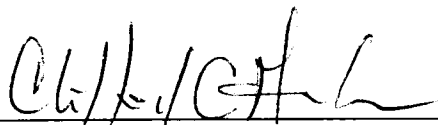
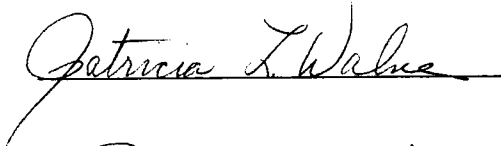


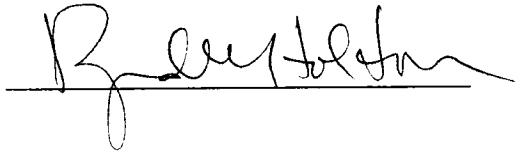
To the Graduate Council:

I am submitting herewith a thesis written by Pamela L. Bruce Inklebarger entitled "Phytoplankton Community Composition in Watts Bar Reservoir, Tennessee, and Some Relationships to Environmental Variables." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.


Clifford Amundsen, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:


Associate Vice Chancellor and
Dean of the Graduate School

**PHYTOPLANKTON COMMUNITY COMPOSITION
IN WATTS BAR RESERVOIR, TENNESSEE,
AND SOME RELATIONSHIPS
TO ENVIRONMENTAL VARIABLES**

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Pamela L. Bruce Inklebarger
May 1997

DEDICATION

This thesis is dedicated to my aunt

Miss Daisy Carolyn Hatcher

for her friendship and support

throughout my life.

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Lastly, my greatest debts are owed to the Lord and to my loving husband, Wayne.

ABSTRACT

Watts Bar Reservoir (WBR), one of nine Tennessee Valley Authority (TVA) regulated mainstream impoundments of the Tennessee River, is intimately associated with a unique seasonal reservoir riparian environment. The impoundment of WBR caused a complete disruption of the riverine biological system and brought about an abrupt formation of a new lacustrine biological system, abutting unadapted, truncated, mesic slopes. The new successional hydric community is threatened by erosion of the unstable shorelines, which may reduce allochthonous organic input, may influence the rate of cultural eutrophication, and may limit the composition and productivity of algal communities due to reduced transparency. The most recent in-depth published information on the ecological health of WBR was conducted by TVA in 1993, and contained phytoplankton productivity estimates based on chlorophyll a concentrations. TVA retains many preserved phytoplankton collections from WBR that have never been taxonomically evaluated. The purpose of this 20 month field-study was to list the phytoplankton genera of WBR and to place their existence into a broader perspective based on the environmental variables recorded in this study and in the literature.

Fifty-six phytoplankton samples were collected on 24 days between September 1994 and May 1996. Approximately ten locations on WBR were sampled primarily with a Wisconsin-style plankton net. The study showed that of the 110 phytoplankton genera assigned an identification, all the genera with more than a 50% frequency thrived in all four seasons, usually occurred abundantly in the full study range of pH,

conductivity, and temperature, and thus were considered the dominant algae of WBR. In decreasing order of relative occurrence in 56 samples these genera were *Pediastrum*, *Fragilaria*, *Melosira*, *Asterionella*, *Scenedesmus*, *Euglena*, *Tabellaria*, *Anabaena*, *Bumilleria*, and *Oscillatoria*. Phytoplankton genera that were present in every season were considered seasonal generalists in WBR, and those that fared better in only one or two seasons were considered seasonal specialists. Watts Bar Reservoir supports a very diverse phytoplankton assemblage with a high generic diversity value of 0.976, determined from an adapted version of Simpson's diversity index. Chlorophytes were found in highest frequency at 48.2%, followed by chrysophytes at 27.3%, cyanophytes at 15.5%, euglenophytes at 4.5%, and pyrrhophytes at 4.5%.

Environmental variables were addressed in respect to three categories: 1) season 2) habitat, and 3) physio-chemical factors. Seasonal phytoplankton community similarity indices (Sørensen's and Jaccard's Indices) for WBR indicated that summer and fall phytoplankton communities were the most similar, followed by spring and fall, spring and summer, winter and spring, winter and summer, and fall and winter communities. Chrysophytes were found to thrive in winter conditions, at which time the frequency of chlorophytes and pyrrhophytes dwindled. The highest total number of phytoplankton genera per sample day (43) was found on August 26, 1996, along with the highest number of genera collected in any one of 56 sample sets (36).

In relation to habitat location, phytoplankton communities in cove-embayment areas had a higher generic richness than main channel-collected phytoplankton, which was probably related to the higher averages for pH, conductivity, and temperature in the

cove-embayment areas. Phytoplankton communities from sample locations or combinations of similar types of sample locations selected for community similarity comparisons ranged from 76.9% to 43.6% in similarity according to Sørensen's Index.

When phytoplankton were distributed by genus along three continua between the field-recorded minimum and maximum ranges of the physio-chemical factors, pH, conductivity, and temperature, cyanophytes were found to occur in a higher than average pH and temperature. Phytoplankton community similarity comparisons indicated that the reported communities of selected southern reservoirs had less than 50% of their phytoplankton in common with those of WBR, according to Sørensen's Index.

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LIST OF ABBREVIATIONS

c	the number in common
C	channel
°C	degrees Celsius
Co. or CO	county
CO ₂	carbon dioxide
d_{max}	maximum d_s
D_{max}	maximum D_s
DO	dissolved oxygen
d_s	inverse of l
D_s	Simpson diversity
Σ	sum the items indicated
ed.	edition or editor
e.g.	for example
e_s	evenness, using D_s
E_s	evenness, using d_s
et al.	and others
ft	feet or foot
g	genera
$(g)_1$	the number of genera in community 1
$(g)_2$	the number of genera in community 2
ha	hectares
i	individual
i.e.	that is
J.	Journal
km	kilometers
l	Simpson dominance
m	meter
M	molar
MC	main channel
mg/L	milligrams per liter
M.S.	Master of Science
msl	mean sea level
n_i	individual species or genus
N	north
(N)	abundance
No. or #	number
O	occurrence(s)
OC	opposite channel
%	percent
PCB	poly-chlorinated biphenyl
pH	potential of Hydrogen
p_i	relative species abundance or relative genus occurrence

pp.	pages
ppm	parts per million
R ₁	rank 1 total
Rec	recreation
RO	relative occurrence
s	species
SRRSZ	summer reservoir riparian shoreline zone
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
ug/L	micrograms per liter
um	micrometer
UTRb	Upper Tennessee River basin
W	west
WBR	Watts Bar Reservoir
WQCB	Water Quality Control Board
WS	wind-sheltered
WUS	wind-unsheltered

1. INTRODUCTION

1.1 Significance of the Study

Watts Bar Reservoir (WBR), (East Central Tennessee, approximately 34° 30'N, 84° 30'W) is the largest of fifteen Tennessee River drainage impoundments upstream of Chattanooga. This half-century-old reservoir was chosen for a systematic, field oriented study of algal presence, community composition, and diversity. This project presents a listing of phytoplankton genera collected over 20 months (September 1994 - May 1996) and considers the influence of the local environment on phytoplankton presence, community composition, and diversity.

Comprehensive lists of algae specific to reservoirs are uncommon. A review of the literature and a personal conversation with biologist Dennis Meinert (1996) of the Tennessee Valley Authority (TVA) indicates there is no recorded study identifying the phytoplankton in WBR. According to Meinert, TVA, which collects phytoplankton for chlorophyll determinations regardless of taxa, retains many preserved phytoplankton collections from WBR that have never been taxonomically evaluated.

The human population in the Tennessee Valley is increasing. More active land use along the reservoirs, including more extensive waterfront residential development, is likely to increase undesirable additions to affective runoff. Increased land development along with the release of associated pollutants, such as fertilizers, may influence the reservoir's pH (potential of hydrogen), conductivity, temperature, transparency, and dissolved oxygen (DO) levels (TVA, 1996a). Any environmental changes and consequential changes in the welfare and composition of aquatic life should be, and often is, locally monitored to determine the biological health status of

reservoirs (TVA, 1994; Placke, 1983). In order for widespread monitoring to be meaningful, identifications of phytoplankton taxa should be included in reservoir assessments. A suggested comprehensive program for researching and recording the biologic history of waterbodies proposes that extant phytoplankton communities be monitored and further suggests core sampling to determine past phytoplankton composition (Siver and Smol, 1993). No core sampling was done in this study. Identifications are critical for the simple reason that phytoplankton are primary autochthonous producers in aquatic systems. These algae provide a resource on which the ultimate success of grazing consumers may depend. Excretions of organic matter from phytoplankton and bits of phytoplankton detritus provide a source of energy for planktonic or benthic organisms acting as decomposers as well (Smith, 1992). Phytoplankton are studied from an ecological perspective in order to evaluate the relationships of and between assemblages of phytoplankton as they are influenced by seasonal conditions, sampling location, and aquatic conditions (McGaha and Steen, 1974). A phytoplankton manual edited by Sournia (1978) states:

Phytoplankton normally consists of a heterogeneous collection of algae and the problems posed by the distribution and seasonal succession of the species present are not only of interest in themselves. Such qualitative differences may have effects on the higher components of the food chain and may thus also be of economic importance.

1.2 Statement of the Problem and Purpose of the Study

Although the photosynthetic productivity of WBR has been assessed (TVA, 1994), the taxonomic composition of phytoplankton communities of WBR is essentially unknown. A determination of empirical relationships between algal community

composition and environmental variables is important to an overall understanding of reservoir ecology. This study provides base level information about phytoplankton community composition and diversity in WBR and determines if the relevant, selected, environmental variables show any influence on the phytoplankton communities. Such algal community information can serve as a basis for researchers to elaborate the study, make taxonomic indicator comparisons, or, ultimately, seek to modify current aquatic and/or land management practices which affect the habitat.

1.3 Objectives

The objectives of my research on Watts Bar Reservoir were to:

- 1) collect, examine, and list the genera of phytoplankton
- 2) determine relationships between algal community composition and certain field measured or empirically described environmental variables.

1.4 Hypotheses and Research Questions

To achieve the purpose of providing a clearly defined study on the current presence, composition, and diversity of phytoplankton genera, a cumulative list of phytoplankton genera was assembled over 20 months and environmental information was collected from WBR in respect to three categories: 1) season, 2) habitat, and 3) physio-chemical factors. The null hypotheses (HO) and subsidiary questions (Q) relating to these categories are delineated as follows and were evaluated by various analyses.

HO: A There is no difference in the presence, community composition, and diversity of phytoplankton found in WBR resulting from the influence of calendar-season phenomena [any physical factors, resulting from climate, season, or weather, of or relating to air moisture, temperature, wind, and solar radiation as discussed in Brower et al. (1990)].

Q1A: Do phenomena typical to the four calendar-seasons influence phytoplankton?

Q2A: If so, are specific divisions or individual genera of phytoplankton characteristically present in relationship to the empirical, physical characteristics of the four seasons?

HO: B There is no difference in the presence, community composition, and diversity of phytoplankton found in WBR resulting from the influence of habitat and observed or measured geomorphological or other environmental dynamics.

Q1B: Are differences reflected when phytoplankton communities from empirically selected habitats are compared?

Q2B: If so, can the differences between phytoplankton communities in the habitats selected for comparison be explained by geomorphological or other environmental dynamics?

HO: C There is no difference in the distribution of phytoplankton genera found in WBR along three continua between the recorded study minimum and maximum ranges of the physio-chemical factors of pH, conductivity, and temperature.

Q1C: Do differences exist in the distribution of phytoplankton genera along the continua between the recorded minimum and maximum ranges for pH, conductivity, and temperature?

Q2C: If so, how is each genus of algae distributed along the continua of recorded minimum and maximum ranges for pH, conductivity, and temperature?

HO: D There is no difference in the distribution of phytoplankton genera among taxonomic divisions or in the number of genera in common when taxa found in WBR are compared to the taxa reported from selected southern reservoirs.

Q1D: Do differences exist in the distributions of phytoplankton genera among taxonomic divisions or in the number of genera in common when taxa of WBR are compared to the taxa reported from selected southern reservoirs?

Q2D: If so, by how much?

