurrence categories (Table 5). With both parameters the highest mean values were associated with dominance and were followed closely by non-dominance levels. The CHLA and KJEL levels in waters in which *Chroococcus* was <u>not</u> detected (non-occurrence) were only one-half those in which the genus was found.

Cryptomonas

Cryptomonas was the 7th most common genus encountered in NES lakes during 1973 (Table 2). It was found to be dominant in 72 (18 percent) of the 393 samples containing the genus. Although *Cryptomonas* dominated primarily in spring samples, it was an important major constituent in summer and fall as well. Hern et al. (1978b), found *Cryptomonas* to be the second most common phytoplankter in the Atchafalaya Basin where it showed no seasonal preference. In that study it dominated under high nutrient, low light (due to inorganic turbidity) conditions. Soeder and Stengel (1974) indicate a low light intensity preference for *Cryptomonas*. Hutchinson (1967) classified both of the common species as eurytopic (having a wide environmental range of tolerance) while Palmer (1969) rated *Cryptomonas* 23rd on his genus organic pollution tolerance list.

Cryptomonas was not associated with extremes for any of the parameters when compared to the other dominant genera under discussion (Table 4). It had values which uniformly fell in the middle ranges of mean values. The few exceptions included a high NO2NO3 value (970 µg/l), and CHLA and TEMP values which approached the low end of the range. The clear association with lower CHLA and KJEL, seen with dominance, is not evident in the non-dominant occurrence of *Cryptomonas*. Hutchinson (1967) cites Fidenegg's (1943) finding of an optimal upper limit for temperature of 12-15°C for *C. erosa*. This is considerably below the mean value of 19.7°C calculated from our data (Table 4) for the genus, but the TEMP trend (22.0, 21.4, and 19.7°C) across the non-occurrence, non-dominance, and dominance categories, respectively, support a cool water optimum for this genus.

Notable differences in mean parameter values among dominance, non-dominance, and non-occurrence were few (Table 5). There was a substantially higher level of NO2NO3 with dominance than in waters in which *Cryptomonas* was not detected (non-occurrence). Non-dominance NO2NO3 levels were intermediate. Dominant occurrences of *Cryptomonas* were associated with low productivity compared to the other genera under discussion.

Cyclotella

Cyclotella meneghiniana and *C. stelligera* were by far the most common species of the genus in this study. Both were considered eutrophic by Lowe (1974). *Cyclotella* was the 4th most common genus encountered in NES lakes during 1973 (Table 2). It was found to dominate in 83 (18.8 percent) of the 441 samples containing the genus. It was most important as a dominant in the summer and fall but was a strong spring contributor also. Palmer (1969) ranked *Cyclotella* 15th in ability to tolerate organic pollution.

The association of *Cyclotella* as a dominant with the second highest TOTALP and ORTHOP values (185 and 110 µg/l respectively) of the 20 genera under discussion (Table 4) support the genus as a more eutrophic form. At the same time, however, the trend in N/P ratio across the occurrence categories (17.7 for dominance; 14.2 for non-dominance; and 13.0 for non-occurrence) suggests that higher relative success of *Cyclotella* is associated with higher N/P ratios. While *Cyclotella* fell within the mid-range of mean values for the other parameters, trends across the occurrence categories (Table 5) for TEMP and DO suggest that higher relative success is associated with warmer waters and lower dissolved oxygen levels, not inconsistent with a eutrophic classification.

There were very little differences associated with the various nitrogen parameters by occurrence category (Table 5). Except for CHLA, which was slightly higher with dominance, there were no noteworthy differences among the remaining parameters.

Dactylococcopsis

Dactylococcopsis was the 16th most common genus encountered in NES lakes during 1973 (Table 2). It was considered dominant in 58 (20 percent) of the 287 samples in which it occurred. *Dactylococcopsis* can be considered primarily a summer and fall dominant form.

While *Dactylococcopsis* as a dominant was associated with TOTALP and ORTHOP values near the high end of the range, its NO2NO3 and NH3 values were among the lowest of the 20 genera listed (Table 4). As with all of the blue-green algae genera in this study, its N/P ratio was low (6.9). *Dactylococcopsis* was associated with warm water (24°C) and low ALK (52 µg/liter).

Significantly lower NO2NO3 and NH3 values were noted with dominance which reflected in a decreased N/P ratio as well (Table 5). Dominant and non-dominant occurrence showed very little difference in phosphorus levels although both were associated with considerably higher levels than the waters in which *Dactylococcopsis* was not detected. As with *Chroococcus* and *Aphanizomenon*, the inorganic nitrogen (NO2NO3, NH3) values are moderate to low and phosphorus is in abundant supply. Nitrogen fixation has not been demonstrated in *Dactylococcopsis*. Summarizing the mean data trends across occurrence categories in Table 5, *Dactylococcopsis* appears to achieve higher relative success in "softer," warmer waters with lower dissolved oxygen and inorganic nitrogen levels and with high phosphorus (low N/P) - in short, conditions typically found in enriched temperate lakes during late-summer, early-autumn.

Dinobryon

Dinobryon was the 26th most common genus encountered in NES lakes during 1973 (Table 2). It was considered dominant in 31 (14 percent) of the 221 samples in which it occurred. One-half of the *Dinobryon* dominant occurrences were in spring samples while the others were equally divided between summer and fall samples.

Dinobryon, as a dominant, was one of just a few genera consistently associated with low mean values for the nutrient series, including the lowest NH3 value (65 µg/l) (Table 4). In addition, it had by far the highest N/P ratio (28.5). Trends in nutrient levels across the occurrence categories (Table 5) reinforce the "preference" of *Dinobryon* for less enriched waters. The dominance of *Dinobryon* is generally associated with cool, clear, highly oxygenated waters (oligo- to mesotrophic). Notably, *Dinobryon* had the smallest mean cell count of any dominant; this reflects the low productivity associated with its presence as a successful competitor.

Dinobryon dominance was associated with substantially lower mean KJEL and CHLA and higher SECCHI values compared with non-dominant and particularly non-occurrence mean values (Table 5). TOTALP and ORTHOP values were less than half of the non-dominant values, while NO2NO3 and NH3 were lower by 209 and 41 μg/l respectively. The N/P ratio for non-dominance, high at 17.7 was higher yet (28.5) with dominance (N/P level for lakes in which *Dinobryon* was not detected was only 12.0). Indeed, Rodhe (1948) found *D. divergens* to be inhibited at phosphate concentrations greater than 5 μg/l in culture studies. Furthermore, Pearsall (1932) concluded that *D. divergens* appears when the N/P ratio rises, which was the usual case in English lakes in the spring. Even though it has long been recognized as an oligotrophic form (Nauman, 1919; Rawson, 1956), it will appear in productive lakes when nutrients have been reduced to levels unacceptable for continued growth of other forms (Hutchinson, 1967). Indeed, our data suggest that waters favorable to the success of *Dinobryon* are low in productivity, temperature, and nutrients and high in clarity.

Fragilaria

Fragilaria was the 27th most common genus encountered in NES lakes during 1973 (Table 2). Although several species were identified, *F. crotonensis* was easily the most common encountered in the study. The genus was considered dominant in 45 (20.9 percent) of the 215 samples in which it occurred. *Fragilaria* showed no seasonal preference as a dominant, occurring equally in spring, summer, and fall. Palmer (1969) ranked it 29th in ability to tolerate organic pollution.

As a dominant, *Fragilaria* had relatively low TOTALP and ORTHOP values, while the nitrogen mean values were mid-range (Table 4). *Fragilaria* was associated with one of the highest N/P ratios, second only to *Dinobryon*. *Fragilaria* tended toward that end of the mean parameter ranges, for most of the physical and chemical parameters, generally associated with low nutrient levels and productivity.

TOTALP and ORTHOP values were lower while NO2NO3 and NH3 values were higher with *Fragilaria* dominance than with non-dominance (Table 5). Although the phosphorus levels associated with dominance and non-dominance were close, they were far lower than the respective levels associated with non-occurrence. The N/P ratio also reflected the changes in nitrogen and phosphorus levels (it doubled to 22.9 with dominance) although little difference was noted between the N/P ratios associated with non-dominance and non-occurrence. CHLA and KJEL values were lower when dominant, reflecting the lower nutrient levels. This trend was followed for most of the parameters addressed here.

In summary, relative success of *Fragilaria* appears to be associated with lower phosphorus levels, indifference to inorganic nitrogen levels, higher water clarity and modest levels of productivity.

Lyngbya

Lyngbya was the 17th most common genus encountered in NES lakes during 1973 (Table 2). It was considered dominant in 99 (34.6 percent) of the 286 samples in which it occurred. Most dominant occurrences of *Lyngbya* were in summer and fall, with a small fraction occurring in spring.

Although TOTALP, ORTHOP, and NH3 values were near center within the total ranges as a dominant, *Lyngbya* showed an N/P ratio of 4.6, the second lowest calculated for the 20 genera (Table 4). *Lyngbya* had the largest cell count (CONC) among the dominants, with an average sample containing nearly 13,000 filaments per milliliter.

Levels of TOTALP and ORTHOP were slightly lower with dominance than with non-dominance and much lower than those associated with lakes in which *Lyngbya* was not detected. Levels of NO2NO3 associated with dominance were only about 25 percent of non-dominance levels and 15 percent of non-occurrence levels (Table 5). KJEL, CHLA, and TEMP levels associated with dominance were higher than with non-dominance or non-occurrence. The N/P ratio with dominance was only about 30 percent of the non-dominant and 25 percent of the non-occurrence values, likely primarily due to the changes in NO2NO3 noted. *Lyngbya*, at least one species of which has recently been shown to reduce acetylene (a criterion for nitrogen-fixing activity) by Stewart (1971), appears to favor a low inorganic nitrogen (NO2NO3 + NH3) environment. Again, as with other blue-green algae, TEMP trends across the occurrence categories (Table 5) suggest increased temperatures are associated with increased relative success. These findings are similar to Hutchinson's (1967) summary in which *Lyngbya* was included in an important group of planktonic blue-green algae genera usually found in great abundance in productive lakes in summer, when nutrient concentrations are relatively low and temperature and productivity are high.

Melosira

Melosira was the most common genus encountered in NES lakes during 1973 (Table 2). It was considered a dominant form in 255 (42 percent) of the 607 samples in which it occurred. *Melosira* was equally important in each of the three seasons, both as a non-dominant and dominant constituent. Palmer (1969) rated it 13th in ability to tolerate organic pollution. The most frequently encountered species were, respectively, *M. distans*, *M. granulata*, *M. granulata angustissima*, *M. italica*, and *M. varians*.

Melosira was uniquely common and, as might be expected, mean parameter values calculated for its occurrence, both as a non-dominant and dominant, were similar to the mean values calculated for the entire data base. An examination of Table 4 reveals that *Melosira* as a dominant was not associated with the extreme mean values for any of the parameters. However, examination of Table 5 reveals that mean parameter values for dominance and non-dominance are, in many cases, quite different from those conditions under which *Melosira* was <u>not</u> detected (non-occurrence). In addition, there were notable differences in several of the parameter means between non-dominant and dominant occurrences (Table 5).

TOTALP and ORTHOP levels show similar trends; those associated with dominance are lowest (94 and 38 μg/l, respectively), with non-dominance somewhat higher (122 and 52 μg/l), and non-occurrence substantially higher (256 and 121 μg/l). Although little difference is noted between the levels of NO2NO3 associated with non-occurrence and dominance, the non-dominance related mean level was much lower (731, 715, and 429 μg/l, respectively). General occurrence (dominant and non-dominant) was associated with lower N/P.

Melosira was associated with lower productivity as indicated by the distinct trends in KJEL and CHLA values across the occurrence categories (Table 5). As a dominant, *Melosira*, on the average, accounted for about 1/3 of the total numerical sample count, which further illustrates its unique position in phytoplankton communities.

Merismopedia

Merismopedia was the 13th most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be dominant in 22 (6.7 percent) of the 328 samples in which it occurred. *Merismopedia* was more common both as a dominant and non-dominant in the summer and fall than it was during spring. Even though *Merismopedia* was obviously common in the NES lakes, and is considered an important blue-green algae plankter elsewhere (Hutchinson, 1967), very little substantive environmental data are available. Palmer (1969) did, however, rank it 36th in ability to tolerate organic pollution.

Merismopedia was found in more enriched waters as a dominant (Table 4). It was associated with one of the lowest N/P ratios (6.1) and clearly the lowest DO value of the 20 genera under discussion. SECCHI and TURB values indicated that *Merismopedia* dominated in some of the most turbid water encountered in the survey. *Merismopedia* was rarely a strong dominant having a mean percent composition of only 16.2.

Differences in the mean parameter values between non-dominance and dominance were generally small (Table 5) but differences in many parameters were clear between occurrence (dominant and non-dominant) and non-occurrence conditions. KJEL and CHLA values (Table 5) suggest that occurrence of *Merismopedia* is associated with high productivity. N/P ratio with dominance was sharply lower (typical for all the blue-green algae genera) while CHLA was only slightly lower than non-dominant conditions. In general, the data support warm, turbid, highly productive, high nutrient conditions to favor the success of *Merismopedia*. The low DO value (6.6 mg/l) suggests strong impacts when *Merismopedia* is dominant.

Microcystis

The principle species encountered in this study were *M. incerta* and *M. aeruginosa*. The former species appeared in twice as many samples as the latter. *M. aeruginosa* is considered to be an indicator of eutrophy, usually occurring in lakes during the warmest season (Hutchinson, 1967). Palmer (1969) ranked *Microcystis* (*Anacystis* in part) 19th in ability to tolerate organic pollution.

Microcystis was the 11th most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be dominant in 53 (15.3 percent) of the 346 samples in which it occurred. *Microcystis* occurred primarily in summer and fall. However, the occurrence of *Microcystis* in 49 first round samples qualifies it as an important spring form as well.

On the whole, *Microcystis* was not distinguished by extremely high or low mean values for any of the parameters (Table 4). CHLA and KJEL values fell toward the high ends of their respective ranges.