1.5 Organizational Plan

This study is presented in five chapters with the contents annotated below.

Chapter 1 contains the introduction, including the significance of the study, statement of the problem and purpose of the study, the objectives, the hypotheses and research questions, and this section, the organizational plan.

Chapter 2 contains the background, including a discussion of TVA's purpose, objectives, and obligations, the evolution of the biological system due to impoundment disturbance, the importance of phytoplankton as producers and as modifiers, the integration of reservoir aquatic and terrestrial communities, the ecological health of WBR, a literature review, and a description of study area.

Chapter 3 contains the methods, including duration of the study, selection, classification and location of sample sites, sample collection, sample analysis, and limitations of the study.

Chapter 4 contains the results and discussion.

Chapter 5 contains the conclusions and recommendations.

2. BACKGROUND

2.1 TVA's Purpose, Objectives, and Obligations

The Tennessee Valley Authority (TVA) was created in 1933 to improve navigation and commerce throughout the Tennessee River Watershed. This publically owned federal corporation of the United States is located in the southeastern United States and transects seven states, serving an area approximately equivalent to the drainage basin of the Tennessee River.

The original objectives of TVA were to build a series of dams and reservoirs for the purposes of improving navigability, flood control, and the provision of hydro-electric power. More than fifty-nine dams were built by TVA between 1936 (Norris Dam) and 1979 (Tellico Dam).

TVA's current obligations also include, but are not limited to: maintaining water quality which is satisfactory for use in industrial, agricultural, and municipal water supplies; supporting water-related recreational activities; assessing shoreline impacts resulting from development; and promoting the reproduction and survival of fish and other aquatic life (TVA, 1996a).

2.2 Evolution of the Biological System Due to Impoundment Disturbance

From 1939 to 1942, the reservoir lands in the Watts Bar impoundment area were stripped of brush and timber prior to flooding to promote navigational safety, to prevent flotage of large debris, and to assist in the future control of malaria. The completion of Watts Bar Dam in 1942 and subsequent impoundments of the Tennessee River caused a complete disruption of the riverine biological system and brought about an

abrupt formation of a new lacustrine biological system. The banks of the Tennessee River that had been carved and defined by years of river currents were obscured by impoundment waters. In certain areas, the highest known (1867) river flood mark level was exceeded by the new reservoir pool, which resulted in unadapted, truncated, mesic slope shorelines (Amundsen, 1994; TVA, 1949). Compared to the area of the original river bed, which was 4,186 hectares (ha) or 10,343 acres, 15,783 ha or 39,000 acres are now inundated when the reservoir is at normal operating level (Amundsen, 1994).

With the habitat shock of impoundment, the riverine plankton populations were probably diluted, but because of flow reduction and an influx of nutrients from flushing and decomposition, plankton population growth and standing crop probably increased (Baxter, 1977). In addressing such readjustment to altered environmental conditions in newly formed impoundments, Baxter also indicated that organisms may have been subjected to toxic substances, such as heavy metals, flushed from terrestrial accumulations. Over time, however, water quality tends to improve (Baxter, 1977). In further consideration of ecological effects on impoundments, opportunistic colonizers from lacustrine habitats may have modified the prior riverine species composition through superior interference competition (Putman, 1994).

2.3 Importance of Phytoplankton as Producers and as Modifiers

Phytoplankton are the premier, autochthonous base of the aquatic food web in WBR, which lacks an extensive vascular, aquatic flora (Amundsen et al., 1995). Well developed vascular aquatic flora, when present, serves to stabilize mineral substrates and may provide a surface for certain epiphytic algae, such as the alga *Chara* on

Justicia (an aquatic macrophyte) (Dennis et al., 1977), more so than it supplies resources for herbivores or provides allochthonous inputs (inputs originating from terrestrial system) to the reservoir. The phytoplankton community is probably the dominant producer (Smeins and Slack, 1982) in this aquatic system, yet the ability to sustain primary production over short periods may be highly variable and dependent on the biological dynamics of the ambient environment, as well as the physical and chemical dynamics. For instance, studies show that grazing protozoans can consume 99% of certain phytoplankton populations in 7 to 14 days (Smith, 1992). According to Reimann as cited in Christoffersen et al. (1990), in the absence of certain competitors, such as *Daphnia*, heterotrophic nanoflagellates thrive on phytoplankton populations. Herbivorous zooplankton and planktivorous fish consume phytoplankton as a primary food source, and are then consumed by carnivorous minnows, larger fish, and so on (Smith, 1992).

Phytoplankton influence and are influenced by their environment. Some phytoplankton "can successively absorb carbon dioxide (CO_2), eliminate bicarbonates, precipitate carbonates, and form hydroxyl ions" (Cole, 1975). In this way plankton modify the aquatic parameters of pH, alkalinity, CO_2 content, and dissolved oxygen (DO) levels. Phytoplankton may also influence turbidity by their sheer density (Placke, 1983).

Some phytoplankton are considered nuisance organisms by various water users, because they release obnoxious odors (*Hydrodictyon*), produce foul tastes (*Stephanodiscus*), contain toxins (*Microcystis*), and physically clog filters for water

uptake (*Spirogyra*) (Palmer, 1959). "Documented algal impacts on water quality in TVA reservoirs have included water supply tastes and odors; odor incidents in embayments; algal mats in embayments; and contribution to hypolimnetic DO depletion." Excessive algal growth causes water quality deterioration that accelerates the process of eutrophication ("a progressive fertilization of a water body") (Placke, 1983).

2.4 Integration of Reservoir Aquatic and Terrestrial Communities

2.4.1 Reservoir Aquatic Communities

The term reservoir is usually applied to an impounded body of water. Though reservoirs are commonly called lakes, no natural lakes, or other sizable historic lacustrine habitats are found in the upper Tennessee River basin (Amundsen, 1994). Placke (1983) suggests that TVA reservoirs should not be evaluated by trophic state indices developed for natural lakes. TVA reservoirs have physical characteristics differing from natural lakes including the following respects: shoreline dynamic factors, depth, thermal stratification, and residence time.

WBR is a mainstream TVA reservoir, as opposed to a tributary reservoir, formed from the damming of the main channel of the Tennessee River. (Placke uses the term "mainstem," rather than "mainstream," which is used in current TVA publications (1996a). TVA engineered management regimes are counter-seasonal to the natural, seasonal river trends, which are high in the winter and low in the summer (Amundsen, 1994; Smith, 1992). TVA now maintains a summer water level for WBR at 225.9 meters (m) (741 ft) above mean sea level (msl) between April and October. The

duration of the summer pool level has recently (1992) been extended from September to October. Weekly one foot fluctuations help control mosquito larvae development along the shorelines during June-August. TVA lowers the water level from 225.9 m msl to around 224.3 m msl (736 ft) from November through March to accommodate expected higher amounts of watershed runoff, when evapotranspiration in deciduous trees is greatly reduced. According to Smith (1996), "in winter deciduous trees intercept very little precipitation." The annual operating guide for WBR is provided in Figure 1 (Amundsen, 1994).

2.4.2 Reservoir Terrestrial Communities

Shorelines of reservoirs are impacted by "the effects of shore processes" due to extended exposure during winter drawdown and year around erosion. The area of shore "between the highest and lowest water lines, together with the part of the land that is splashed by waves and the area below the lowest water level that is intermittently uncovered by waves" is called the eulittoral (Baxter, 1977). The eulittoral is also referred to as a mudflat (Amundsen, 1994). The area just above the eulittoral area is called the epilittoral (Baxter, 1977). The epilittoral and eulittoral together are also referred to as a reservoir riparian zone. The epilittoral area in the summer and winter is considered the summer reservoir riparian shoreline zone (SRRSZ) (Amundsen, 1994). Since the now truncated, once mesic, shores of WBR typically have low stability, scouring currents and wave erosion contribute to siltation dynamics, resulting in the

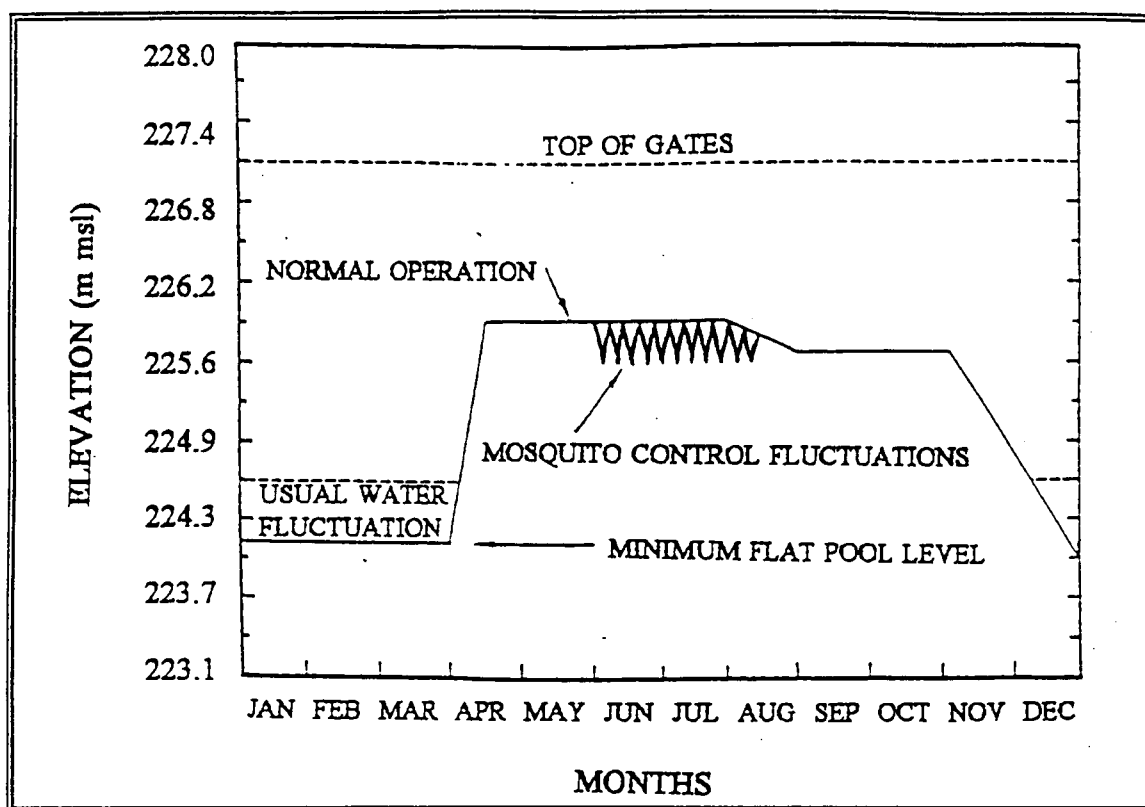


Figure 1 Annual Operating Guide for Watts Bar Reservoir

Source: Amundsen, C.C. 1994. "Reservoir Riparian Zone Characteristics in the Upper Tennessee River Valley." *Water, Air, and Soil Pollution* 77:469-493.

local formation of scarps, seasonal mudflats, and sandbars. During the winter season most coves become a broad mudflat and the main channel and embayments become outlined by narrower mudflats all with a bordering SRRSZ of forest or managed landscape.

2.4.3 Integration

Eutrophication is defined as a "progressive fertilization of a waterbody" with resulting changes in water quality, while "cultural eutrophication" is qualified as a process when excessive amounts of nutrients, from municipal and industrial wastes or from poor land use practices, rapidly accelerate aquatic productivity (Placke, 1983). Therefore, the former is expected, the later anthropogenically induced.

This water quality problem necessitates continuous monitoring and maintenance of good ecological health for the organisms living in aquatic systems and good water quality for human usage. An approach to the solution may be by way of determining the structure and composition of aquatic communities to assist in understanding the dynamics of freshwater food webs; or by employment of biological indicators (including the use of phytoplankton productivity as a biological indicator of the trophic status or eutrophication). The underlying concern which drives all of these studies is the desire and necessity of understanding the ecological dynamics of aquatic ecosystems in order to conserve them from excessive cultural eutrophication and other degrading, anthropogenically induced, stresses. Of special interest to this study is the understanding and conserving of the unique "seasonal reservoir riparian environments" surrounding and influencing (by way of "organic material and energy exports") the

engineered half-century-old impoundment of WBR. The Upper Tennessee Valley contains some 50,000 ha of these between pool "seasonal reservoir riparian environments" (Amundsen et al., 1995).

The input of "organic material and energy exports" into WBR originate, for the most part, from one of two main places: from primary production within the reservoir (autochthonous) or from terrestrial inputs from the riparian zone (allochthonous). Primary aquatic inputs or terrestrial inputs originating outside WBR, such as from streams or from the abutting upstream reservoir, will be referred to as other autochthonous or other allochthonous (Amundsen et al., 1995).

The reduction of the SRRSZ due to erosion has potentially threatening consequences for partial loss of allochthonous input into the aquatic system and loss of "continuous favorable habitats for perennial hydric species" inhabiting "the successional hydric community" (Amundsen et al., 1995). A partial loss of allochthonous input into the aquatic system could potentially influence success or failure within certain Divisions of algae. As reported in van den Hoek et al. (1995), some members of the Division Euglenophyta can either rely solely on organic compounds for their nutrition (e.g. *Atasia*) or use organic compounds as a supplement to photosynthetic production (e.g. in the genus *Euglena*).

About 50% of all species of the Division Pyrrophyta (Dinophyta) are either obligately (as *Protoperidinium*) or facultatively (as *Ceratium*) heterotrophic. The estuarine alga, *Gymnodinium fungiforme*, and the freshwater alga, *Peridinium cinctum*, are two other demonstrated examples of a tendency toward heterotrophy.

Members of the Division Chrysophyta may also be obligately or facultatively heterotrophic. In phytoplanktonic assemblages where chrysophytes are dominant, bacteria can contribute to over 50% of the planktonic resource base through phagotrophic and saprotrophic consumption (van den Hoek et al., 1995).

No conclusive evidence of heterotrophic tendencies in Divisions Chlorophyta or Cyanophyta was found in the literature. Stein and Amundsen (1967) report, however, that chlorophytes developing in snow were successfully cultured only in the presence of vitamin-containing media studies in lighted growth chambers. Although cyanophytes are not known to exhibit heterotrophy, certain cyanophytes possess heterocysts where they convert atmospheric nitrogen to a usable form in the absence of oxygen, which ultimately is exported to other cells as glutamine (van den Hoek et al., 1995). Cyanophytes and "a wide variety of algae" possess long-term storage potential of nitrogen and phosphorus (Placke, 1983). Algae which possess heterotrophic capabilities, those which can fix nitrogen to contribute to amino acids, and those which store nutrients, may have competitive advantages over algae that are obligate photoautotrophs, or that do not possess the ability to fix nitrogen or store nutrients.

The reduction of riparian vegetation providing allochthonous input may affect phytoplankton in two ways: decreased primary production from limiting nutrients or light limitations imposed by turbidity, ultimately resulting from erosion. The reduction of the SRRSZ by erosion may lead to more mudflat and soil exposure to wave action and reduce the width of the required (for WBR) 50 ft riparian strip (TVA, 1996a). Less allochthonous input into the aquatic system will result from both the strip's recession

and the reduction of plant material within the strip. Without an adequate riparian zone, elevated rates of erosion and sedimentation amounts would result. According to Placke (1983), mainstream reservoirs are already marked for their slightly higher dissolved and suspended solids. Phytoplankton productivity, especially in mainstream reservoirs, is partially controlled by the high turbidity resulting from suspended materials (Placke, 1983). Placke writes "Turbidity is markedly increased by local runoff, high discharge from upstream dams and water level fluctuations for mosquito control." As observed during this study, turbidity may also be increased by bank erosion and silt upsurge from boat waves. (On October 28, 1995 a rise of ten parts per million (ppm) in conductivity, a measure of the amount of ions, was recorded after the passage of a large boat; from 130 to 140 ppm).

In conclusion, the ecological health of WBR and other reservoirs in the TVA system, ultimately depends on the condition of the shorelines.

2.5 Ecological Health of Watts Bar Reservoir

The variables relating to water quality in this study were primarily pH, conductivity, and temperature; and secondarily, DO and transparency. The water quality of WBR and other regional reservoirs is monitored and managed by several governmental organizations. Tennessee's Water Quality Control Board (WQCB) has specified uses of the Waters of the State. Common uses described by the WQCB include:

sources of water supply for domestic and industrial purposes; propagation and maintenance of fish and other aquatic life; recreation in and on the waters including the safe consumption of fish and shellfish; livestock watering and irrigation; navigation; generation of power; propagation and maintenance of

wildlife; and the enjoyment of scenic and aesthetic qualities of waters.

Malanson (1993) in *Riparian Landscapes*, emphasizes that the values possessed by a body of water should not be limited to uses of the water, but should also include the values of the riparian zone.

General Water Quality Criteria were established by the WQCB as a way of interpreting water quality from field samples compared with an assigned standardized limiting value for each applicable variable (out of usually 10 variables, such as pH) specific to each applicable use (out of usually seven, such as for domestic water supply), which would enable the Waters of the State to support their designated uses (Tennessee Department of Environment and Conservation (TDEC), 1995).

TVA assessments have considered many of the variables listed by the WQCB and included others. The term "trophic" generally refers to the position of organisms in a food web. Table 1 (adapted from Placke, 1983) compares the "trophic potential" and "trophic response" variables considered in TVA's tributary and mainstream reservoirs. Placke writes "trophic status has been used indiscriminately to describe both the abundance of nutrients and the intensity of biological productivity supported by the nutrient flux." A distinction between trophic potential and trophic response was drawn because the term "trophic status" is ambiguous. Trophic potential variables are those which may potentially effect the trophic status of a reservoir and include pH, turbidity, climate, hydraulic regime, and nutrient concentrations. Trophic response variables are those which are quantitative, biological manifestations that may have a direct impact on the quality of reservoir water. Trophic response variables include productivity

**Table 1 Comparison of "Trophic Potential" and "Trophic Response"
Variables Considered in TVA's Mainstream and Tributary Reservoirs**

Mainstream	Tributary
<u>Trophic Potential</u>	
<u>Trophic Response</u>	

Shorter hydraulic retention time
(average 10 days for all nine
mainstream reservoirs)

Longer hydraulic retention time
(average 138 days for 11
largest)

Shallow mean depth
(average 6.6 m for all nine
mainstream reservoirs)

Deep mean depth
(average 18.1 m for 11 largest)

Inconsistent thermal stratification

Strong thermal stratification

Higher inorganic turbidity
(average Secchi 1.2 m for four
mainstream reservoirs)

Lower inorganic turbidity
(average Secchi 2.5 m for 11
largest)

Relatively constant alkalinity
(range 43.8 - 59.6 mg/L for four
mainstream reservoirs)

Variable alkalinity
(range 4.6 - 82.6 mg/L for 11
largest)

Higher unit phosphorus load, lower
retention, higher in-lake P
concentration (average P load =
31.3 g/m²/yr, R_p = -0.03, {P} =
0.03 mg/L for four mainstream
reservoirs)

Lower unit phosphorus load, higher
retention, lower in-lake P
concentration (average P load =
4.0 g/m²/yr, R_p = 0.48, {P} =
0.01 mg/L for 11 largest
reservoirs)

Phytoplankton remain diversified
during summer; algal abundance
generally lower

Phytoplankton dominated by blue-green
algae during summer (except Norris);
algal abundance often high

Chlorophyll production limited
primarily by light and hydraulics
rather than nutrients

Chlorophyll production strongly
correlated with P and N
concentrations

Some embayments have algae and
macrophyte problems

Embayments kept free of macrophytes
by drawdown

Adapted from: Placke, J.F. 1983. *Trophic Status Evaluation of TVA Reservoirs*. Tennessee Valley Authority, Knoxville, Tennessee. Technical Report TVA/ONR/WR-83/7.

rates, chlorophyll concentration, phytoplanktonic community structure, and macrophyte manifestation.

TVA has determined which combination of trophic potential and trophic response variables are most important in influencing TVA's tributary and mainstream reservoirs and has generated a "Mainstem" Reservoir Index (six variables) and a Tributary Reservoir Index (four variables) (Placke, 1983). These indices and their applications will be further discussed in the literature review section.

In order to determine the ecological health of waterbodies in the Upper Tennessee River basin (UTRb) seven, including WBR, were assessed by the Division of Water Pollution Control's monitoring network in 1990. The UTRb is one of 14 major basins located in Tennessee, as shown in Figure 2. Of the seven assessed, two waterbodies were classified as monitored and five waterbodies were classified as evaluated. If the waterbody was classified as monitored, it meant the data were less than five years old. Evaluated waterbodies were assessed using data more than five years old. WBR was classified as monitored and a 20% portion was declared as not supporting its designated uses. Poly-chlorinated biphenyl (PCB) contamination, industrial and municipal discharges, and urban runoff from Oak Ridge and Knoxville were reasons mentioned for the non-supporting assessment. The other 80% portion of WBR was considered fully supporting, but threatened (Tennessee Department of Health and Environment, 1990).

A more recent and in depth study on the ecological health (summary of vital signs and use suitability monitoring) of WBR was conducted by TVA in 1993. The

- | | | |
|-----------------------------|---------------------|------------------------|
| 1. Mississippi River | 6. Elk-Shoal | 11. Upper Tennessee |
| 2. Memphis | 7. Duck River | 12. Clinch River |
| 3. Hatchie River | 8. Lower Cumberland | 13. French Broad River |
| 4. Obion-Forked Deer | 9. Upper Cumberland | 14. Holston River |
| 5. Western Tennessee Valley | 10. Lower Tennessee | |



Figure 2 Location of Major Basins in Tennessee

Source: Tennessee Department of Health and Environment. 1990. *The Status of Water Quality in Tennessee*. Technical Report No. 305(b).

study included analysis of the water (temperature, DO, pH, phosphorus, chlorophyll a, and Secchi depth), sediments, benthic macroinvertebrates, aquatic macrophytes, fish community, fecal bacteria, and fish tissue for PCB contamination (TVA, 1994).

Current published information on the ecological health of WBR was found in the June 1996 edition of *TVA River Neighbors*. WBR was rated a C+ or 78 on an apparent scale of 40 (poor) to 100 (good). The data for this evaluation, however, were obtained from sampling reported in 1994 (TVA, 1996b).

2.6 Literature Review

Studies of freshwater phytoplankton supply researchers with information useful in a number of different applications. Awareness of phytoplankton community structure and composition is important in understanding the dynamics of freshwater food webs (Christoffersen et al., 1990). This study provides base level information about phytoplankton community composition. The knowledge of phytoplankton composition in bodies of water, particularly the consideration of chrysophytes, may enhance environmental monitoring through the identification of biological indicators. The list of phytoplankton genera found in WBR in this 20 month study can be compared to other lists in the literature that rank algae into categories such as Palmer's (1959) clean water algae list. Such grading systems help identify aquatic biological indicators and the ecological health of waterbodies.

Siver and Smol (1993) and Dixit et al. (1992) have reviewed many literary sources concerning phytoplankton in biomonitoring and as biological indicators. A symposium in 1990 at Oak Ridge National Laboratory evaluated "the scientific basis,

current state of development, validation, and use of biological markers (biomarkers) in environmental research" (McCarthy and Shugart, 1990). In order to determine any predictable relationship (leading to biological indicators) between phytoplankton composition and environmental variables, studies have been conducted to determine how phytoplankton respond to specific physio-chemical factors, such as pH, temperature, conductivity, DO, and transparency (Singh and Mahajan, 1987; Placke, 1983; Crouch, 1978; McGaha and Steen, 1974). This WBR study includes analyses of such field measured environmental variables to determine any influence on the phytoplankton communities described. Siver and Smol (1993) cite numerous researchers who have conducted studies relating phytoplankton composition, especially that of chrysophytes, to environmental variables.

Some studies relate phytoplankton productivity to the eutrophic condition of a waterbody in that significant increases in standing crops are considered by some to be good indicators of the overall trophic status tending toward eutrophism (Wade, 1984; Crouch, 1978). Placke (1983) discusses two drawbacks (involving the difficulty and questionable accuracy and precision in measurements, and relating rates of phytoplankton productivities with quantities of standing crop accumulation) of using primary productivity routinely as a trophic status or eutrophic condition indicator.