Differences in mean values between non-dominant and dominant occurrences of *Microcystis* were minimal (Table 5). With dominance, levels of TOTALP, ORTHOP, NO2NO3, and NH3 were consistently lower. Comparison of conditions across the occurrence categories (Table 5) indicates that occurrence is associated with lower inorganic (NO2NO3 + NH3) nitrogen and higher organic (KJEL-NH3) nitrogen levels than were found for waters in which *Microcystis* was not detected. N/P ratios for dominant and non-dominance occurrence (9.7 and 9.3, respectively) were much lower than the mean for non-occurrence (18.3), while the inverse relationship was true with respect to CHLA and KJEL. Both dominant and non-dominant occurrence was associated with more turbid waters. SECCHI relationships were also quite consistent with standing crop and productivity estimates from KJEL and CHLA.

To generalize, "typical" waters favoring the success of *Microcystis* can be characterized as relatively warm, turbid, moderate to low in inorganic nitrogen (particularly as NO2NO3), relatively high in phosphorus, with moderate to high ALK and pH, and with high levels of organic production. The conditions generally reflect those found in enriched temperate waters during late summer and early fall.

Nitzschia

Nitzschia was the 9th most common genus encountered in NES lakes during 1973 (Table 2). This diatom was considered to be dominant in 28 (7.5 percent) of the 374 samples in which it occurred. *Nitzschia* occurred equally in each of the 3 seasons but achieved dominance more frequently in summer and fall. Palmer (1969) ranked *Nitzschia* 9th in ability to tolerate organic pollution.

As a dominant, *Nitzschia* was associated with the lowest water transparency (SECCHI values of 36 inches) of the 20 genera under discussion (Table 4). While the TURB value was similarly low, and TOTALP and ORTHOP values were toward the low end of the range, most mean parameter values were mid-range.

The most notable difference between conditions associated with non-dominance and dominance was a lower level of ORTHOP with dominance (Table 5). Both ORTHOP and TOTALP were lower where *Nitzschia* occurred than in those waters in which it was not detected. Upward trends across the occurrence categories (dominance, non-dominance and non-occurrence, respectively) were noted in the values of NH3, KJEL, N/P, TURB, and SECCHI (Table 5). A slightly lower level was noted for NO2NO3 with dominance than with non-dominance. Large between-species differences (to be presented in a future report) reduce the value of genus-level generalizations for *Nitzschia.*

Oscillatoria

Oscillatoria was the 5th most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be dominant in 105 (24.5 percent) of the 428 samples in which it occurred. *Oscillatoria* was slightly more common in the summer and fall than during the spring. Palmer (1969) ranked *Oscillatoria* 2nd in ability to tolerate organic pollution.

While *Oscillatoria* rarely had extreme mean parameter values (Table 4), it shared with *Nitzschia* the distinction of being associated with the most turbid waters. This is consistent with Baker et al., (1969) who found *O. agardhii* to be easily injured by intense illumination. It should be noted that *O. limnetica* was by far the most common *Oscillatoria* species encountered in our study. However, some evidence, as discussed by Hutchinson (1967), indicates that in Lake Erie, during the autumn pulse, *Oscillatoria* favors low turbidity and therefore high illumination. In Tables 4 and 5 *Oscillatoria* is shown to be associated with relatively high cell concentration, CHLA, and NH3 values.

Differences in mean parameter values between non-dominant and dominant occurrences were slight (Table 5). The most notable differences were the lower NO2NO3 levels and higher KJEL and CHLA levels with dominance. Across the occurrence categories (Table 5), upward trends are noted in SECCHI, TURB, DO, NO2NO3, and N/P, while downward trends were noted for the mean values of CHLA, KJEL, TEMP and ALK.

Raphidiopsis

Raphidiopsis was the 30th most common genus encountered in NES lakes during 1973 (Table 2). It was considered a dominant in 45 (25.4 percent) of the 177 samples in which it occurred. *Raphidiopsis* was most common in summer and fall, particularly as a dominant. Only 2 dominant occurrences were noted in spring samples. Again, as with *Merismopedia*, the environmental requirements of *Raphidiopsis* are rarely mentioned in the literature, even though it is one of the more common phytoplankton genera.

Raphidiopsis was associated with two extreme mean parameter values (Table 4). It had the highest TEMP (25.4°C) and the highest PERC value (38.9 percent) as a dominant. In addition, *Raphidiopsis* was near the low end of the range of dominant values for ORTHOP.

There were important differences in mean values among the conditions associated with the occurrence categories in Table 5. With dominance, the ORTHOP value was among the lowest of the 20 genera compared. By contrast, the non-dominance mean value for ORTHOP was approximately 5-fold higher. The NO2NO3 level for general occurrence (dominance and non-dominance) was about one-half that found in waters in which *Raphidiopsis* was not detected. Little can be inferred, from the inconsistent trends noted across occurrence categories, with respect to those conditions favoring "success" of *Raphidiopsis*. Non-dominance values, with few exceptions, suggested more highly enriched (eutrophic) conditions than were associated with either dominance or with waters in which *Raphidiopsis* was not detected. That the N/P ratio was higher with dominance is of particular interest, as all but one of the other blue-green forms showed lower N/P ratios with dominance than with non-dominance. The other genus, *Oscillatoria*, remained essentially unchanged with respect to N/P ratio.

Scenedesmus

Scenedesmus was the 2nd most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be dominant however, in only 50 (9 percent) of the 553 samples in which it occurred. *Scenedesmus* was quite common in each of the 3 seasons sampled.

Scenedesmus was especially noteworthy among the 20 most dominant genera, with unusually high mean values for several parameters (Table 4). The TOTALP value was 166 µg/l greater than the next highest value. The ORTHOP value for *Scenedesmus* was similarly extreme. *Scenedesmus* as a dominant was also associated with the highest CHLA and KJEL values. In Hutchinson's (1967) review, *Scenedesmus* was considered to be a faculative heterotroph and thought to require higher concentrations of inorganic nutrients when living autotrophically than do strictly phototrophic species. In addition, Palmer (1969) ranked *Scenedesmus* 4th in ability to tolerate organic pollution.

While *Scenedesmus* was obviously associated with highly enriched and productive water, on the average it accounted for only about 20 percent of the total count. In most cases its presence alone could not account for the high CHLA values. *Scenedesmus* was the only non-blue-green algal genus with a dominant N/P ratio less than 10. However, *Scenedesmus* is frequently associated with pre-blue-green algal-bloom communities (Williams, 1975).

Significant differences between non-dominant and dominant occurrences of *Scenedesmus* were seen in the exceptionally higher values for TOTALP and ORTHOP with dominance (Table 5). Differences in phosphorus levels between non-dominance and non-occurrence were far less pronounced. Also important were the larger (by about 800 µg/l and 40 µg/l) values for KJEL and CHLA respectively, with dominance. Once again, non-dominance values more nearly approximated non-occurrence than dominance values.

Stephanodiscus

Stephanodiscus was the 18th most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be a dominant in 73 (26.5 percent) of the 275 samples in which it occurred. *Stephanodiscus* occurred commonly in each of the 3 seasons sampled. Palmer (1969) ranked *Stephanodiscus* 32nd in ability to tolerate organic pollution. Although *S. astraea* was the most commonly identified species among the samples, several small *Stephanodiscus* forms were commonly noted for which species designations remain unconfirmed.

Stephanodiscus can be noted for association with clearly the highest NO2NO3 values (1201 µg/l) of the 20 genera under consideration (Table 4). It was also associated with very turbid water of high ALK and relatively low TEMP.

Stephanodiscus showed higher values for TOTALP, ORTHOP, NH3, KJEL, and especially NO2NO3, with dominance than with non-dominance (Table 5). The NO2NO3 value with dominance (1201 µg/l) was nearly 3 times as high as that in waters in which *Stephanodiscus* was not detected (404 µg/l). The higher N/P ratio, with dominance, is a reflection of the large difference in NO2NO3. A substantially higher mean value (about 10 µg/l higher) for CHLA occurred with dominance. Little difference was noted between non-dominance and non-occurrence values for CHLA. A strong trend in the ALK values noted across the occurrence categories (Table 5) suggests that increased relative success of *Stephanodiscus* is associated with high alkalinity values.

Synedra

Synedra was the 3rd most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be a dominant in 48 (10.4 percent) of the 462 samples in which it occurred. *Synedra* was equally common in each of the 3 sampling seasons. Most of the species of *Synedra* commonly encountered in this study have been reported by Lowe (1974) to prefer eutrophic conditions. *Synedra ulna* and *S. delicatissima* were the species most commonly identified in the samples, although it should be noted that many of the *Synedra* encountered were not taken to species when positive identification could not be made. Palmer (1969) also considered the genus high in its ability to tolerate organic pollution (ranked 9th).

As with some of the other extremely common genera, the mean parameter values tended to mimic the mean values calculated for all the lake data. *Synedra* mean values tended to be centrally located within the various parameter ranges (Table 4). TOTALP and ORTHOP values were slightly towards the low end, while NO2NO3 and NH3 values were slightly shifted towards the high end. The net result of these shifts is a high N/P ratio of 21.

The most significant difference between non-dominant and dominant occurrence mean values was with NO2NO3 which with dominance was more than 300 µg/l higher and nearly double that noted in waters in which *Synedra* was not detected (Table 5). TOTALP was slightly lower with dominance (and less than one-half the non-occurrence value), and the combination resulted in a higher N/P ratio with dominance. CHLA and KJEL data trends (Table 5) suggest that *Synedra* success is associated with lower productivity and phytoplankton standing crops.

Tabellaria

Tabellaria was only the 43rd most common genus encountered in NES lakes during 1973 (Table 2). It was considered to be dominant in 20 (16.4 percent) of the 122 samples in which it occurred. *Tabellaria fenestrata* accounted for 19 of the dominant occurrences and 80 of the total occurrences. It occurred often in each of the 3 seasons but attained dominance largely in spring or summer. Lowe (1974) indicated a spring and fall maxima for *T. fenestrata*. Rawson (1956) included *Tabellaria* in a small group of diatoms that are most usually found in oligotrophic waters of western Canadian lakes.

Tabellaria as a dominant was frequently at or near the extreme mean values for many of the parameters (Table 4). It had the lowest TOTALP, ORTHOP, CHLA, KJEL, PH, and ALK values, while the NO2NO3 value was the second lowest calculated. A pH value of 6.9 is consistent with Lowe's (1974) optimum range of 5.0-7.1 for the species. The association of *Tabellaria* with clear water is evidenced by the highest SECCHI and TURB values recorded among the 20 genera. *Tabellaria* occurred as a dominant in relatively low concentrations (about 1500 cells/ml) and yet, on the average, accounted for about 30 percent of the total count (one of the higher PERC values).

Tabellaria, in dominance, was associated with much lower levels of TOTALP, ORTHOP, NO2NO3, and KJEL, as compared to non-dominance conditions (Table 5). On the other hand, the non-dominance values still remain lower than those noted for non-occurrence. N/P ratio and CHLA values were also lower with dominance. Productivity and phytoplankton standing crop, as estimated by CHLA and KJEL, are far lower for general occurrence (dominance and non-dominance) than for non-occurrence. TEMP was higher with dominance (22.1 vice 20.5°C), which seems high in light of the upper limit of the optimal temperature range established by Findenegg (1943) of 12 to 15°C for *Asterionella* in Austrian lakes. A discussion of the various opinions concerning the controlling influence of temperature on the development of various taxa is presented in Hutchinson (1967). A sharply higher value (by 44 inches) of SECCHI depth over the non-dominant condition suggests a high water-transparency requirement for optimal growth of *Tabellaria*. Even the non-dominance-related SECCHI mean (62 inches) is one of the higher values recorded among the 20 genera evaluated.

DISCUSSION

Environmental conditions associated with the occurrence of various phytoplankton genera are examined in this report to determine the usefulness of genus level data for identifying indicators of water quality. Severe criticisms of limnological investigations conducted at the genus level have been primarily directed towards the variability in environmental requirements of the species comprising many genera. Weber (1971) provided a graphic illustration citing *Cyclotella* as an example of a genus with individual species having requirements at all levels of the trophic scale. He concluded that it is pointless to discuss diatom populations at the genus level. Our data, for the most part, supports this point of view, especially the data defining ranges of environmental conditions associated with specific genus occurrence, whether it be dominant or not. The value of the criticism is not restricted to the diatoms, as we have shown similar results for most of the major groups occurring in freshwater plankton communities. There are, however, a number of genera which are either monospecific, have just a few species, or were only represented in NES lakes by a few species in the South and East. Data associated with these would reflect monospecific requirements and should be useful (even at the genus level) on at least a regional basis.

We have found very few environmental restrictions for the common phytoplankton genera discussed in this report. *Asterionella* showed the clearest seasonal preference, particularly as a dominant, occurring mostly in the spring. Although no genus, unless exceptionally rare, was completely absent during any of the seasons, many preferred summer and fall conditions where temperature and/or light were more suitable for their growth. The range-diagrams in Appendix A illustrate the extremely wide ranges of chemical and physical conditions associated with the occurrences of most genera. Although dominance-related data for some genera were considerably modified, the ranges were still quite wide.

The ranking schemes (Table 3 and 4) used for comparing the differences between central tendencies of the various genera are important to illustrate trends with potential application in lake water quality assessment. Many of the genera followed consistent patterns, ranking them similarly for many of the parameters. Shifts in conditions associated with dominance were often consistent in direction. *Scenedesmus*, one of the most common genera encountered, had mean values calculated from total occurrence data which consistently placed it mid-way down the ranked lists (Table 3). Conditions associated with dominant occurrence of *Scenedesmus* on the other hand are characterized by extremely high mean values for certain key parameters (TOTALP, ORTHOP, KJEL, and CHLA) reflecting highly enriched conditions during times of important *Scenedesmus* growth (Table 4). If these relationships, particularly dominant occurrence trends, reflect conditions of competitive advantage for the genera, then the information may be used to evaluate or even predict water quality.

Of considerable interest is the consistent relationship noted between the occurrence of blue-green algae and low N/P ratios. The attainment of high relative importance (dominance) among the blue-green genera represented was invariably associated with very low N/P ratios. The competitive advantage of nitrogen-limiting (low N/P) conditions to a nitrogen-fixing blue-green algae seems obvious. What is far less clear is the similar affinity of the low N/P waters for the non-nitrogen-fixers. Certainly these waters are, for the most part, highly enriched with phosphorus. The facility of some of the blue-greens for luxury uptake of phosphorus under such enriched conditions may provide a partial clue. It should be noted that low N/P ratios (Table 5) were invariably associated with higher KJEL values and, with a notable exception (*Anabaena*), with average or lower NH3. Therefore organic nitrogen (KJEL-NH3) is high with low N/P ratios. A possible key to the nitrogen nutrition of the blue-greens (particularly the non-nitrogen-fixers) may indeed lie in the organic nitrogen component either through direct assimilation by the blue-greens (see Williams, 1975) or as a source for conversion by the bacteria often intimately associated with blue-green colonies and filaments.

To this point in the report, genera have been discussed on an individual basis. In nature, it is an exceedingly rare event to find just one species or genus forming a community. As such, biological prediction and/or interpretation of water quality should not be based upon the presence of one taxa but should instead consider the community of organisms.

An effort is being undertaken to develop and test several phytoplankton water quality indices using mean parameter values calculated for the dominant occurrences of each genus. Fundamental to the application of each index is the consideration of community structure. Indices have been developed from our data using the following key parameters: TOTALP, KJEL, CHLA, SECCHI, and cell count (CONC). Multivariate and single parameter indices are being tested. The indices of our own development, and some 28 others (both biological and physical), presently in common use, are being tested for their ability to rank lakes according to trophic state.

TOTALP and CHLA were chosen as standards for comparison purposes since total phosphorus is considered to be the most important nutrient associated with eutrophication in freshwaters, and chlorophyll a, the most reliable indicator of eutrophic biological response. The Spearman rank correlation coefficient (rs) was calculated for each index-standard combination. The correlation coefficient is then used to rate the effectiveness of each index in predicting the reference standard ranking.

The preliminary results are encouraging. The phytoplankton indices have correlation coefficients as high as 0.72 against the TOTALP standard and 0.79 against the CHLA standard (0.79 was the best correlation achieved against the CHLA standard). Two well known indices, Nygaard's trophic state (Nygaard, 1949) and Palmer's organic pollution indices (Palmer, 1969) did not fair as well, since the highest correlation for the series of indices against standard was 0.55. A report, soon to be published in this series, will evaluate the study results, and comment further on the application and usefulness of phytoplankton indices of water quality calculated at the genus level.

REFERENCES

Findenegg, I. 1943. Untersuchungen öber die ökologie und die produktionsverhältniss des planktons in kärntner Seengebiete. Int. Revue ges. Hydrobiol. Hydrogr. 43:368-429.

Fogg, G. E., W. D. P. Stewart, P. Fay, and A. E. Walsby. 1973. The Blue-Green Algae. Academic Press, New York, N.Y. 459 pp.

Forest, H. S. 1954. Handbook of algae. The University of Tennessee Press, Knoxville, Tennessee. 467 pp.

Hern, S. C., V. W. Lambou, F. A. Morris, M. K. Morris, W. D. Taylor, and L. R. Williams. 1978a. Phytoplankton water quality relationships in U. S. lakes. Part III: Genera *Dactylococcopsis* through *Gyrosigma*. U. S. Environmental Protection Agency. National Eutrophication Survey Working Paper No. 707. vii + 85 pp.

Hern, S. C., W. D. Taylor, L. R. Williams, V. W. Lambou, M. K. Morris, F. A. Morris, and J. W. Hilgert. 1978b. Distribution and importance of phytoplankton in the Atchfalaya Basin. EPA-600/3-78-001. U. S. Environmental Protection Agency, Las Vegas, Nevada. 194 pp.

Hutchinson, G. E. 1967. A treatise on limnology. II. Introduction to lake biology and the limnoplankton. John Wiley and Sons, Inc., New York. 1,115 pp.

Lambou, V. W., F. A. Morris, M. K. Morris, W. D. Taylor, L. R. Williams, and S. C. Hern. 1978. Phytoplankton water quality relationships in U. S. lakes. Part IV: Genera *Hantzschia* through *Pteromonas*. U. S. Environmental Protection Agency. National Eutrophication Survey Working Paper No. 708. vii + 105 pp.

Lowe, R. L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. EPA-670/4-74-005. U. S. Environmental Protection Agency, Cincinnati, Ohio. 334 pp.

Morris, M. K., W. D. Taylor, L. R. Williams, S. C. Hern, V. W. Lambou, and F. A. Morris. 1978. Phytoplankton water quality relationships in U. S. lakes. Part V: Genera *Quadrigula* through *Zygnema*. U. S. Environmental Protection Agency. National Eutrophication Survey Working Paper No. 709. vii + 105 pp.

Naumann, E. 1919. Nagra synpunkter angaende planktons okolgi. Med sarskild Hansyn till fytoplankton. Svensk. bot. Tidskr. 13:129-158.

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

Pearsall, W. H. 1932. Phytoplankton in the English Lakes. II. The composition of the Phytoplankton in relation to dissolved substances. J. Ecol. 20:241-262.

Prescott, G. W. 1962. Algae of the Western Great Lakes Area. 2nd Ed. Wm. C. Brown Company, Dubuque, Iowa. 977 pp.

Prescott, G. W., H. T. Croasdale, and W. C. Vinyard. 1977. A synopsis of North American Desmids. Part II. Desmidiaceae: Placodermae. Section 2. University of Nebraska Press, Lincoln, Nebraska. 411 pp.

Rawson, D. S. 1956. Algal indicators of trophic lake types. Limnol. Oceanogr. 1:18-25.

Reimer, C. W. 1965. Diatoms and their physico-chemical environment. In: Biological Problems in Water Pollution (3rd seminar, 1962), C. M. Tarzwell (ed.). U. S. Public Health Service publication No. 999-WP-25. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. pp. 19-28.

Rodhe, W. 1948. Environmental requirements of freshwater plankton algae. Symb. Bot. Upsal. 10(1):1-149.

Smith, G. M. 1950. The fresh-water algae of the United States. (2nd ed.). McGraw-Hill Book Company, New York. 719 pp.

Soeder, C. J., and E. Stengel. 1974. Physico-chemical factors affecting metabolism and growth rate. In: Algal Physiology and Biochemistry. W. D. P. Stewart (ed.). Botanical Monographs, Volume 10. University of California Press. Berkeley, California. pp. 714-740.

Stewart, W. D. P. 1971. Physiological studies on nitrogen-fixing blue-algae. Plant and Soil, Special Volume (1971) pp. 377-391.

Taylor, W. D., L. R. Williams, S. C. Hern, V. W. Lambou, F. A. Morris, and M. K. Morris. 1978. Phytoplankton water quality relationships in U. S. lakes. Part I: Methods, rationale, and data limitations. U. S. Environmental Protection Agency. National Eutrophication Survey Working Paper No. 705. vii + 68 pp.

Taylor, W. D. (in press). Freshwater algae of the Rae Lakes Basin, Kings Canyon National Park. U. S. Environmental Protection Agency, Las Vegas, Nevada.

Tiffany, L. H. and M. E. Britton. 1952. The algae of Illinois. Hafner Publishing Company, New York. 407 pp.

Weber, C. I. 1966. A guide to the common diatoms at Water Pollution Surveillance Systems Stations. U. S. Environmental Protection Agency, Cincinnati, Ohio. 98 pp.

Weber, C. I. 1971 (unpublished). The relationship between water quality and diatom distribution. Presented at the Symposium "Plankton Organisms as Indicators of their Environment", Sponsored by the American Microscopic Society and held at the 22nd annual Meeting of the American Institute of Biological Sciences, Colorado State University, Fort Collins, August 30 - September 3. 32 pp.

Williams, L. R. 1975. Heteroinhibition as a factor in *Anabaena flos-aquae* waterbloom production. In: Proceedings; Biostimulation - nutrient assessment workshop. EPA-660/3-75-034. U. S. Environmental Protection Agency, Corvallis, Oregon. pp. 275-317.

Williams, L. R., S. C. Hern. V. W. Lambou, F. A. Morris, M. K. Morris, and W. D. Taylor. 1978. Phytoplankton water quality relationships in U. S. lakes. Part II: Genera *Acanthosphaera* through *Cystodinium*. U. S. Environmental Protection Agency. National Eutrophication Survey Working Paper No. 706. vii + 119 pp.

BIBLIOGRAPHY

List of reports containing all phytoplankton data collected in 1973 which was used in the series "Phytoplankton Water Quality Relationships in U.S. Lakes." Corresponding U.S. EPA NES Working Paper (WP) numbers in parentheses.

Hern, S. C., J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, L. R. Williams, W. D. Taylor, and F. A. Hiatt. 1977. Distribution of Phytoplankton in South Carolina Lakes. EPA-600/3-77-102, Ecological Research Series. v + 64 pp. (WP No. 690)

Hern, S. C., J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, L. R. Williams, W. D. Taylor, and F. A. Hiatt. 1978. Distribution of Phytoplankton in Delaware Lakes. EPA-600/3-78-027, Ecological Research Series. v + 33 pp. (WP No. 678)

Hiatt, F. A., S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, L. R. Williams, and W. D. Taylor. 1977. Distribution of Algae in Pennsylvania. U.S. EPA National Eutrophication Survey Working Paper No. 689. iv + 74 pp.

Hiatt, F. A., S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, L. R. Williams, and W. D. Taylor. 1978. Distribution of Phytoplankton in Tennessee Lakes. EPA-600/78-016, Ecological Research Series. v + 40 pp. (WP No. 692)

Hilgert, J. W., V. W. Lambou, F. A. Morris, R. W. Thomas, M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, and S. C. Hern. 1977. Distribution of Phytoplankton in Virginia Lakes. EPA-600/3-77-100, Ecological Research Series. v + 40 pp. (WP No. 692)

Hilgert, J. W., V. W. Lambou, F. A. Morris, M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, and S. C. Hern. 1978. Distribution of phytoplankton in Ohio Lakes. EPA-600/3-78-015, Ecological Research Series. v + 94 pp. (WP No. 688)

Lambou, V. W., F. A. Morris, R. W. Thomas, M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, and J. W. Hilgert. 1977. Distribution of Phytoplankton in Maryland Lakes. EPA-600/3-77-124, Ecological Research Series. v + 24 pp. (WP No. 684)

Lambou, V. W., F. A. Morris, M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, and J. W. Hilgert. 1977. Distribution of Phytoplankton in West Virginia Lakes. EPA-600/3-77-103, Ecological Research Series. v + 21 pp. (WP No. 693)

Morris, F. A., M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, J. W. Hilgert, and V. W. Lambou. 1978. Distribution of Phytoplankton in Indiana Lakes. EPA-600/3-78-078, Ecological Research Series. v + 70 pp. (WP No. 682)

Morris, F. A., M. K. Morris, L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, J. W. Hilgert, and V. W. Lambou. 1978. Distribution of Phytoplankton in Georgia Lakes. EPA-600/3-78-011, Ecological Research Series. v + 63 pp. (WP No. 680)

Morris, M. K., L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, and F. A. Morris. 1978. Distribution of Phytoplankton in Illinois Lakes. EPA-600/3-78-050, Ecological Research Series. v + 128 pp. (WP No. 681)

Morris, M. K., L. R. Williams, W. D. Taylor, F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, and F. A. Morris. 1978. Distribution of Phytoplankton in North Carolina Lakes. EPA-600/3-78-051, Ecological Research Series. v + 73 pp. (WP No. 687)

Taylor, W. D., F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, R. W. Thomas, M. K. Morris, and L. R. Williams. 1977. Distribution of Phytoplankton in Alabama Lakes. EPA-600/3-77-082, Ecological Research Series. v + 51 pp. (WP No. 677)

Taylor, W. D., F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, and L. R. Williams. 1978. Distribution of Phytoplankton in Florida Lakes. EPA-600/3-78-085, Ecological Research Series. v + 112 pp. (WP No. 679)

Taylor, W. D., F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, M. K. Morris, and L. R. Williams. 1978. Distribution of Phytoplankton in Kentucky Lakes. EPA-600/3-78-013, Ecological Research Series. v + 28 pp. (WP No. 683)

Williams, L. R., W. D. Taylor, F. A. Hiatt, S. C. Hern, J. W. Hilgert, V. W. Lambou, F. A. Morris, R. W. Thomas, and M. K. Morris. 1977. Distribution of Phytoplankton in Mississippi Lakes. EPA-600/3-77-101, Ecological Research Series. v + 29 pp. (WP No. 685)

Williams, L. R., F. A. Morris, J. W. Hilgert, V. W. Lambou, F. A. Hiatt, W. D. Taylor, M. K. Morris, and S. C. Hern. 1978. Distribution of Phytoplankton in New Jersey Lakes. EPA-600/3-78-014, Ecological Research Series. v + 59 pp. (WP No. 686)

APPENDIX A

A-1. Occurrence of 57 phytoplankton genera as related to total phosphorus levels.

A-2. Occurrence of 57 phytoplankton genera as related to total Kjeldahl nitrogen levels.