A local, TVA directed study, was conducted during the growing season in 1979 to thoroughly and comparatively investigate the trophic status (leading to a eutrophic ranking) of 15 TVA reservoirs. Four of the 15 were mainstream reservoirs and 11 were tributary reservoirs. WBR was not one of the four mainstream reservoirs evaluated in

1979, but limited data from 1975 were used in the "calculation of TVA mainstream reservoir trophic state index values," for WBR. Data from other reservoirs not included in the 15 in the 1979 study were included in the indices using data from other sources, so they could also be eutrophically ranked (Placke, 1983).

The trophic status of TVA mainstream reservoirs as discussed above was evaluated using the following six variables in the "Mainstem" Reservoir Index: percent surface area less than five feet deep, hydraulic retention time, pool elevation drawdown, Secchi depth (transparency), percent surface area with algal mat and macrophyte coverage, and chlorophyll a concentrations. Based on these variables the rank of mainstream TVA reservoirs from most eutrophic to least eutrophic was: Guntersville, Wheeler, Watts Bar, Fort Loudoun, Wilson, Nickajack, Chickamauga, Kentucky, and Pickwick Reservoirs.

The trophic status of TVA tributary reservoirs was evaluated using the following four variables in the Tributary Reservoir Index: biologically available inorganic carbon, chlorophyll a concentrations, total phosphorus, and total nitrogen.

2.7 Description of the Study Area

Watts Bar Dam, on the Tennessee River in East Tennessee, was closed in 1942. Table 2 includes a physical description of WBR (Hammons, 1996; Amundsen, 1994; TVA, 1987; TVA, 1949). The impoundment is designated as in the Watts Bar, Fort Loudoun, and Melton Hill Reservoir Watershed by TVA (TVA, 1994). WBR is located in the Upper Tennessee River basin (UTRb), which constitutes 2,521 square miles. Major parts or all of Blount, Knox, Loudon, Monroe, and Roane Counties are

Table 2 Physical Description of Watts Bar Reservoir

Location of Watts Bar Dam

Tennessee River Mile (TRM) 529.9; at 35°37'N, 84°37'W; approximately 11.3 km southeast of Spring City; between Fort Loudoun and Chickamauga Reservoirs; Upper Tennessee River basin of Tennessee Valley; elevation approximately 785 feet.

Closure of Dam

January 1, 1942

Prior to Impoundment

Average low-water slope (m/km)	0.16
Area of original river bed (ha)	4,186
Highest known flooding elevation of original river (meters (m) above mean sea level (msl))	225.4

Reservoir

Elevation at top of gates (m msl)	227
Elevation of winter drawdown zone (m msl)	224
Elevation of summer pool (m msl)	225.9

Shoreline Impacts

Area of flood zone: area between summer pool and top of dam gates elevations (ha)	1,902
Area of mudflat: area between summer pool and winter drawdown zone elevations (ha)	2,549
Area of reservoir at summer pool elevation (ha)	15,783
Length of reservoir shoreline (km)	1,241

Drainage

Area of Tennessee River basin (ha)	10,595,690
Area above dam (ha)	4,500,000

General

Mean depth (m)	7.9
Average discharge (cubic meters/second)	28,252
Winter-summer water level fluctuation (m)	1.8 - 2.0
Average water retention time (days)	17

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- Sources: Amundsen, C.C. 1994. "Reservoir Riparian Zone Characteristics in the Upper Tennessee River Valley." *Water, Air, and Soil Pollution* 77:469-493.
- Hammons, S.L. 1996. "Reservoir Riparian Island Habitats and Representative Arboreal Species Importance in Watts Bar, Tennessee." M.S. thesis, University of Tennessee, Knoxville, Tennessee. pp. 116.
- Tennessee Valley Authority (TVA). 1987. "Fishery Status Assessment of Watts Bar Reservoir with Management Recommendations." Office of Natural Resources and Economic Development. Technical Report Series TVA/ONRED/AWR-88/5.
- TVA. 1949. *The Watts Bar Project*. U.S. Government Printing Office, Washington, D.C. Technical Report No. 9.

encompassed by the UTRb, as well as minor parts of Rhea, Meigs, Cumberland, Bledsoe, and Sevier Counties (TDHE, 1990). Fort Loudoun and Tellico Reservoirs are upstream on the Tennessee - Little Tennessee River. Three major tributaries, the Clinch, Emory, and Piney Rivers also join the main channel of WBR within river miles 530 - 602.

Watts Bar is one of ten TVA reservoirs located in the Valley and Ridge physiographic province (with elevations ranging from 600 to 3,000 feet), which is one of six such provinces in the Tennessee River Watershed. A map of the provinces in relation to the entire Tennessee River Watershed is provided in Figure 3. The climate of the Tennessee Valley is characterized as warm, humid, and temperate; receiving 46 to 54 inches of rainfall annually. TVA considers the erosion potential in the soils of the Valley and Ridge physiographic province to be low, based on the parent material composition of sandstone, shale, limestone, and clay. Exceptions for the low erosion potential were mentioned for slopes lacking adequate vegetative cover, but unfortunately, the erosion potential of shoreline soils impacted by the abrading actions of boat waves was not strongly considered in TVA's publication *Shoreline Management Initiative* (1996a).

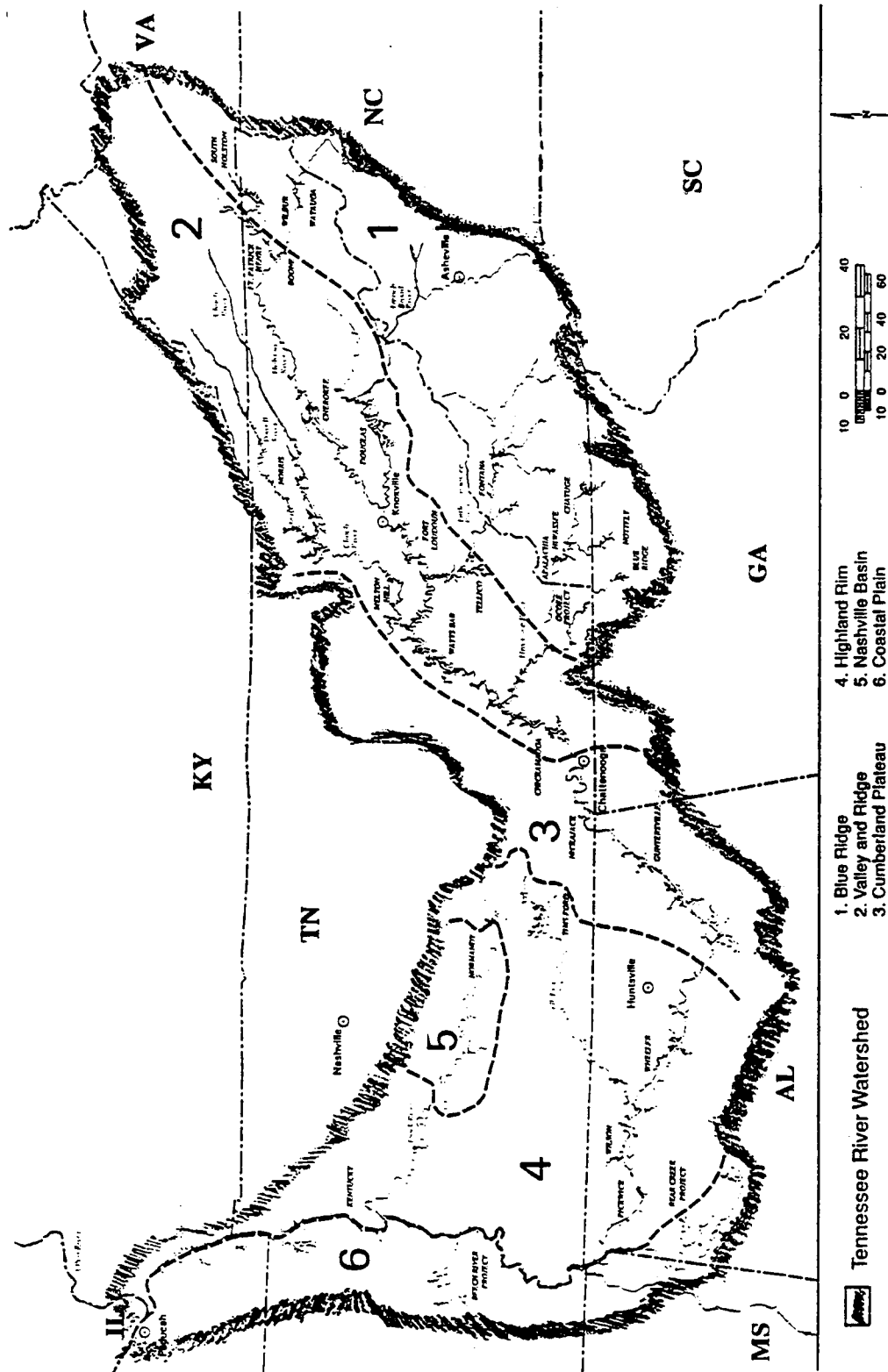


Figure 3 Location of the Six Physiographic Provinces of the Tennessee Valley and the Tennessee River Watershed

Source: Tennessee Valley Authority. 1996a. *Shoreline Management Initiative: An Assessment of Residential Shoreline Development Impacts in the Tennessee Valley*. Norris, Tennessee. Technical Report No. TVA/RG/EM-96/4.

3. METHODS

3.1 Duration of the Study

Preliminary sampling occurred June - August 1994. Collections continued thereafter from September 10, 1994, through May, 18 1996; The data were recorded and analyzed for this project. Samples were taken about every two months during the late fall, winter, and early spring, and once every one to two weeks in the late spring, summer, and early fall. Fifty-six samples were collected on 24 days of the 20 month period.

3.2 Selection, Classification, and Location of Sample Sites

Characteristic and empirically common habitats were selected to maximize the potential diversity of phytoplankton sampled and to be ostensibly representative of the entire reservoir. The habitat characteristics of the sampling sites were generally classified as: embayment, cove, channel, and other. The classification of embayment refers to a wide, deep inlet, which does not become fully exposed as a mudflat during winter drawdown and is navigable by boat. The classification of cove refers to a narrow, shallow inlet, which becomes mostly exposed as a mudflat during winter drawdown and is not navigable by boat. The classification of channel refers to the main body of water in and around the original river channel, or area resembling the main channel, such as the less traveled side of an island located along the main channel. The classification category other (which is also used as a map reference name) includes: any samples whose precise collection location was not recorded, algae collected in a stagnant mudflat pool, algae collected in contact with the bottom substrate (benthic or

benthos), or algae collected on a retaining wall (periphyton-organisms on submerged substrates above the bottom) (Brower et al., 1990).

Table 3 provides the sample locations in terms of Tennessee River Miles (TRM), the local reference name, the number of samples taken at that site, and the assigned habitat description. The habitat description is not meant to be all-inclusive, but merely reflects the above described classifications and highlights the habitat characteristics which empirically influenced the extant phytoplankton community composition and diversity the most. A map showing each sampling location on WBR is provided in Figure 4. The map reference (Ref.) number(s) (#) in Table 3 correspond with the sample locations on the map.

3.3 Sample Collection

A Wisconsin-style plankton net (# 40-A50, obtained from Wildco Wildlife Supply Company) of 80 micron mesh size was used to collect phytoplankton. Duration of each boat trawl sample was between two and three minutes. Shoreline trawls or trawls executed standing on a dock consisted of ten throws of the plankton net extending approximately 7.62 m (25 ft) in all possible directions. The net was allowed to sink below the surface periodically to collect phytoplankton throughout the photic zone (3 m), characteristic of mainstream reservoirs (Placke, 1983).