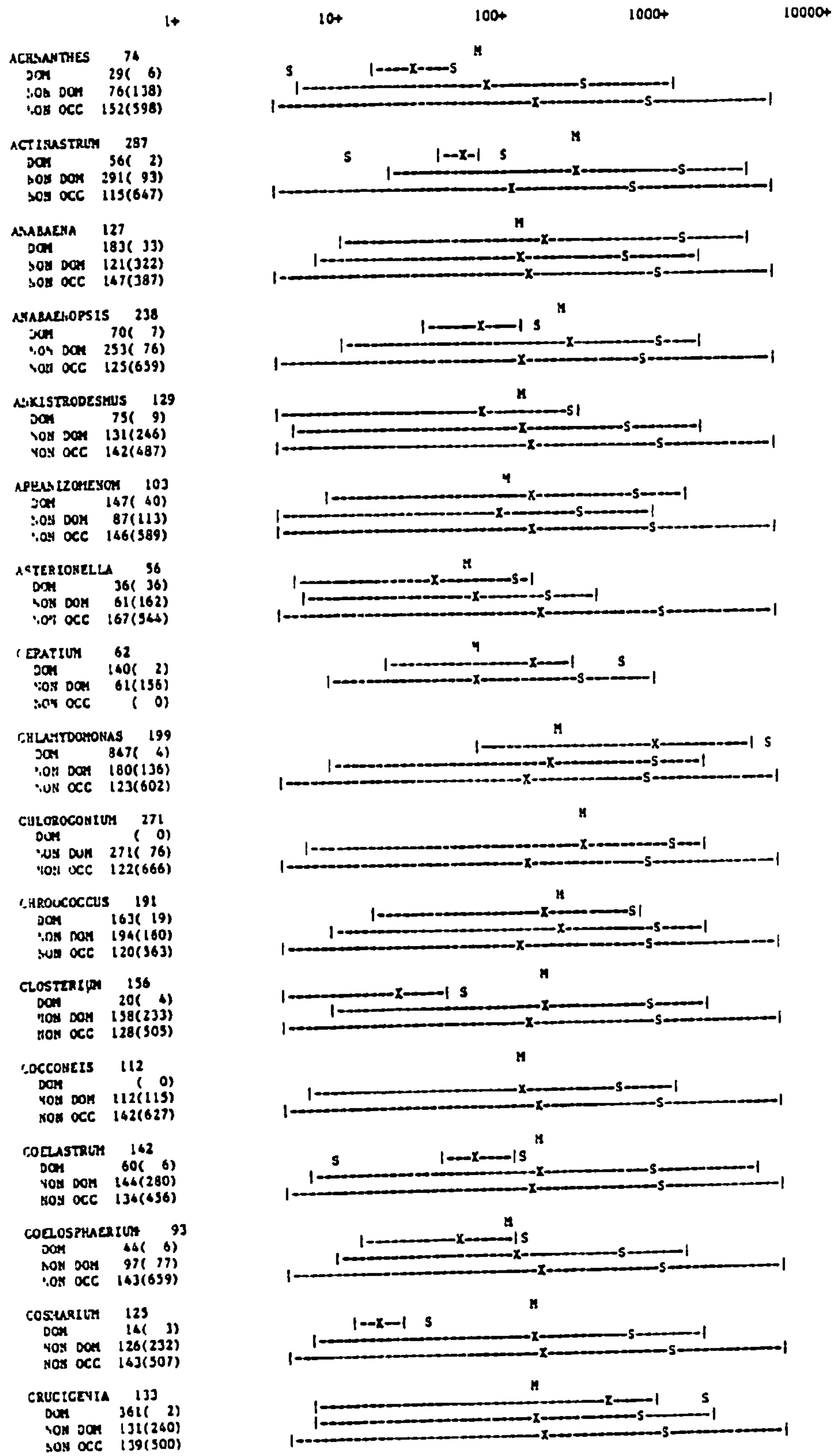
A-3. Occurrence of 57 phytoplankton genera as related to chlorophyll a levels.

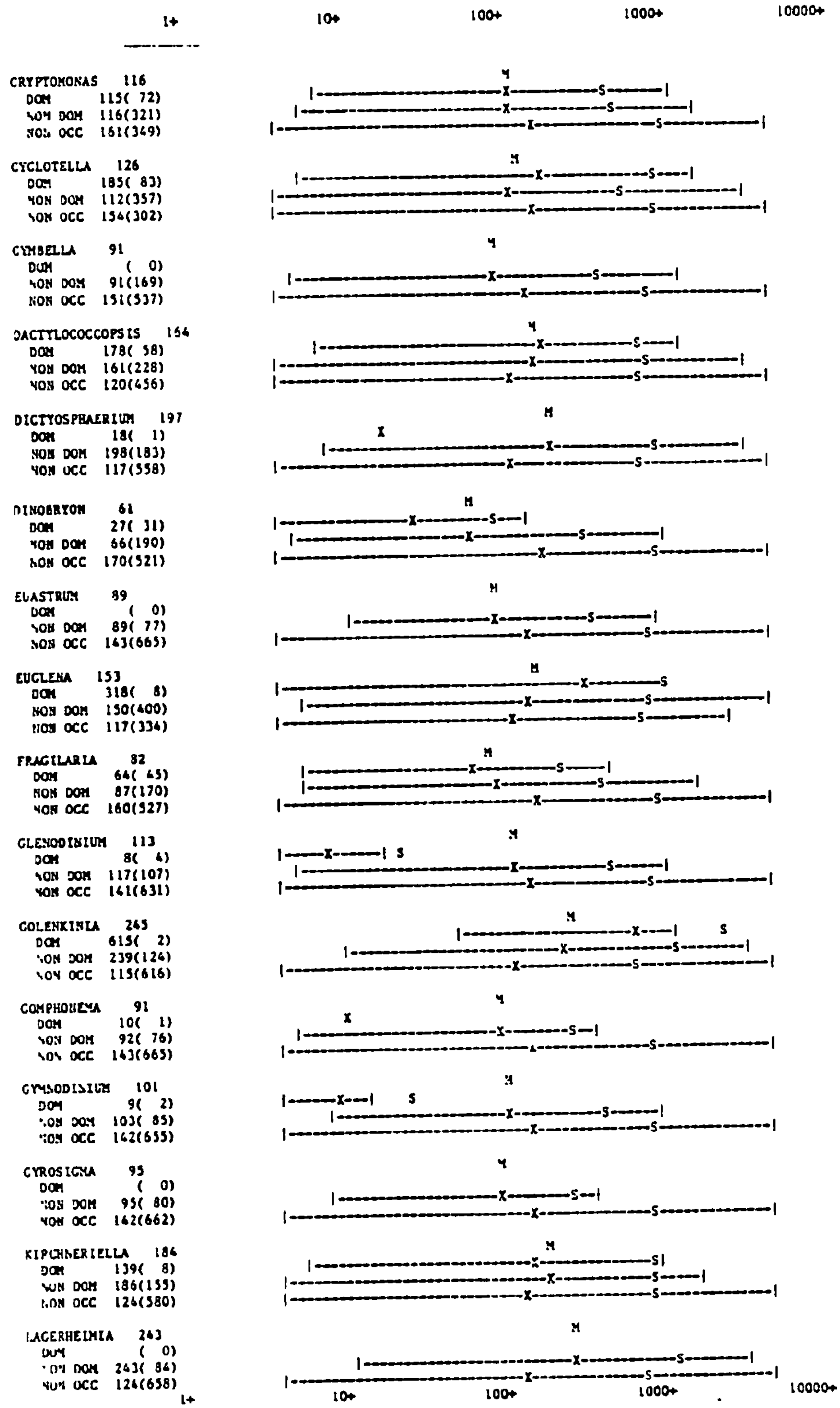
A-4. Occurrence of 57 phytoplankton genera as related to N/P ratio values.

This appendix was generated by computer. Because it was only possible to use upper case letters in the printout, all scientific names are printed in upper case and are not italicized.

Using total phosphorus (Appendix A-1) as an example, the various terms, symbols and layout are defined as follows. The range, mean, and twice the STDV are plotted against a logarithmic scale for dominance (DOM), non-dominance (NONDOM) and non-occurrence (NONOCC) categories. The symbol (+) following scale-numerals locates the proper position of each value. The range limits are delineated in most cases with a vertical bar. An "X" indicates the mean value for the respective occurrence categories, while "M" is the mean value for all occurrences of the genus. "S" gives the positions of 2 standard deviations on either side of the mean. Values of S below zero were omitted. Occasionally S fell on the position of the vertical bar designating the range limit in which case S replaced the bar. Immediately following the genus name is the mean occurrence parameter value (M) in μg/l. For the remaining categories, DOM, NONDOM, and NONOCC, the mean parameter value (X) in μg/l is given, followed in parentheses by the number of occurrence values or, in the case of NONOCC, the number of non-occurrence values in the category.

A-1. Occurrence of 57 phytoplankton genera as related to total phosphorus levels.





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NON OCC 161(349)
CYCLOTELLA 126
DOM 185(83)
NON DOM 112(357)
NON OCC 154(302)
CYMBELLA 91
DOM (0)
NON DOM 91(169)
NON OCC 151(537)
DACTYLOCOCCOPSIS 154
DOM 178(58)
NON DOM 161(228)
NON OCC 120(456)
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DOM 18(1)
NON DOM 198(183)
NON OCC 117(558)
DINOBRYON 61
DOM 27(31)
NON DOM 66(190)
NON OCC 170(521)
EUASTRUM 89
DOM (0)
NON DOM 89(77)
NON OCC 143(665)
EUGLENA 153
DOM 318(8)
NON DOM 150(400)
NON OCC 117(334)
FRAGILARIA 82
DOM 64(45)
NON DOM 87(170)
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DOM 8(4)
NON DOM 117(107)
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DOM 615(2)
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DOM 10(1)
NON DOM 92(76)
NON OCC 143(665)
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DOM 9(2)
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NON OCC 142(655)
GYROSIGMA 95
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NON OCC 142(662)
KIRCHNERIELLA 184
DOM 139(8)
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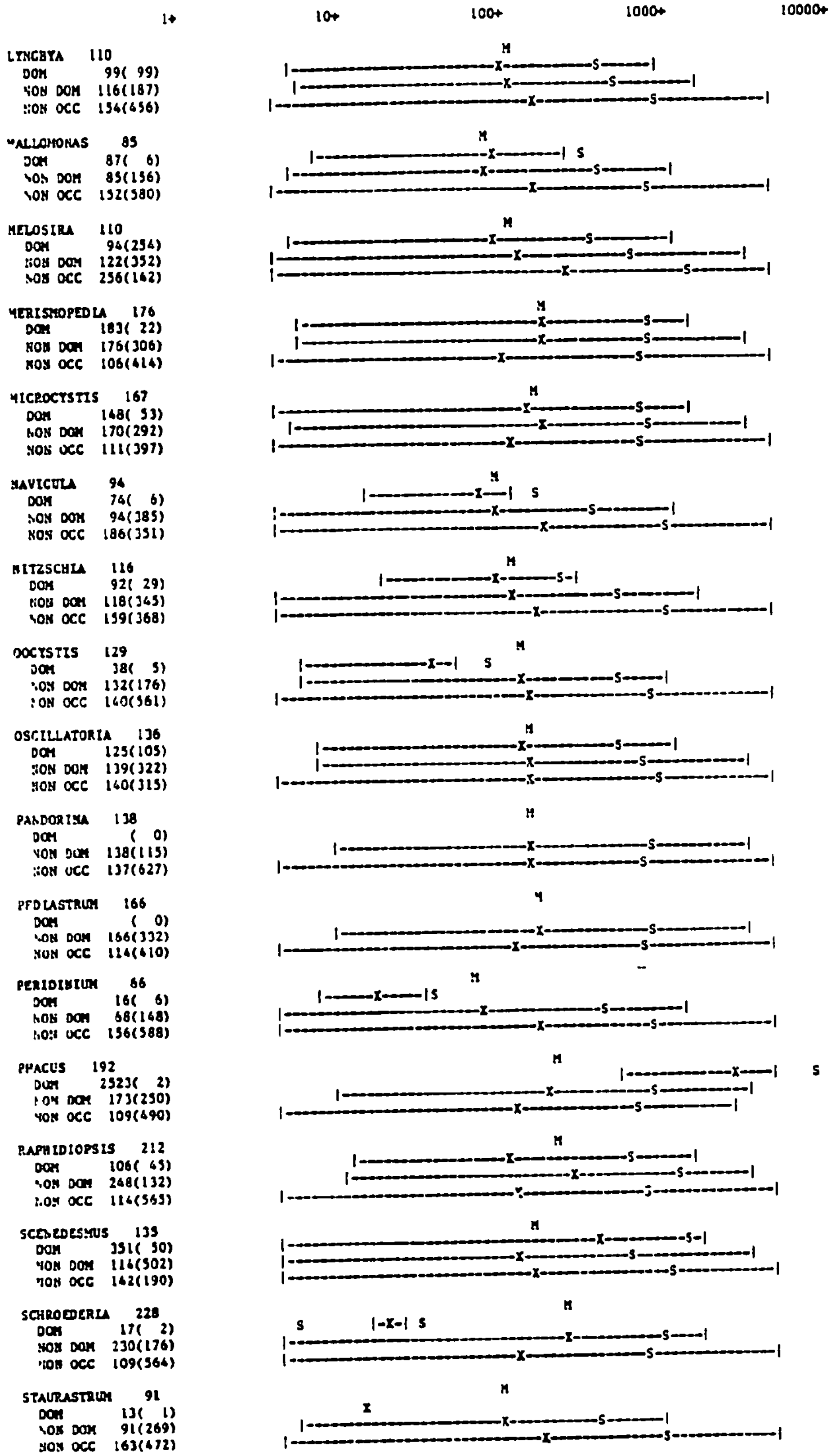

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NON OCC 114(410)
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DOM 16(6)
NON DOM 68(148)
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PHACUS 192
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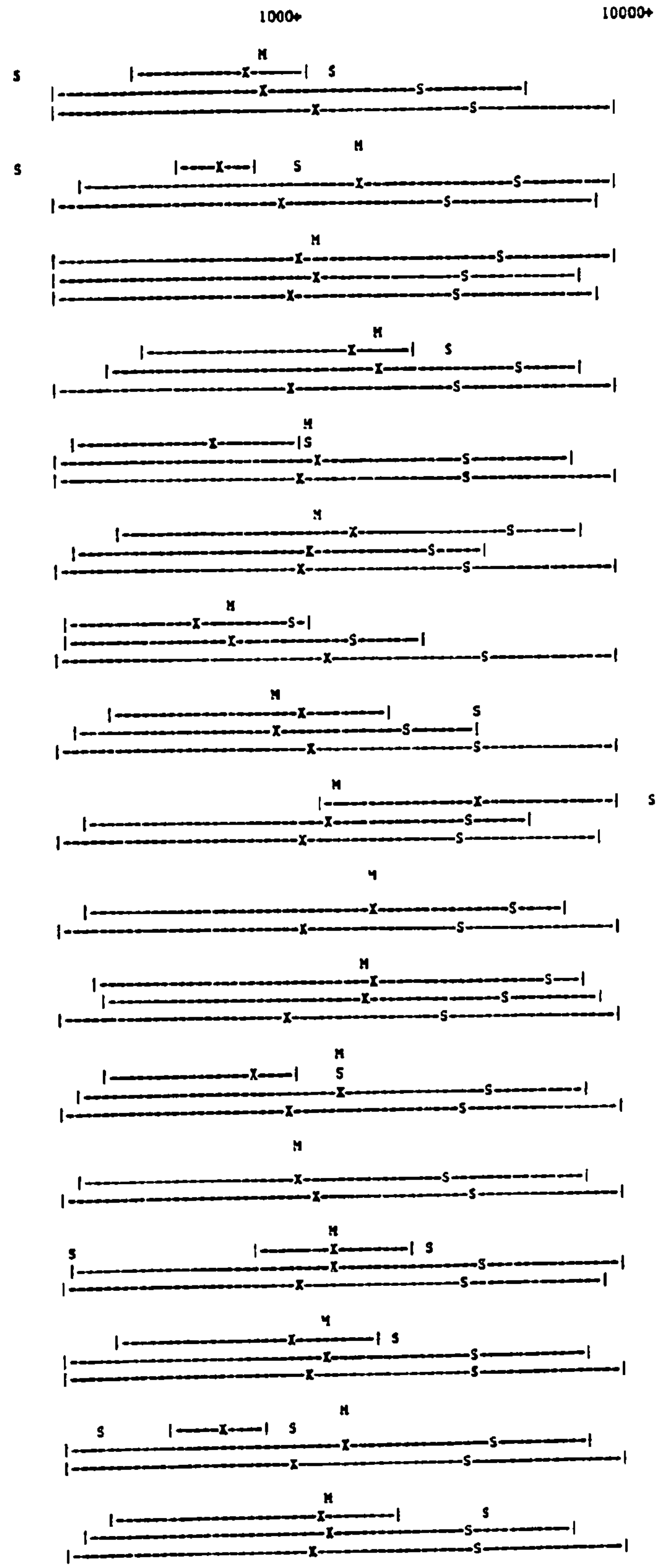
NON DOM 173(250)
NON OCC 109(490)
RAPHIDIOPSIS 212
DOM 106(45)
NON DOM 248(132)
NON OCC 114(565)
SCENEDESMUS 135
DOM 351(50)
NON DOM 114(502)
NON OCC 142(190)
SCHROEDERIA 228
DOM 17(2)
NON DOM 230(176)
NON OCC 109(564)
STAURASTRUM 91
DOM 13(1)
NON DOM 91(269)
NON OCC 163(472)

```
                           1+         10+         100+        1000+       10000+

STEPHANODISCUS   112                              M
  DOM         116( 73)          |-----------------X----------S---|
  NON DOM     111(202)          |-----------------X----------S-------|
  NON OCC     126(275)          |-----------------X----------S-------|

SURIRELLA     135                                   M
  DOM           0(  0)
  NON DOM     135( 98)      |-----------------------X-----------S---------|
  NON OCC     137(644)      |-----------------------X-----------S-----------|

SYNEDRA       98                                  M
  DOM          82( 48)         |------------------X-----------S-------|
  NON DOM     100(413)      |---------------------X-------------S-------------|
  NON OCC     202(281)      |--------------------------X----------S---------|

TABELLARIA    42                            M
  DOM          22( 20)        |----------X---------S---|
  NON DOM      46(102)        |--------------X-------------S----------|
  NON OCC     156(620)      |--------------------------X----------S-----------|

TETRAEDRON    165                                    M
  DOM          18(  5)        S     |---X--|S
  NON DOM     167(318)          |------------------------X-----------S----------|
  NON OCC     116(419)      |---------------------X-------------S-------------|

TRACHELOMONAS  118                                M