The collecting procedure involved spraying the pulled net with ambient reservoir water to rinse organisms lodged in the mesh into the collecting chamber. Prompt examination of samples provided a reliable determination of the taxa present in the original conditions. If samples could not be examined the same day, they were

**Table 3 Sample Locations and Habitat Descriptions,
Watts Bar Reservoir,
East Tennessee**

Map Ref. #	TRM Location	Local Reference Name	# Samples Taken	Habitat Description
1	531.0	Lowe Branch	2	Wind-sheltered area of L.B. embayment; Wind-unsheltered area of L.B. embayment;
		other	1	Benthic sample only
2	542.5	Euchee Marina	2	Cove, wind-sheltered, warmer water, less nutrient input from lawn-fertilizers (more input from many moored boats); Embayment, wind-unsheltered, cooler water, more nutrient input from lawn fertilizers (less input from fewer moored boats)
3	576.7	cow cove	1	Cove, wind-sheltered, warmer water, high nutrients from cattle with observed access to reservoir water, no stream
4	577.4	Wilson Island	2	Channel side of island, deeper with more boat traffic; Opposite side, shallower with less boat traffic
5	580.0	mudflat	12	Cove, warmer water, further from allochthonous riparian input, no shade
6	580.1	riparian	12	Channel edge, closer to allochthonous riparian input, some shade
7	580.2	dock	4	Channel, with dock extending;
		other	2	Stagnant pool separated from WBR only in winter (annual dredging for boat launch);
		other	2	Benthic samples;
		other	2	Wall-dwelling periphyton
8	580.7	barn cove	7	Cove, some agriculture, no residential development, seldomly accessed by cattle, abutted by forest on one side and field on the other, no stream, low slope shoreline
9	582.3	Cave Creek	3	Embayment, cold water and other autochthonous stream input, abutted by SRRSZ
10	582.3	Cave Creek	3	Channel trawls taken across the mouth of Cave Creek embayment;
		other	1	Channel trawl, location not specified
Ten Ref. #'s	Range of Miles 51.3	Ten Reference Locations	Total # Samples 56	Specific, widespread habitats were selected to maximize the diversity of phytoplankton sampled and to be representative of the entire reservoir

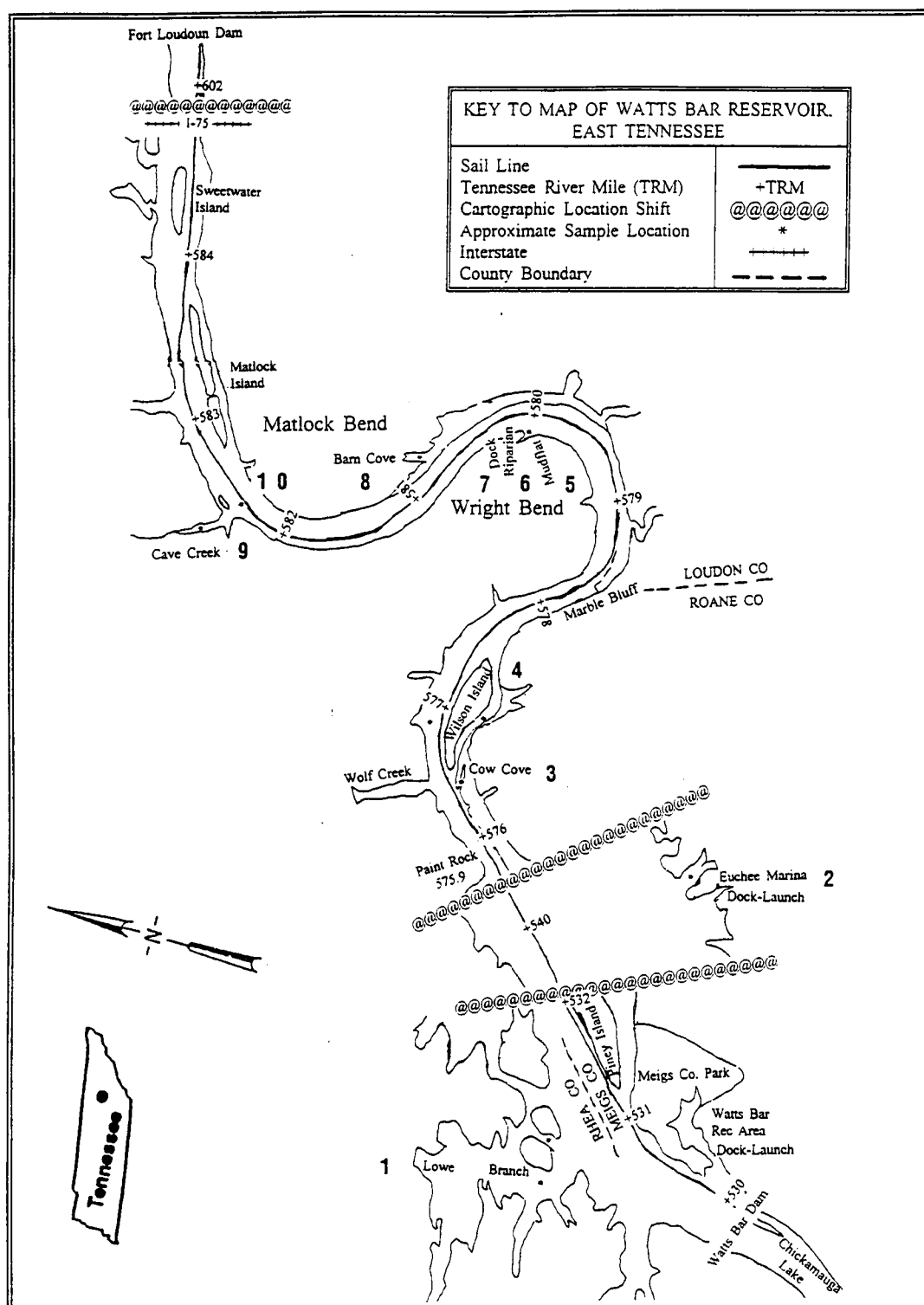


Figure 4 Location of Sampling Sites Established on Watts Bar Reservoir for Phytoplankton and Environmental Analyses Conducted from September 1994 through May 1996.

Adapted from: Atlantic Mapping, Inc. 1994. "Recreation and Fishing Guide: Watts Bar Lake." Marietta, Georgia.

preserved using 2% glutaraldehyde in 0.1 M cacodylate buffer in a pH of 7.2 and were refrigerated.

A container was used to obtain a surface water sample at each phytoplankton collection site. The pH, conductivity (parts per million, ppm), dissolved oxygen (DO) content (milligrams per liter, mg/L), were measured by small hand-held, digital-reading instruments. Water temperature (degrees Celsius, °C) was measured by a hand-held thermometer. Transparency (meter, m) was measured with a Secchi disc.

All the digital-reading instruments were calibrated before use. The sensors on the pH meters, Oakton Model pH Testr 1, were soaked in a pH buffer of 7.0 for 30 minutes and calibrated accordingly. The sensor on the conductivity meter, Oakton Model TDS Testr 1, was soaked in Conductivity Calibration Standards for 30 minutes and calibrated according to the temperature of the calibration solution. The sensors on the dissolved oxygen DO probes (Corning Modular Meter System equipped with a DO module) were soaked in zero oxygen solution (Mfg. Corning Diagnostics Inc.) for 30 minutes and calibrated accordingly.

The pH and conductivity were measured in an plastic container to increase repeatability of the measuring technique. Each instrument was rinsed with ambient reservoir water to remove any residual ions. After 30 seconds of agitating the instrument, so that the sensor had good contact with the water, the measurement was recorded when the reading steadied.

Two DO probes were used most of the time, but their readings rarely corresponded. Initially the DO sensor was placed in ambient water in an inert

container, and measurements were recorded. Later in the study, water was collected by slowly submersing a small plastic bottle until the bottle was filled to the top. The lid was placed on the container under water, being careful not to capture any air bubbles. The containers were taken to a stable area, where the DO measurements were taken. When this second method was applied, the readings on the meters correlated more closely. DO data were excluded from the results due to the unreliability of the DO meters in consistently and precisely recording dissolved oxygen.

Water temperature was measured just beneath the surface of the water under a shade. Secchi disc measurements were averaged between the depth where black and white were no longer discerned as lowered and the depth at which they became visible as raised (Cole, 1975). When possible, two pH meters, two conductivity meters, two DO probes, and two thermometers were used.

3.4 Sample Analysis

A Wild model M-11 compound microscope with 100, 200, and 400 total magnifications was used in algal identification. Three or more sub-samples from each collection bottle were analyzed for the composition of algae, (phytoplankton - floating photosynthetic plants, periphyton, and benthos, all in the size range of nano <20 μm and micro 20 - 200 μm). The relative abundance of living algae and zooplankton (any non-photosynthetic, zootomic biota), and their conspicuous activity (such as the seasonal mobility of *Fragilaria*) were also observed and recorded. Algae were identified to genera using various keys to freshwater algae and other sources were used for general references including: van den Hoek et al., 1995; Walne, 1991; Bold and Wynne, 1985;

Reynolds, 1984; Sournia, 1978; Crossman et al., 1977; Prescott, 1970; Whitford and Schumacher, 1969; Palmer, 1959; Forest, 1954; Smith, 1933.

Calculations of dominance, diversity, and evenness values of phytoplankton in WBR were based on the methods cited in Brower et al. (1990), as were phytoplankton community similarity comparisons calculated using Sørensen's and Jaccard's Similarity Indices. The Mann-Whitney test was also used to compare the distribution of genera among Divisions from WBR to selected southern reservoirs (Brower et al., 1990).

3.5 Limitations of the Study

This study reports the genera of phytoplankton collected at selected sampling sites from Watts Bar Reservoir. Omissions in taxonomic comprehensiveness may have occurred due to such factors as the aperiodic reservoir water-level dynamics, failure of physical sampling instruments, net mesh size, logistic and weather-related problems with sampling periodicity, and limiting phytoplankton sampling to within three meters of the surface and to a few exploratory benthic and wall-dwelling periphyton samples. Past studies by TVA found active phytoplankton growth primarily restricted to surface waters and the photic zone (as measured by a Secchi disc) was rarely found to extend below three meters in mainstream reservoirs (Placke, 1983). The photic zone (as measured by a Secchi disc), was never noted to exceed 1.5 m in this study.

4. RESULTS AND DISCUSSION

4.1 Phytoplankton Presence, Community Composition, and Diversity

One hundred and ten phytoplankton genera, representing five Divisions, were collected from Watts Bar Reservoir (WBR) during the 20 month study (Table 4). Approximately one-half (53) of these genera belonged to the Division Chlorophyta. The Division Chrysophyta was represented by 30 genera, Cyanophyta by 17 genera, and Euglenophyta and Pyrrophyta by five genera each. The relative occurrence (RO) of the Divisions and of all the genera identified in 56 samples is given in parentheses in Table 4.

Forty-two genera comprised ten percent or greater of the RO in 56 samples (Table 5). Table 4 shows that chlorophytes comprised 48.2% of the occurrences over the duration of the study. That is to say, in a given sample on a given day during the study, more chlorophytes were likely to be found than any taxa within any other Division. The chrysophytes followed with a RO of 27.3%. Cyanophytes, at 15.5%, comprised only half the number of occurrences as the chrysophytes. Euglenophytes (4.5%) had the same RO as the pyrrophytes (4.5%). The average number of occurrences per genus was 8.6 ($946/110$)¹ over 20 months (Appendix A).

Appendix A provides information about each genus and seasons. Of particular interest in Appendix A is the record of the number of times each genus occurred during

¹The reason that the total number of phytoplankton taxa in Table 6 (614) does not match the total in Appendix A (946), is that each genus was considered only once per sample day (24 days) in Table 6, whereas taxonomic occurrence in every sample (56 samples) was considered in Appendix A.

Table 4 Phytoplankton Genera Collected from Watts Bar Reservoir and Relative Occurrence of Divisions as Determined by Number of Genera Per Division Divided by Total Number of Genera (110) and Relative Occurrence of Each Genus as Determined by the Total Number of Samples in Which Each Genus Occurs Divided by the Total Number of Samples (56)

CHLOROPHYTA (48.2%)

Actinastrum (50%)
Ankistrodesmus (32.1%)
 **Arthrodesmus* (1.8%)
Asterococcus (16.1%)
Binuclearia (5.4%)
Botryococcus (3.6%)
Chaetosphaeridium (1.8%)
Chara (1.8%)
 **Characiochloris* (1.8%)
Chlamydomonas (8.9%)
Chlorella (1.8%)
 **Chlorosarcina* (8.9%)
Closterium (8.9%)
Coelastrum (10.7%)
Cosmarium (42.9%)
Docidium (1.8%)
Eudorina (12.5%)
Golenkinia (14.3%)
Gonium (1.8%)
Groenbladia (3.6%)
Hydrodictyon (1.8%)
Kirchneriella (10.7%)
 **Lauterborniella* (1.8%)
 **Malleleochloris* (1.8%)
Microsterias (1.8%)
Microspora (3.6%)
Mougeotia (5.4%)
Nephrocytium (1.8%)
Oedogonium (33.9%)
Oocystis (1.8%)
Pandorina (30.3%)
Pediastrum (76.8%)
 **Phyllobium* (3.6%)
Phymatodocis (3.6%)
 **Phytomorula* (1.8%)
Pleodorina (3.6%)
Pleurotaenium (3.6%)
 **Quadrigula* (3.6%)
Rhizoclonium (12.5%)
Scenedesmus (62.5%)
Selenastrum (3.6%)

**Sphaerellopsis* (3.6%)
Sphaerocystis (16.1%)
 **Sphaeroplea* (1.8%)
Spirogyra (39.3%)
 **Spondylomorrum* (1.8%)
Sorastrum (1.8%)
Staurostrum (32.1%)
Tetraedron (1.8%)
Ulothrix (10.7%)
Uronema (1.8%)
Volvox (14.3%)
Zygnema (1.8%)

CHRYSTOPHYTA (27.3%)

Amphipleura (1.8%)
Amphora (3.6%)
Asterionella (71.4%)
Bumilleria (53.6%)
Caloneis (1.8%)
 **Characidiopsis* (5.4%)
Chrysamoeba (1.8%)
Chrysosphaerella (1.8%)
Cyclotella (1.8%)
Cymbella (10.7%)
Dinobryon (25%)
Fragilaria (73.2%)
Gyrosigma (19.6%)
 **Lagynion* (1.8%)
Mallomonas (5.4%)
Melosira (73.2%)
Navicula (44.6%)
Opephora (1.8%)
 **Peroniella* (1.8%)
 **Phaeoplaca* (1.8%)
Rhipidodendron (1.8%)
Stephanodiscus (37.5%)
Stipitococcus (5.4%)
Surirella (5.4%)
Synedra (1.8%)
Synura (16.1%)
Tabellaria (58.9%)
 **Tetraedriella* (1.8%)

Tribonema (41.1%)

**Uroglenopsis* (1.8%)

CYANOPHYTA (15.5%)

Anabaena (55.3%)
Aphanocapsa (1.8%)
Arthrospira (10.7%)
 **Borzia* (1.8%)
Coelosphaerium (7.1%)
Dactylococcopsis (3.6%)
Gloeotheca (1.8%)
Gomphosphaeria (25%)
 **Heterohormogonium* (1.8%)
Lyngbya (8.9%)
Merismopedia (48.2%)
Microcystis (50%)
Nostoc (1.8%)
Oscillatoria (53.6%)
 **Schizothrix* (3.6%)
Spirulina (23.2%)
 **Tetrapedia* (1.8%)

EUGLENOPHYTA (4.5%)

Euglena (60.7%)
Eutreptia (1.8%)
Lepocinclis (1.8%)
Phacus (26.8%)
Trachelomonas (17.8%)

PYRRHOPHYTA (4.5%)

Ceratium (39.3%)
Glenodinium (5.4%)
Gymnodinium (32.1%)
 **Oodinium* (1.8%)
Peridinium (1.8%)

* Indicates uncertainty in identification. Asterisked taxa resembled the recorded genus, and can be noted, for instance, as *Arthrodesmus*-like.

Table 5 Forty-Two Phytoplankton Genera Comprising a Relative Occurrence of Ten Percent or Greater in Fifty-Six Samples from Watts Bar Reservoir

80-60%	Genus	59-40%	Genus	39-20%	Genus	19-10%	Genus
76.8	<i>Pediastrum</i>	58.9	<i>Tabellaria</i>	39.3	<i>Spirogyra</i>	19.6	<i>Gyrosigma</i>
73.2	<i>Fragilaria</i>	55.3	<i>Anabaena</i>	39.3	<i>Ceratium</i>	17.8	<i>Trachelomonas</i>
73.2	<i>Melosira</i>	53.6	<i>Bumilleria</i>	37.5	<i>Stephanodiscus</i>	16.1	<i>Asterococcus</i>
71.4	<i>Asterionella</i>	53.6	<i>Oscillatoria</i>	33.9	<i>Oedogonium</i>	16.1	<i>Sphaerocystis</i>
62.5	<i>Scenedesmus</i>	50.0	<i>Actinastrum</i>	32.1	<i>Ankistrodesmus</i>	16.1	<i>Synura</i>
60.7	<i>Euglena</i>	50.0	<i>Microcystis</i>	32.1	<i>Staurastrum</i>	14.3	<i>Golenkinia</i>
		48.2	<i>Merismopedia</i>	32.1	<i>Gymnodinium</i>	14.3	<i>Volvox</i>
		44.6	<i>Navicula</i>	30.3	<i>Pandorina</i>	12.5	<i>Eudorina</i>
		42.9	<i>Cosmarium</i>	26.8	<i>Phacus</i>	12.5	<i>Rhizoclonium</i>
		41.1	<i>Tribonema</i>	25.0	<i>Dinobryon</i>	10.7	<i>Coelastrum</i>
				25.0	<i>Gomphosphaeria</i>	10.7	<i>Kirchneriella</i>
				23.2	<i>Spirulina</i>	10.7	<i>Cymbella</i>
						10.7	<i>Arthrospira</i>
						10.7	<i>Ulothrix</i>

Table 6 Number of Phytoplankton Genera in Watts Bar Reservoir Occurring Per Sample Day
in Each Division, Total Number of Genera Occurring Per Sample Day,
and Total and Percent of Genera in Each Division

Division	9/10	10/29	11/12	1/14	3/22	3/31	5/18	5/25	6/9	6/17	7/1	7/9	7/29	8/5	8/9	8/19	8/26	9/7	9/16	9/23	10/21	10/28	12/2	5/18	Total	%
Chlorophyta	4	12	12	6	1	7	13	16	9	15	8	11	12	7	14	12	17	11	5	13	14	7	9	6	241	39.2
Chrysophyta	3	9	8	8	6	8	7	4	5	12	6	9	12	7	10	11	10	10	9	7	10	9	11	11	202	32.9
Cyanophyta	3	3	3	4	2	2	3	1	0	4	3	4	8	3	8	8	10	8	2	6	4	5	4	6	104	16.9
Euglenophyta	0	2	4	1	1	1	2	2	0	2	0	2	1	1	2	3	3	1	0	1	3	1	3	1	37	6
Pyrrophyta	1	2	2	0	1	0	2	0	2	1	0	2	2	1	1	2	3	0	2	2	3	0	1	0	30	5
Total	11	28	29	19	11	18	27	23	16	34	17	28	35	19	35	36	43	30	18	29	34	22	28	24	614	100

the study, along with the frequencies of seasonal occurrence and the ranges of environmental factors, pH, conductivity, and temperature, in which each genus occurred. In order to derive statistical information for the purpose of describing diversity from the data on phytoplankton occurrence gathered in this study, an analogy was drawn between occurrence and abundance. Since the data on phytoplankton occurrences resembled the hypothetical set of species abundance data in Brower et al. (1990), values for calculating various diversity indices were altered in the following ways:

1. # each individual species (i) was substituted with # each individual genus (i)
2. total # species (s) was substituted with total # genera (g) (total = 110)
3. abundance of each individual species (n_i) was substituted with occurrence of each individual genus (n_i)
4. total species abundance (N) was substituted with total genus occurrence (O) (total = 946)
5. relative species abundance (p_i) was substituted with relative genus occurrence (p_i).

Various diversity indices were adapted to determine dominance and evenness (measures of diversity) using occurrences rather than abundances, and using the previously described substitutions. The adapted diversity indices and calculations from Brower et al. (1990) are described (also refer to Appendix A) as follows:

A. Dominance and Derivatives Thereof

1. Simpson dominance, l

$$l = \frac{\sum n_i^2 - O}{O(O - 1)} = \frac{22,030 - 946}{946(946 - 1)} = \frac{21,084}{893,970} = 0.0236$$

2. Simpson diversity, D_s

$$D_s = 1 - l = 1 - 0.0236 = 0.976$$

3. Inverse of l , d_s

$$d_s = 1/l = 1/0.0236 = 42.37$$

4. $1 - E_s$ (an expression of dominance), see below $= 1 - 0.984 = 0.016$

5. $1 - e_s$, (an expression of dominance) see below $= 1 - 0.341 = 0.659$

B. Evenness and Derivatives Thereof

1. Evenness (E_s), using D_s

$$D_s \text{ (Simpson diversity)} = 1 - l = 1 - 0.0236 = 0.976$$

$$D_{max} \text{ (maximum } D_s) = \frac{g-1}{g} \times \frac{O}{O-1} = \frac{110-1}{110} \times \frac{946}{946-1} = 0.992$$

$$E_s = D_s/D_{max}, \text{ where } 0.976/0.992 = 0.984$$

2. Evenness (e_s), using d_s

$$d_s \text{ (inverse of } l) = 1/l = 1/0.0236 = 42.37$$

$$d_{max} \text{ (maximum } d_s) = \frac{g(O-1)}{O-g} = \frac{110(946-1)}{946-110} = 124.3$$

$$e_s = d_s/d_{max}, \text{ where } 42.37/124.3 = 0.341$$

Results of the various indices that reflect measures of diversity are presented in Table 7². These results were evaluated and discussed according to Brower et al. (1990). Dominance as determined by Simpson's index expresses the probability that randomly collected individuals from a community would belong to the same "genus." The value calculated for dominance in this study was near zero ($l = 0.0236$), which

²Sample sites in this study were systematically selected rather than randomly selected, so conclusions drawn from these indices may be biased.

Table 7 Results of Phytoplankton Diversity Calculations for Dominance and Evenness for Watts Bar Reservoir

Diversity Indices	Value
Number of "genera" (g)	110
Number of "Occurrences" (O)	946
l , Simpson dominance	0.0236
D_s , Simpson diversity	0.976
d_s , inverse of l	42.37
D_{max} , maximum D_s	0.992
E_s , evenness, using D_s	0.984
d_{max} , maximum d_s	124.3
e_s , evenness, using d_s	0.341
$1 - E_s$	0.016
$1 - e_s$	0.659

Adapted from: Brower, J.E., J.H. Zar, and C.N. von Ende. 1990. *Field and Laboratory Methods for General Ecology*, 3rd ed. Wm. C. Brown Publishers, Dubuque, Iowa.

signifies that there was a very low chance of randomly collected individuals belonging to the same "genus." Consequently, this low dominance reflected high diversity ($1 - I = 0.976$). According to the inversion of Simpson's dominance index, one would have to sample about 42 pairs of individuals at random from the "entire aggregation" to assemble a pair that belonged to the same "genus." Levins proposed the inversion described above to be a measure of niche breadth (Brower et al., 1990).

An advantage of Simpson's indices is that they consider the number of taxa ("genera" (g) in this case), the total number of individuals ("occurrence(s)" (O) in this case), and the proportion of the total "occurrences" encompassed by each "genus." Hulburt in Brower et al. (1990), however, "severely criticizes most diversity indices," but credits D_s (a measure of evenness) "as being biologically meaningful" when it is referred to as "the probability of interspecific encounter." In this study the probability of a member of one "genus" in the phytoplankton community encountering (being found with) a member of a different "genus" is very high (0.976).

Evenness in this study refers to how evenly the number of "occurrences" of a given individual phytoplankton "genus" was spread throughout all the "genera," while considering the maximum possible values for a given "O" and "g," so that maximum diversity occurred when the individuals were "distributed as evenly as possible among the [genera]." For simplicity the values of evenness E_s and e_s were subtracted from one to arrive at "an expression of dominance." Low dominance was reflected by a value near zero, which was the case for $1 - E_s$ (0.016). Again, low dominance reflects high diversity (Brower et al., 1990).