  DOM          97(  4)                S    |----X--|S
  NON DOM     118(224)          |-------------------X-----------S-------|
  NON OCC     146(514)      |------------------------X-------------S----------|

TREUBARIA     146                                   M
  DOM            (  0)
  NON DOM     146( 94)             |------------------X----------S------|
  NON OCC     136(648)      |-----------------------X-------------S-----------|
                           1+         10+         100+        1000+       10000+
```

A-2. Occurrence of 57 phytoplankton genera as related to total Kjeldahl nitrogen levels.



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NON OCC	927(647)
ANABAENA	1138
DOM	1015(33)
NON DOM	1151(322)
NON OCC	956(387)
ANABAENOPSIS	1697
DOM	1393(7)
NON DOM	1725(76)
NON OCC	960(659)
ANKISTRODESMUS	1087
DOM	573(9)
NON DOM	1106(246)
NON OCC	1020(487)
APHANIZOMENON	1175
DOM	1437(40)
NON DOM	1082(113)
NON OCC	1009(589)
ASTERIONELLA	627
DOM	491(36)
NON DOM	657(162)
NON OCC	1197(544)
CERATIUM	851
DOM	1046(2)
NON DOM	848(156)
NON OCC	1095(584)
CHLAMYDOMONAS	1232
DOM	3143(4)
NON DOM	1176(136)
NON OCC	999(602)
CHLOROGONIUM	1592
DOM	(0)
NON DOM	1592(76)
NON OCC	980(666)
CHROOCOCCUS	1529
DOM	1630(19)
NON DOM	1517(160)
NON OCC	888(563)
CLOSTERIUM	1279
DOM	698(4)
NON DOM	1289(233)
NON OCC	932(505)
COCCONEIS	958
DOM	(0)
NON DOM	958(115)
NON OCC	1059(627)
COELASTRUM	1207
DOM	1208(6)
NON DOM	1207(280)
NON OCC	960(456)
COELOSPHAERIUM	1146
DOM	888(6)
NON DOM	1166(77)
NON OCC	1030(659)
COSMARIUM	1285
DOM	586(3)
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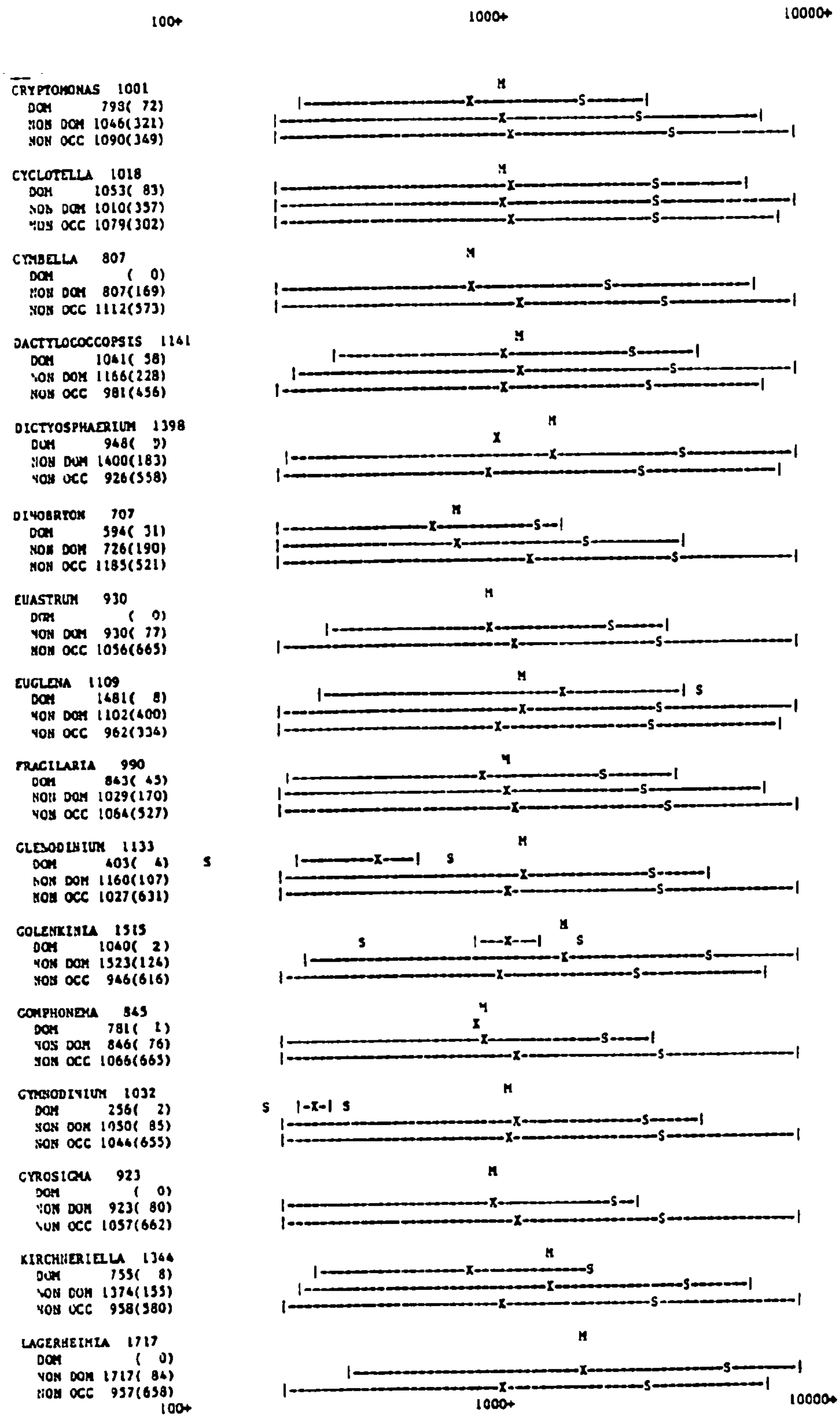
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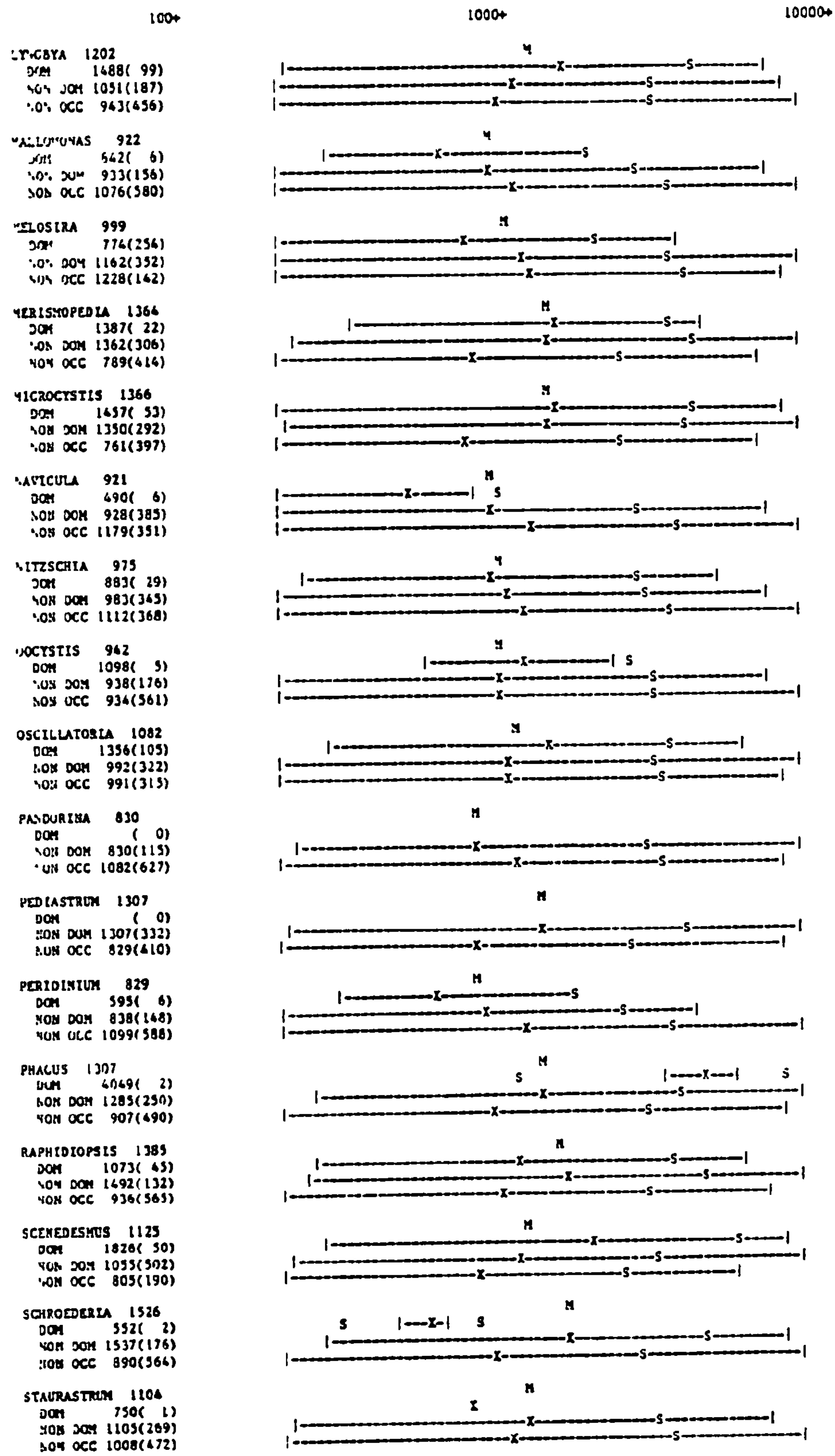
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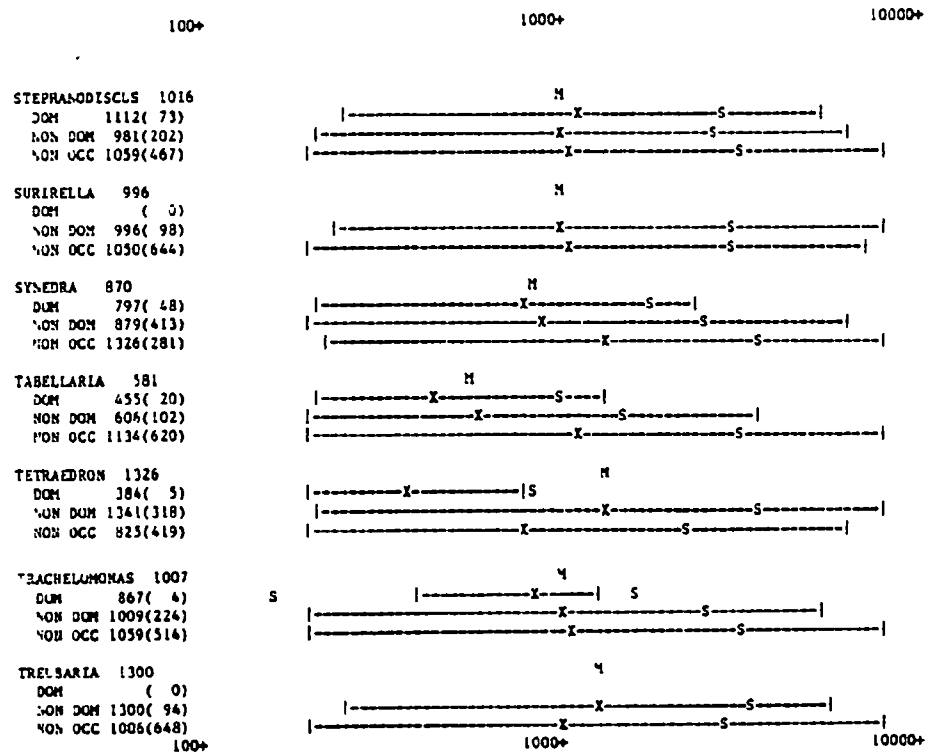
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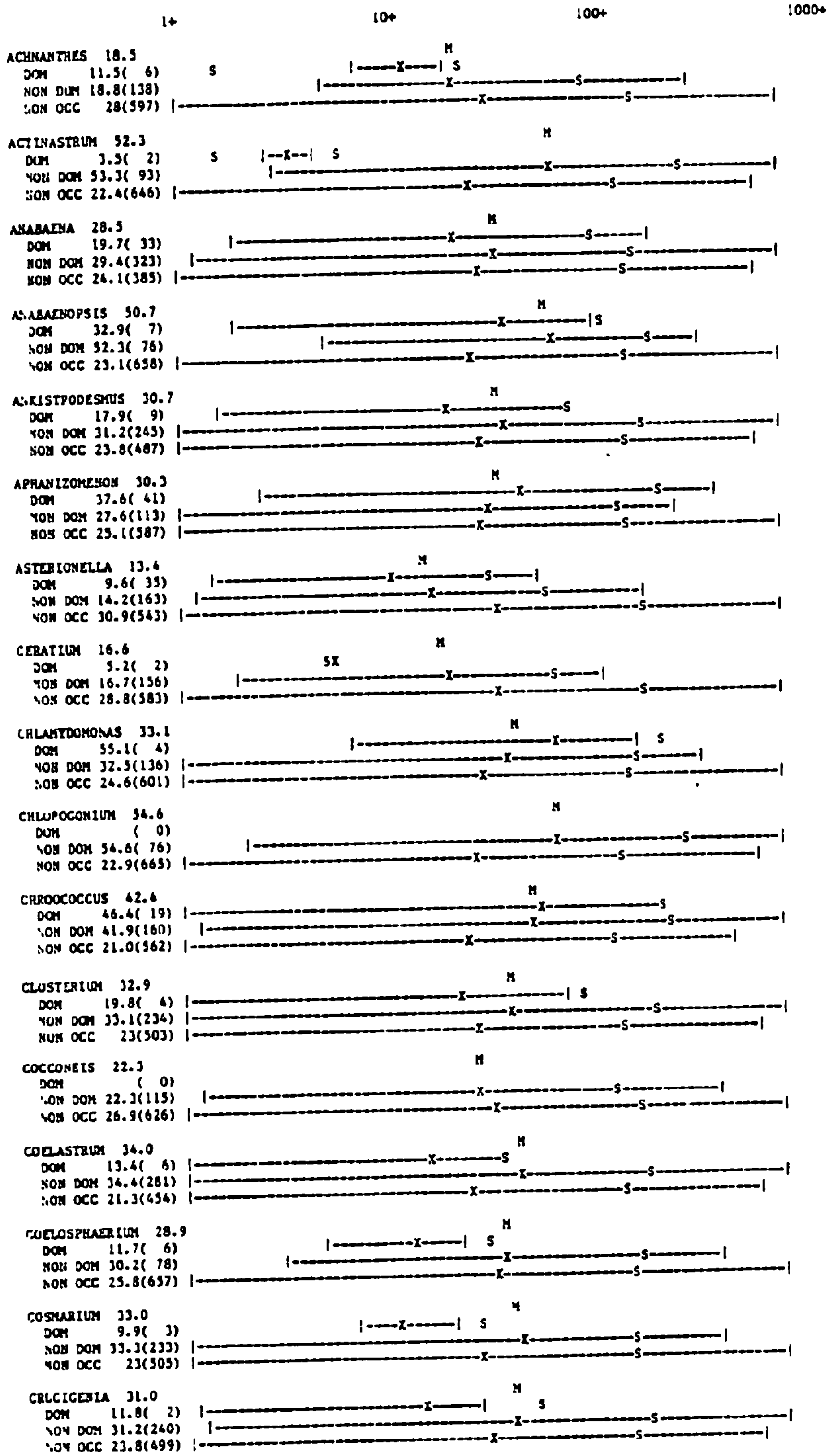
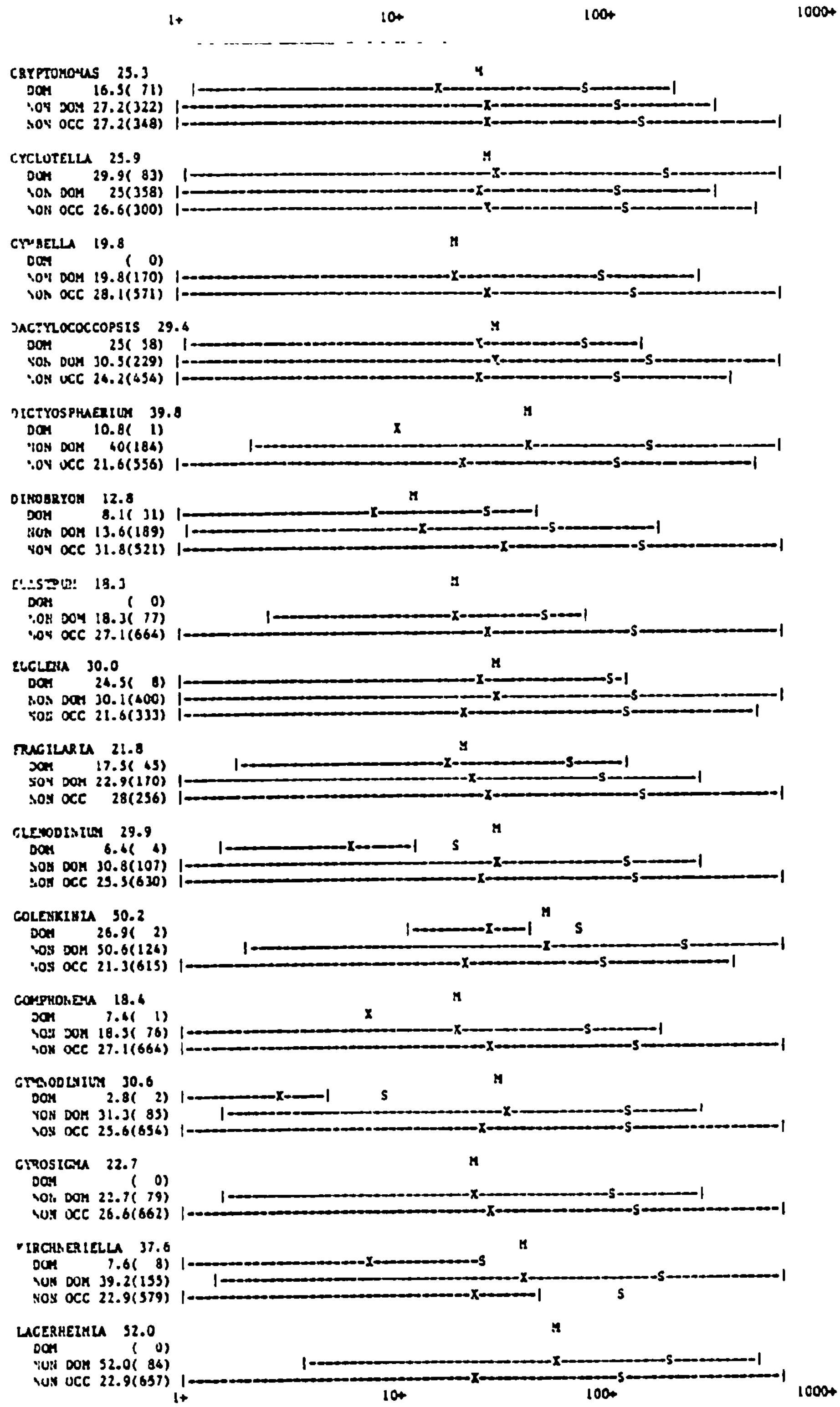
1000+
10000+

A-3. Occurrence of 57 phytoplankton genera as related to chlorophyll a levels.

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NON OCC 26.6(300)
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NON OCC 28.1(571)
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NON OCC 24.2(454)
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NON OCC 21.6(556)
DINOBRYON 12.8
DOM 8.1(31)
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EUASTRUM 18.3
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EUGLENA 30.0
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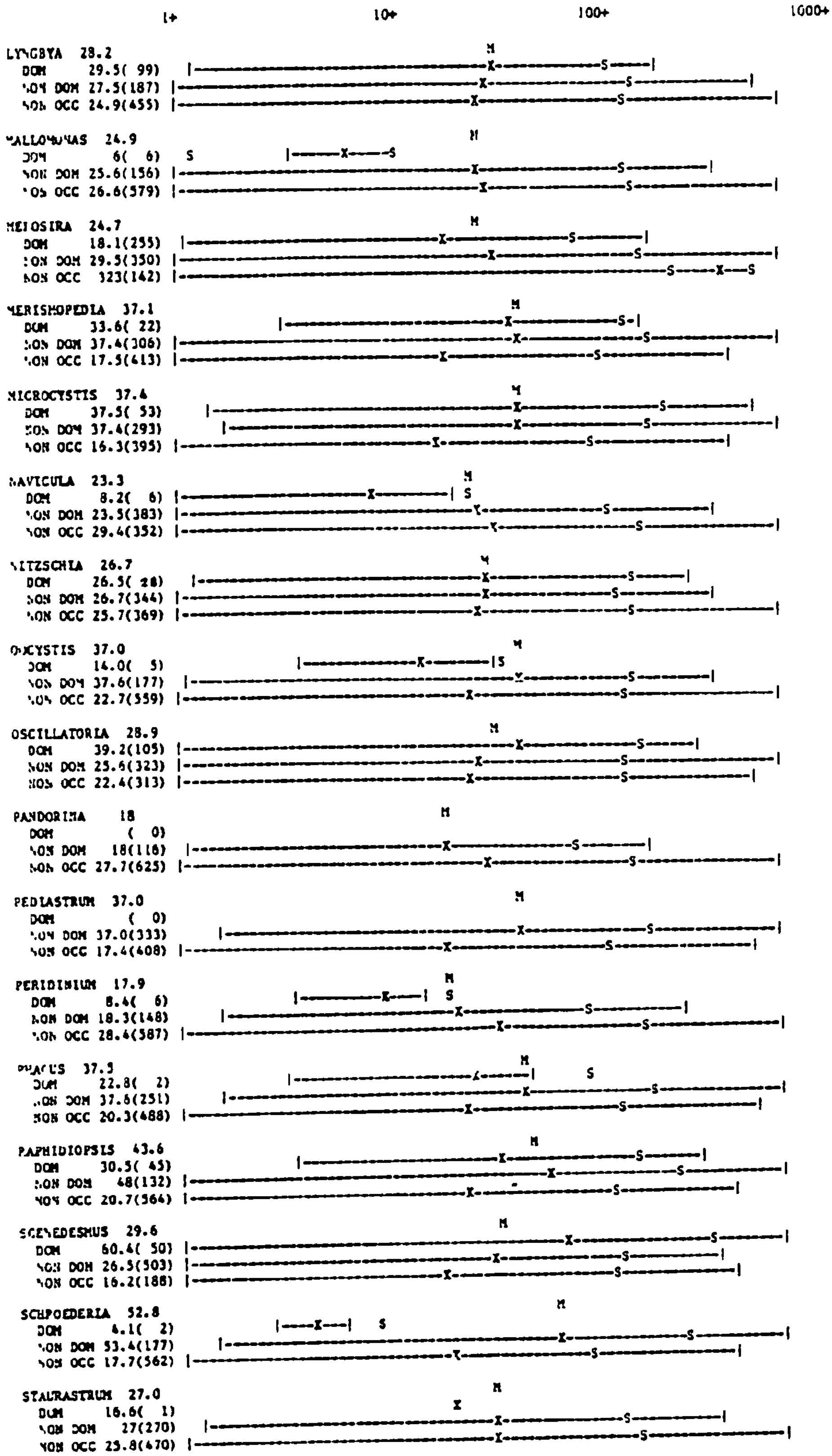
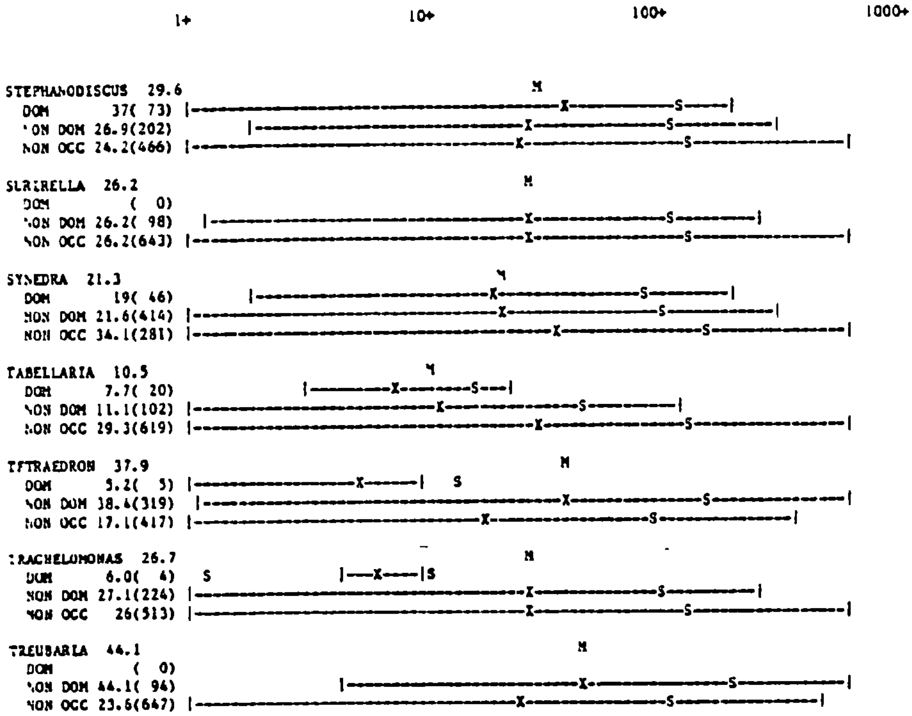
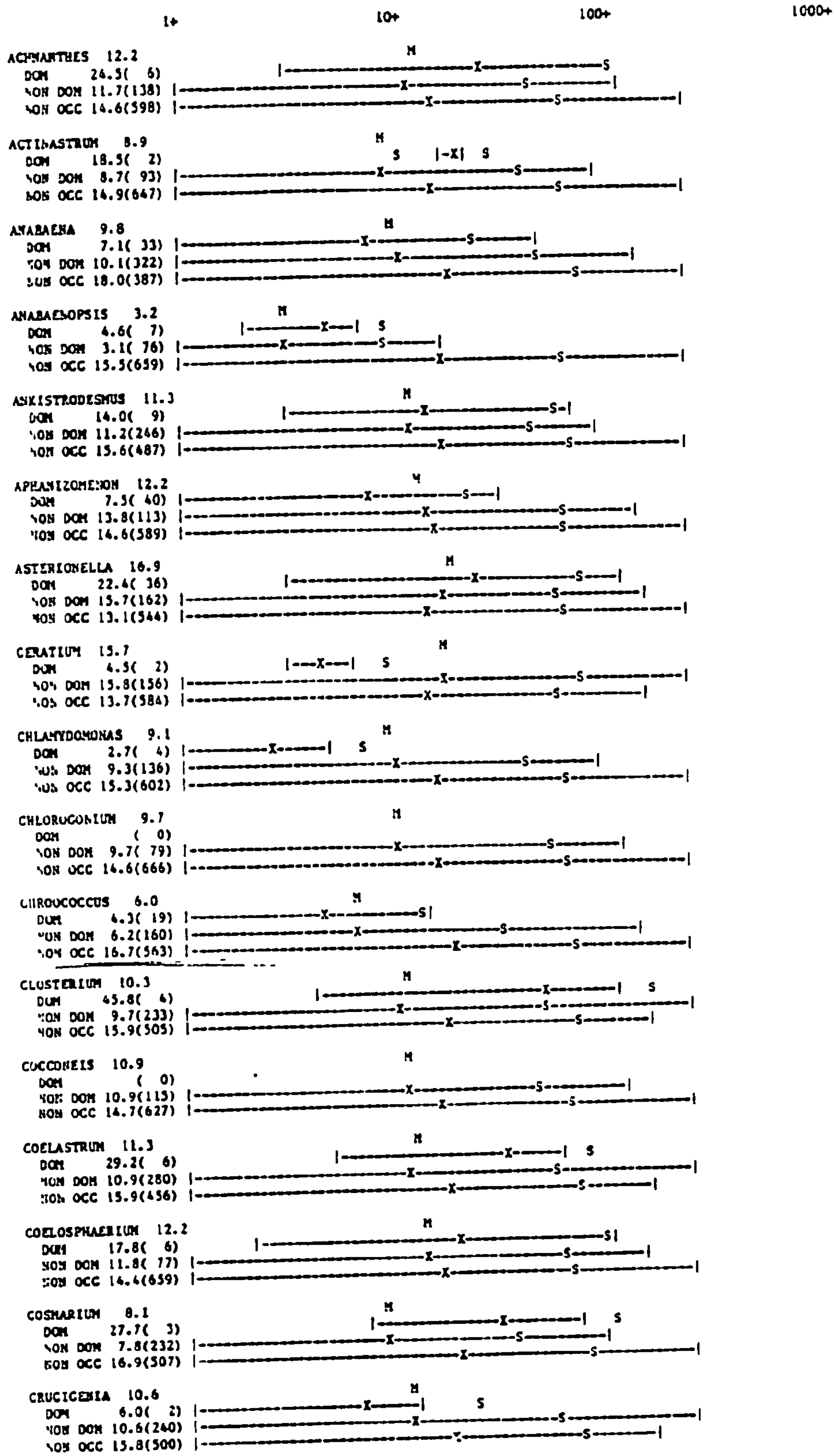
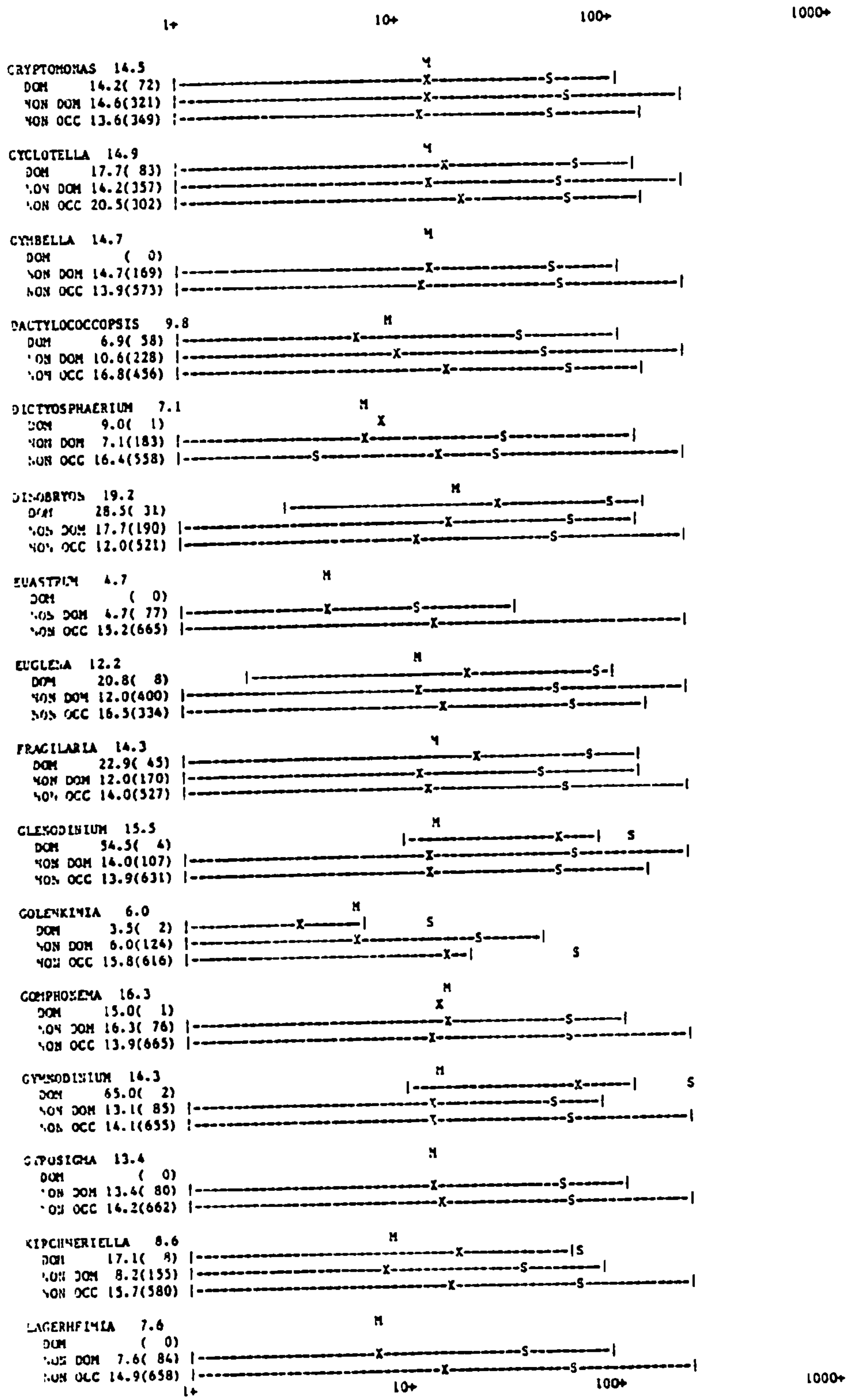
GOLENKINIA 50.2
DOM 26.9(2)
NON DOM 50.6(124)
NON OCC 21.3(615)
GOMPHONEMA 18.4
DOM 7.4(1)
NON DOM 18.5(76)
NON OCC 27.1(664)
GYMNODINIUM 30.6
DOM 2.8(2)
NON DOM 31.3(85)
NON OCC 25.6(654)
GYROSIGMA 22.7
DOM (0)
NON DOM 22.7(79)
NON OCC 26.6(662)
KIRCHNERIELLA 37.6
DOM 7.6(8)
NON DOM 39.2(155)
NON OCC 22.9(579)
LACERHEIMIA 52.0
DOM (0)
NON DOM 52.0(84)
NON OCC 22.9(657)
1+ 10+ 100+ 1000+

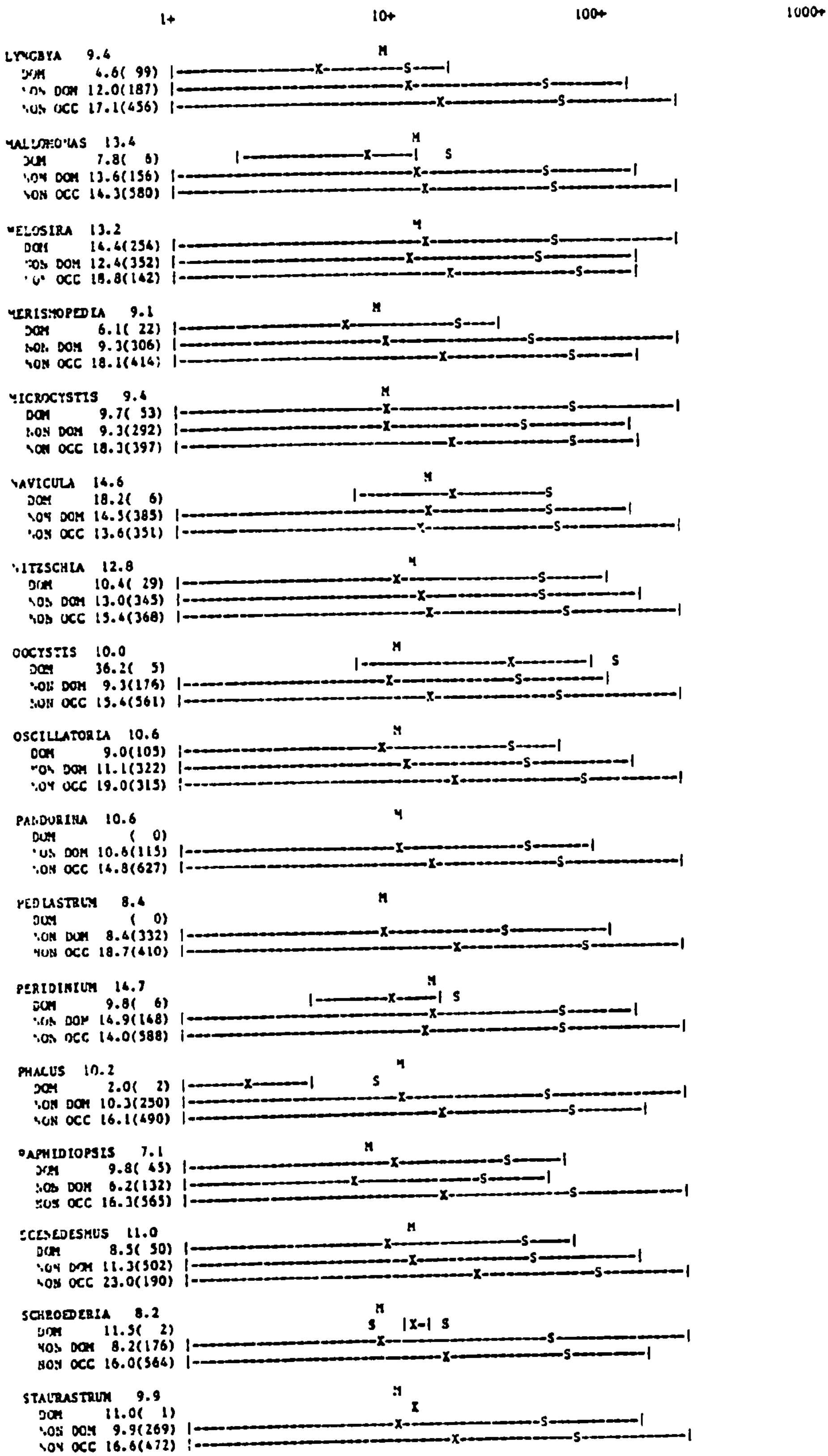

1+
10+
100+
1000+
LYNGBYA 28.2
DOM 29.5(99)
NON DOM 27.5(187)
NON OCC 24.9(455)
MALLOMONAS 24.9
DOM 6(6)
NON DOM 25.6(156)
NON OCC 26.6(579)
MELOSIRA 24.7
DOM 18.1(255)
NON DOM 29.5(350)
NON OCC 323(142)
MERISMOPEDIA 37.1
DOM 33.6(22)
NON DOM 37.4(306)
NON OCC 17.5(413)
MICROCYSTIS 37.4
DOM 37.5(53)
NON DOM 37.4(293)
NON OCC 16.3(395)
NAVICULA 23.3
DOM 8.2(6)
NON DOM 23.5(383)
NON OCC 29.4(352)
NITZSCHIA 26.7
DOM 26.5(28)
NON DOM 26.7(344)
NON OCC 25.7(369)
OOCYSTIS 37.0
DOM 14.0(5)
NON DOM 37.6(177)
NON OCC 22.7(559)
OSCILLATORIA 28.9
DOM 39.2(105)
NON DOM 25.6(323)
NON OCC 22.4(313)
PANDORINA 18
DOM (0)
NON DOM 18(116)
NON OCC 27.7(625)
PEDIASTRUM 37.0
DOM (0)
NON DOM 37.0(333)
NON OCC 17.4(408)
PERIDINIUM 17.9
DOM 8.4(6)
NON DOM 18.3(148)
NON OCC 28.4(587)
PHACUS 37.5
DOM 22.8(2)
NON DOM 37.6(251)
NON OCC 20.3(488)
RAPHIDIOPSIS 43.6
DOM 30.5(45)
NON DOM 48(132)
NON OCC 20.7(564)
SCENEDESMUS 29.6
DOM 60.4(50)
NON DOM 26.5(503)
NON OCC 16.2(188)
SCHROEDERIA 52.8
DOM 4.1(2)
NON DOM 53.4(177)
NON OCC 17.7(562)
STAURASTRUM 27.0
DOM 16.6(1)
NON DOM 27(270)
NON OCC 25.8(470)