Table 1 compares the characteristics of TVA's mainstream and tributary reservoirs. Phytoplankton communities in the four mainstream reservoirs (out of 15 total reservoirs evaluated in the early 1980's), tended to remain diversified in the summer and showed a lower apparent algal abundance, than in the tributary reservoirs. Placke (1983) writes that "based on the limited number of samples collected, the amplitude of seasonal variations in algal abundance and composition appears attenuated in the [mainstream] reservoirs as compared to the tributary reservoirs." In conclusion, the results of the various diversity indices from this study on WBR (Table 7) agree with Placke's general conclusions for mainstream reservoirs: i.e., WBR, a mainstream reservoir, showed high algal diversity, but low densities for any one genus.

4.2 Influence of Seasonal Phenomena

"Atmospheric conditions control the climate, season, and daily weather conditions" (Brower et al., 1990). Season as defined in Webster's Dictionary, 1960, is "any one of the four arbitrary divisions of the year, characterized chiefly by differences in [phenomena] temperature, weather, number of hours of daylight, and growth of plants; spring, summer, fall, or winter." The dates of the seasons and number of sample days in each season per year for this study are indicated as follows:

<u>Season</u>	<u>Dates</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>
Summer	Jun 21 - Sep 21	1	9	0
Fall	Sep 22 - Dec 20	2	4	0
Winter	Dec 21 - Mar 19	0	1	0
Spring	Mar 20 - Jun 20	0	6	1

For the 24 sample days the phytoplankton genera were organized and totaled by Division (including only a single representative genus per day from multi-samples to

maximize the detection of seasonal phenomena influences), and Table 6 and Figure 5 were devised. Selected, pronounced trends, including Divisional: dominance, highest and lowest occurrence, parallelism, and parallel and/or divergent occurrences, are discussed in chronological order over the 20 month study (4.2.1). Community similarity indices, developed by Sørensen and Jaccard, are used to compare total seasonal occurrences (4.2.2). Genus-specific characterizations are provided in Appendices A and B including, total # of occurrences, % of those occurrences/season, and ranges of physio-chemical conditions in which each genus was found (4.2.3).

4.2.1 Divisional Analysis

An overview of the influence of seasonal phenomena on phytoplankton in a Divisional analysis is presented in Figure 6, which shows seasonal relative occurrence (RO) by Division (as calculated from Table 6 by grouping seasonal dates over 1994, 1995, and 1996).

Chrysophytes were found in their lowest Divisional occurrence (three) on September 9, 1994 (Figure 5). Chrysophytes exhibited Divisional dominance over chlorophytes during a decline of chlorophyte occurrences, starting on January 14, 1995 and extending through March 31, 1995. Though frequent intermittent taxonomic occurrences were not documented between November 12, 1994 and March 22, 1995, it appears that chlorophyte occurrences declined at a steady rate from 12 to their lowest Divisional occurrence (one). Conditions were empirically favorable for the highest Divisional occurrence of euglenophytes on November 12, 1994.

Chrysophytes dominated in the winter at 42.1%, followed by the chlorophytes

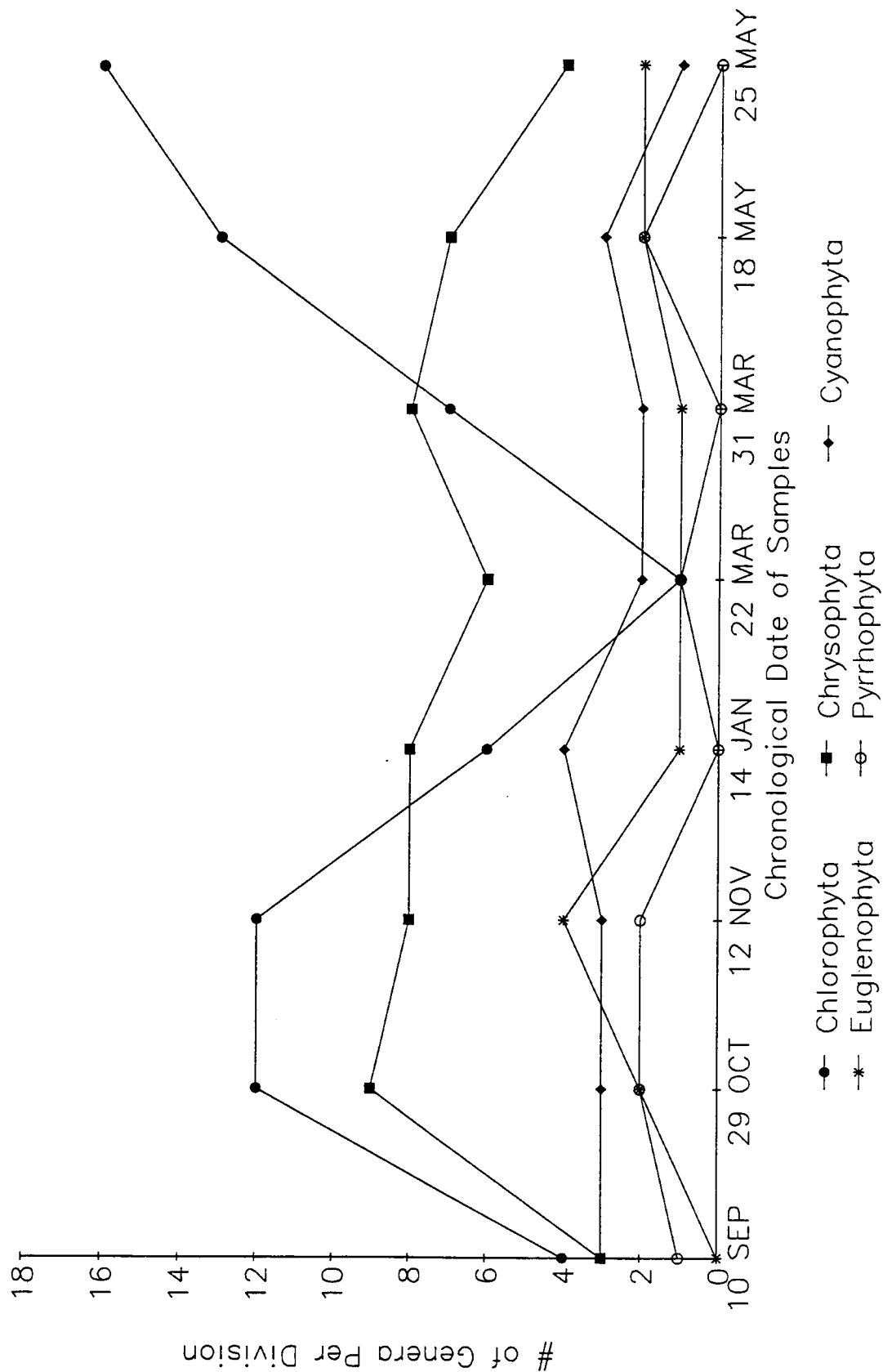


Figure 5 Daily Variability in Occurrence of Phytoplankton of Watts Bar Reservoir by Division

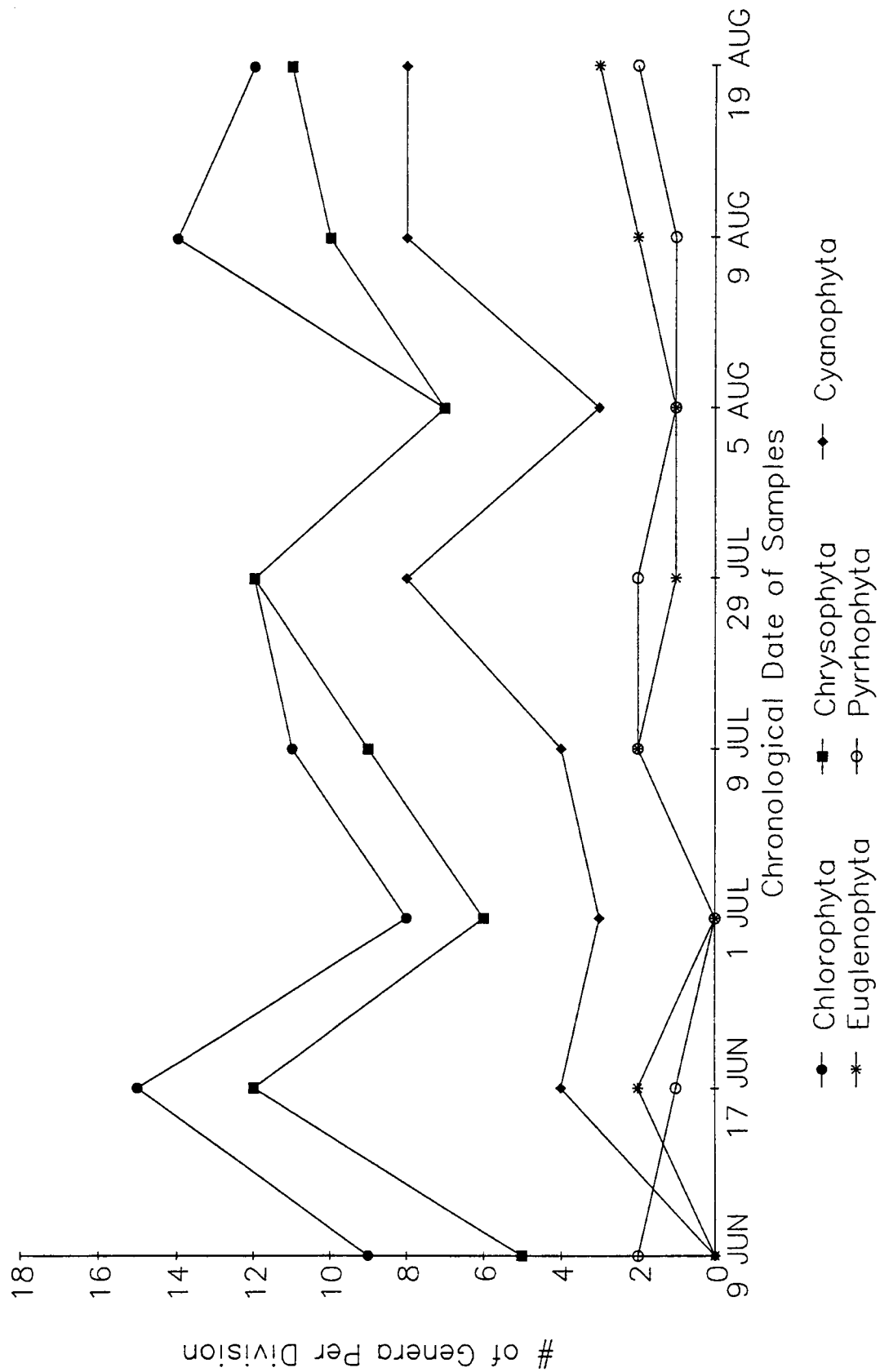


Figure 5 (continued)