1+
10+
100+
1000+
STEPHANODISCUS 29.6
DOM 37(73)
NON DOM 26.9(202)
NON OCC 24.2(466)
SURIRELLA 26.2
DOM (0)
NON DOM 26.2(98)
NON OCC 26.2(643)
SYNEDRA 21.3
DOM 19(46)
NON DOM 21.6(414)
NON OCC 34.1(281)
TABELLARIA 10.5
DOM 7.7(20)
NON DOM 11.1(102)
NON OCC 29.3(619)
TETRAEDRON 37.9
DOM 5.2(5)
NON DOM 38.4(319)
NON OCC 17.1(417)
TRACHELOMONAS 26.7
DOM 6.0(4)
NON DOM 27.1(224)
NON OCC 26(513)
TREUBARIA 44.1
DOM (0)
NON DOM 44.1(94)
NON OCC 23.6(647)

A-4. Occurrence of 57 phytoplankton genera as related to N/P ratio values.




1+ 10+ 100+ 1000+
CRYPTOMONAS 14.5
DOM 14.2(72)
NON DOM 14.6(321)
NON OCC 13.6(349)
CYCLOTELLA 14.9
DOM 17.7(83)
NON DOM 14.2(357)
NON OCC 20.5(302)
CYMBELLA 14.7
DOM (0)
NON DOM 14.7(169)
NON OCC 13.9(573)
DACTYLOCOCCOPSIS 9.8
DOM 6.9(58)
NON DOM 10.6(228)
NON OCC 16.8(456)
DICTYOSPHAERIUM 7.1
DOM 9.0(1)
NON DOM 7.1(183)
NON OCC 16.4(558)
DINOBRYON 19.2
DOM 28.5(31)
NON DOM 17.7(190)
NON OCC 12.0(521)
EUASTRUM 4.7
DOM (0)
NON DOM 4.7(77)
NON OCC 15.2(665)
EUGLENA 12.2
DOM 20.8(8)
NON DOM 12.0(400)
NON OCC 16.5(334)
FRAGILARIA 14.3
DOM 22.9(45)
NON DOM 12.0(170)
NON OCC 14.0(527)
GLENODINIUM 15.5
DOM 54.5(4)
NON DOM 14.0(107)
NON OCC 13.9(631)
GOLENKINIA 6.0
DOM 3.5(2)
NON DOM 6.0(124)
NON OCC 15.8(616)
GOMPHONEMA 16.3
DOM 15.0(1)
NON DOM 16.3(76)
NON OCC 13.9(665)
GYMNODINIUM 14.3
DOM 65.0(2)
NON DOM 13.1(85)
NON OCC 14.1(655)
GYROSIGMA 13.4
DOM (0)
NON DOM 13.4(80)
NON OCC 14.2(662)
KIRCHNERIELLA 8.6
DOM 17.1(8)
NON DOM 8.2(155)
NON OCC 15.7(580)
LAGERHEIMIA 7.6
DOM (0)
NON DOM 7.6(84)
NON OCC 14.9(658)
1+ 10+ 100+ 1000+


1+
10+
100+
1000+
LYNGBYA 9.4
DOM 4.6(99)
NON DOM 12.0(187)
NON OCC 17.1(456)
MALLOMONAS 13.4
DOM 7.8(6)
NON DOM 13.6(156)
NON OCC 14.3(580)
MELOSIRA 13.2
DOM 14.4(254)
NON DOM 12.4(352)
NON OCC 18.8(142)
MERISMOPEDIA 9.1
DOM 6.1(22)
NON DOM 9.3(306)
NON OCC 18.1(414)
MICROCYSTIS 9.4
DOM 9.7(53)
NON DOM 9.3(292)
NON OCC 18.3(397)
NAVICULA 14.6
DOM 18.2(6)
NON DOM 14.5(385)
NON OCC 13.6(351)
NITZSCHIA 12.8
DOM 10.4(29)
NON DOM 13.0(345)
NON OCC 15.4(368)
OOCYSTIS 10.0
DOM 36.2(5)
NON DOM 9.3(176)
NON OCC 15.4(561)
OSCILLATORIA 10.6
DOM 9.0(105)
NON DOM 11.1(322)
NON OCC 19.0(315)
PANDORINA 10.6
DOM (0)
NON DOM 10.6(115)
NON OCC 14.8(627)
PEDIASTRUM 8.4
DOM (0)
NON DOM 8.4(332)
NON OCC 18.7(410)
PERIDINIUM 14.7
DOM 9.8(6)
NON DOM 14.9(148)
NON OCC 14.0(588)
PHACUS 10.2
DOM 2.0(2)
NON DOM 10.3(250)
NON OCC 16.1(490)
RAPHIDIOPSIS 7.1
DOM 9.8(45)
NON DOM 6.2(132)
NON OCC 16.3(565)
SCENEDESMUS 11.0
DOM 8.5(50)
NON DOM 11.3(502)
NON OCC 23.0(190)
SCHROEDERIA 8.2
DOM 11.5(2)
NON DOM 8.2(176)
NON OCC 16.0(564)
STAURASTRUM 9.9
DOM 11.0(1)
NON DOM 9.9(269)
NON OCC 16.6(472)

```
                    1+                      10+                     100+                     1000+

STEPHANODISCUS  14.9                             M
  DOM     17.8( 73) |-----------------------------X-------------S-----|
  NON DOM 13.8(202) |--------------------------X---------------S-------------|
  NON OCC 13.7(467) |--------------------------X---------------S---------|

SURIRELLA  15.2                                  M
  DOM         (  0)
  NON DOM 15.2( 98) |---------------------------X-------------S-------|
  NON OCC 14.0(644) |--------------------------X---------------S-------------|

SYNEDRA  15.1                                    M
  DOM     21.0( 48) |-------------------------------X-------------S-----|
  NON DOM 14.4(413) |---------------------------X--------------S-------------|
  NON OCC 12.5(281) |-------------------------X----------------S---------|

TABELLARIA  18.0                                   M
  DOM     11.3( 20)                 |--------X---------S-----|
  NON DOM 19.3(102) |------------------------------X-------------S-------|
  NON OCC 13.3(620) |--------------------------X---------------S-------------|

TETRAEDRON   7.9                           M
  DOM     20.0(  5)               |-----------------X---------| S
  NON DOM  7.7(318) |--------------------X-------------S-------------|
  NON OCC 18.9(419) |------------------------------X--------------S----------|

TRACHELOMONAS  12.5                             M
  DOM      6.3(  4)         S  |------X--|  S
  NON DOM 12.6(224) |--------------------------X--------------S--------------|
  NON OCC 14.9(514) |---------------------------X--------------S---------|

TREUBARIA   7.9                            M
  DOM         (  0)
  NON DOM  7.9( 94) |---------------------X----------------S---------|
  NON OCC 15.0(648) |---------------------------X--------------S-------------|
                    1+                      10+                     100+                     1000+
```

APPENDIX B

RANGE OF PARAMETER VALUES WITHIN THREE OCCURRENCE CATEGORIES FOR *Anabaena, Cryptomonas* AND *Dinobryon*

The ranges of CHLA, TURB, SECCHI, PH, DO, TEMP, TOTALP, ORTHOP, NO2NO3, NH3, KJEL, ALK, and N/P associated with dominance (DOM), non-dominance (NONDOM) and occurrence (OCC) are presented in tabular form using data for *Anabaena, Cryptomonas* and *Dinobryon* as representative examples.

APPENDIX B. RANGE OF PARAMETER VALUES WITHIN THREE OCCURRENCE CATEGORIES FOR *Anabaena*, *Cryptomonas*, AND *Dinobryon*

PARAMETER	CATEGORY OCCUR.	CATEGORY RANGE	*Anabaena*	*Cryptomonas*	*Dinobryon*
CHLA (µg/l)	DOM	MIN	1.9	1.2	0.6
		MAX	147.4	198.0	45.3
	NONDOM	MIN	1.2	0.8	1.1
		MAX	595.0	312.0	170.5
	OCC	MIN	1.2	.8	0.6
		MAX	595.0	312.0	170.5
TURB (% trans.)	DOM	MIN	39	17	58
		MAX	95	100	100
	NONDOM	MIN	5	1	1
		MAX	100	98	100
	OCC	MIN	5	1	1
		MAX	100	100	100
SECCHI (inches)	DOM	MIN	11	2	19
		MAX	144	222	252
	NONDOM	MIN	6	5	2
		MAX	252	185	185
	OCC	MIN	6	2	2
		MAX	252	222	252
PH	DOM	MIN	6.5	5.2	6.2
		MAX	10.3	9.3	8.9
	NONDOM	MIN	5.6	5.5	5.2
		MAX	10.2	10.3	9.7
	OCC	MIN	5.6	5.2	5.2
		MAX	10.3	10.3	9.7

(Continued)

APPENDIX B. RANGE OF PARAMETER VALUES WITHIN THREE OCCURRENCE CATEGORIES FOR *Anabaena*, *Cryptomonas*, AND *Dinobryon* (Continued)

PARAMETER	CATEGORY OCCUR.	CATEGORY RANGE	*Anabaena*	*Cryptomonas*	*Dinobryon*
DO (mg/l)	DOM	MIN	2.8	3.5	6.2
		MAX	16.0	15.5	11.3
	NONDOM	MIN	1.9	1.9	1.6
		MAX	15.5	15.2	12.8
	OCC	MIN	1.9	1.9	1.6
		MAX	16.0	15.5	12.8
TEMP (°C)	DOM	MIN	14.9	8.5	9.7
		MAX	30.2	29.5	29.0
	NONDOM	MIN	7.2	6.8	7.2
		MAX	32.2	32.2	31.4
	OCC	MIN	7.2	6.8	7.2
		MAX	32.2	32.2	31.4
TOTALP (µg/l)	DOM	MIN	10	7	4
		MAX	3084	1159	137
	NONDOM	MIN	7	6	5
		MAX	1609	1609	1029
	OCC	MIN	7	6	4
		MAX	3084	1609	1029
ORTHOP (µg/l)	DOM	MIN	2	2	1
		MAX	2009	851	85
	NONDOM	MIN	1	1	1
		MAX	1189	1189	555
	OCC	MIN	1	1	1
		MAX	2009	1189	555

(Continued)

APPENDIX B. RANGE OF PARAMETER VALUES WITHIN THREE OCCURRENCE CATEGORIES FOR *Anabaena, Cryptomonas,* AND *Dinobryon* (Continued)

PARAMETER	CATEGORY OCCUR.	CATEGORY RANGE	*Anabaena*	*Cryptomonas*	*Dinobryon*
NO2NO3 (μg/l)	DOM	MIN	20	21	19
		MAX	3429	9745	989
	NONDOM	MIN	17	17	17
		MAX	9745	7557	7557
	OCC	MIN	17	17	17
		MAX	9745	9745	7557
NH3 (μg/l)	DOM	MIN	35	31	31
		MAX	3024	532	164
	NONDOM	MIN	30	20	22
		MAX	569	979	979
	OCC	MIN	30	20	22
		MAX	3024	979	979
KJEL (μg/l)	DOM	MIN	204	243	207
		MAX	8199	2949	1532
	NONDOM	MIN	199	199	199
		MAX	6349	6250	3699
	OCC	MIN	199	199	199
		MAX	8199	6250	3699
ALK (mg/l as $CaCO_3$)	DOM	MIN	10	10	10
		MAX	275	261	198
	NONDOM	MIN	10	10	10
		MAX	283	334	281
	OCC	MIN	10	10	10
		MAX	283	334	281

(Continued)

APPENDIX B. RANGE OF PARAMETER VALUES WITHIN THREE OCCURRENCE CATEGORIES FOR *Anabaena*, *Cryptomonas*, AND *Dinobryon* (Continued)

PARAMETER	CATEGORY		*Anabaena*	*Cryptomonas*	*Dinobryon*
	OCCUR.	RANGE			
N/P	DOM	MIN	0.0	0.0	3.0
		MAX	44.0	103.0	137.0
	NONDOM	MIN	0.0	0.0	0.0
		MAX	130.0	210.0	130.0
	OCC	MIN	0.0	0.0	0.0
		MAX	130.0	210.0	137.0

List of completed parts in the series "Phytoplankton Water Quality Relationships in U.S. Lakes." U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada 89114.

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