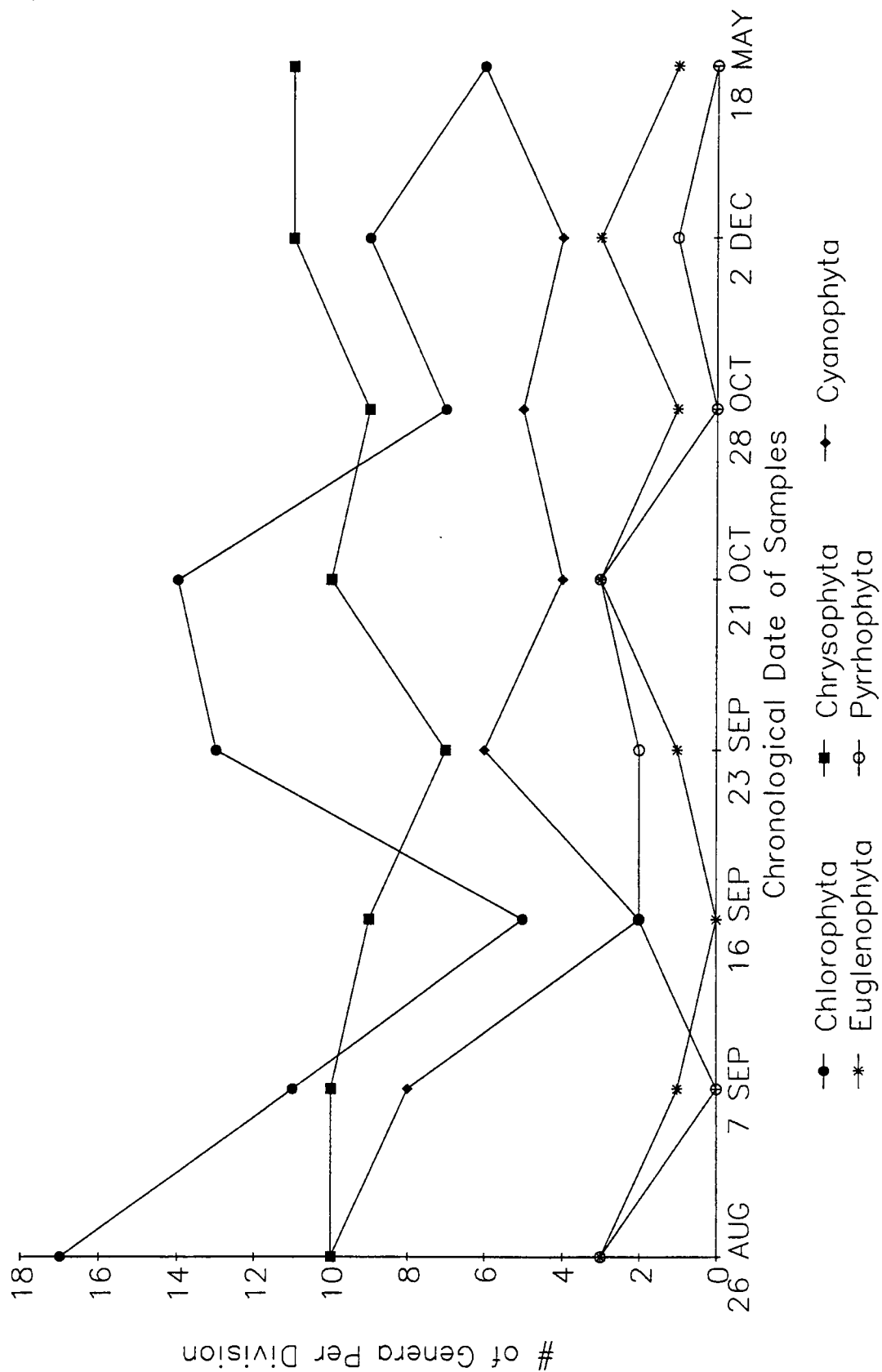


Figure 5 (continued)

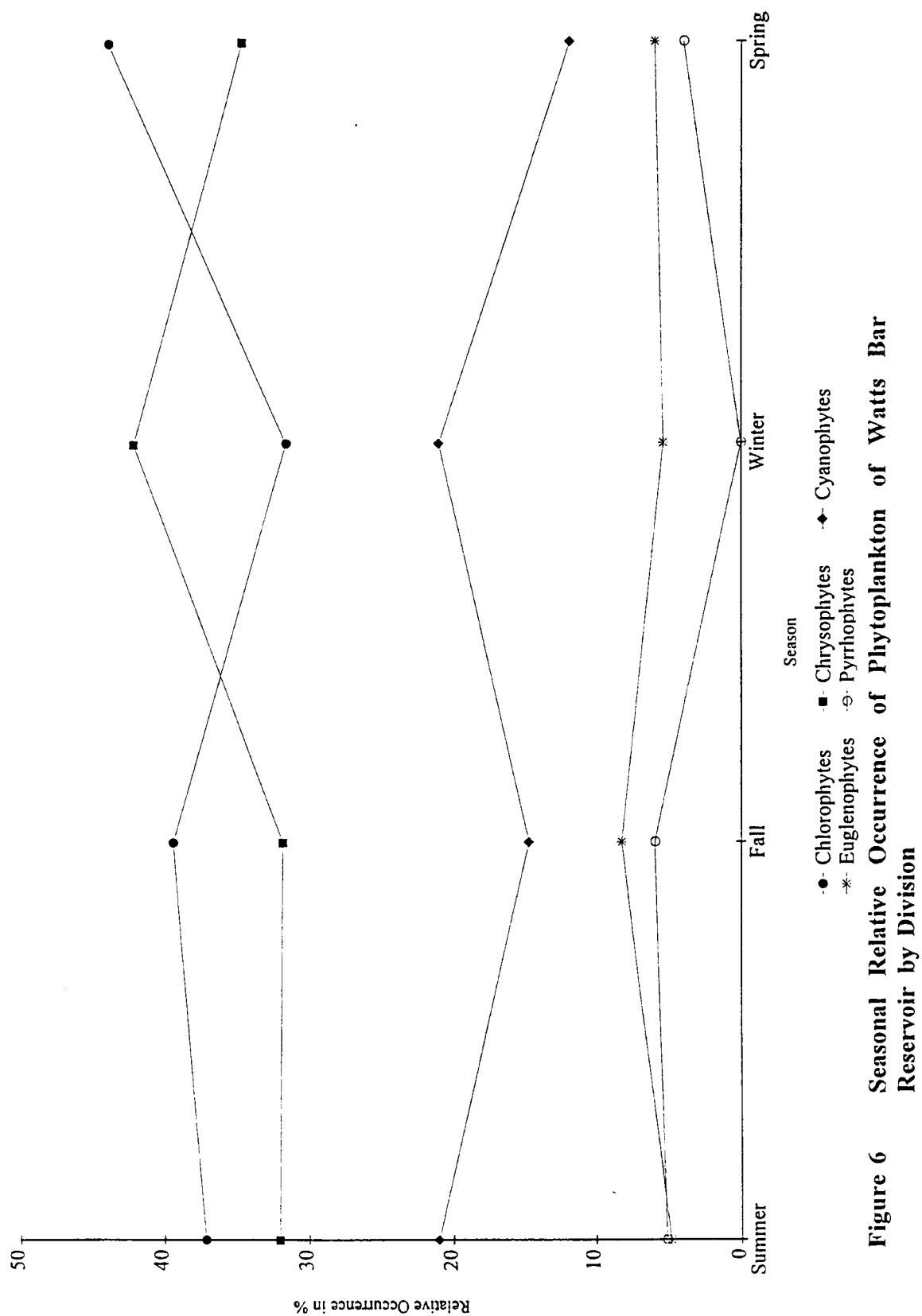


Figure 6 Seasonal Relative Occurrence of Phytoplankton of Watts Bar Reservoir by Division

at 31.6%, the cyanophytes at 21.0%, and the euglenophytes at 5.3%. No pyrrhophytes were found on the winter sample date. Chrysophytes, as assigned to a Class under the Division Heterokontophyta by van den Hoek et al. (1995), were formerly considered to prefer cold water, but culture experiments of certain species demonstrated that their optimum temperature for growth "greatly" exceeded the temperatures at which they were collected naturally. van den Hoek et al. conclude that "the correlation with low temperatures is therefore likely to be at best indirect." Stevenson et al. (1996) in *Algal Ecology* provide an in-depth examination of periphyton responses to seasonal phenomena and states that "Partial review of temperature effects on freshwater phytoplankton can be found in Hutchinson (1967), Fogg (1975), and Reynolds (1984)." Finding no pyrrhophytes on the winter sample date was expected since, according to van den Hoek et al. (1995), pyrrhophytes "tend on the whole to be more predominant in warm water communities."

Conditions preferred by chlorophytes improved around the end of March and steadily increased from the Divisional low in chlorophyte occurrence (one) to 16 in two months as shown in Figure 5. Chrysophytes showed a general decline from March 31 through June 9, followed by two Divisional highs on June 17 and July 29, as compared to a single notable peak of chrysophytes in Wilson Reservoir in June (Wade, 1984). June 9 was also the only study day in which cyanophytes were not found, which might in part be explained by a two week period of cloudiness (Appendix C).

Two notable declines apparent for all Divisions can be observed in Figure 5 on July 1 and August 5, which might be explained by cloudiness and zooplankton

herbivory (Appendix C). Divisional parallelism (similar sequence of rises and falls) generally exists between June 9 and August 19. The sample day of August 26 was a highlight in the study because, chlorophytes showed the highest Divisional and study occurrence (17), and cyanophytes were found most frequently on this day (10), compared to the other sample days. The highest total number of phytoplankton genera (per sample day) was found on August 26 (43), which was unexpected because the weather was cloudy and rainy (Appendix C). Conditions on August 26 must have also been favorable for the pyrrhophytes, which had one of two of their highest recorded occurrences (the other peak was October 21) (Table 6). The number of chlorophyte occurrences along with those of cyanophytes, euglenophytes, and pyrrhophytes declined after August 26, followed by another peak around the onset of fall (Figure 5). The number of chlorophyte occurrences dropped off through December, which left the chrysophytes dominating once more. According to Lund, as cited in Ridley and Steel (1975), chrysophytes have a tendency to tolerate lower temperatures as long as they have adequate light.

A long-term trend in the daily (sample days) occurrences of cyanophytes and pyrrhophytes was observed in Figure 5. Their occurrences seemed to follow a "somewhat parallel" pattern from March 31 through September 7, but after September 7 seemed to follow a "somewhat divergent" pattern. A runs test for trend data was performed according to Sokal and Rohlf (1995) and is shown in Figure 7. If cyanophytes and pyrrhophytes followed a parallel pattern in Figure 5, such as staying the same, both increasing, both decreasing, or one staying the same and one increasing

Day	1	2	3	4	5	6	7	8	9	10
Parallel or Divergent Runs		-	+	-	-	-	+	+	-	-
		—	—	—	—	—	—	—	—	—
Day	11	12	13	14	15	16	17	18		
Parallel or Divergent Runs	+	+	-	+	-	+	+	+		
	—	—	—	—	—	—	—	—		
Day	19	20	21	22	23	24				
Parallel or Divergent Runs	-	-	-	-	-	-				
	—	—	—	—	—	—				

$$t_s = \frac{r - Ur}{r} = \frac{r - [(2n - 1)/3]}{(16n - 29)/90}$$

$$t_s = \frac{11 - [(2(23) - 1)/3]}{(16(23) - 29)/90}$$

$$t_s = \frac{-4}{3.766} = -1.06$$

Statistical Table BB concludes that at $n = 23$, 11 runs (r) are significant at the 0.05 level.

Figure 7 A Runs Test to Determine Randomness in the Occurrence of Cyanophytes and Pyrrhophytes from Watts Bar Reservoir

Sources: Rohlf, F.J. and R.R. Sokal. 1995. *Statistical Tables*, 3rd ed. W.H. Freeman and Co., New York, New York.
 Sokal, R.R. and F.J. Rohlf. 1995. *Biometry*, 3rd ed. W.H. Freeman and Co., New York, New York.

towards it, the interval between the two sampling days was rated positive. If one decreased and the other increased, or if one stayed the same and the other increased or decreased away from it, the interval between the sampling days was rated negative. Following this scheme, 11 runs "sets of like signs preceded or followed by unlike signs" were identified. Since the number of runs (11) was equal to the critical value (11) in Table BB (Rohlf and Sokal, 1995) for $n = 23$, "the hypothesis of random arrangement of successive differences" was rejected "with a one-tail type I error rate" of 0.05 or 1 - 0.95 (Sokal and Rohlf, 1995). The results imply that the observed patterns of "somewhat parallel" followed by "somewhat divergent" are not random, but present a trend which (other than the possibility of specific features that characterize these algae, such as heterotrophic tendencies or nitrogen converting abilities) cannot be explained by the measured or observed environmental conditions recorded in this study or from the tests applied.

A typical "spring maximum" for diatoms, which did not occur in this study until three days before summer, was described in *Phytoplankton Manual* edited by Sournia (1978) and in Wade (1984), who studied phytoplankton on Wilson Reservoir (a mainstream reservoir downstream from WBR on the Tennessee River). Placke's publication (1983) provides a description of seasonal phytoplankton dynamics (as discussed according to the dominance of individual genera) for each of the fifteen reservoirs included in the study. From these dynamics it was concluded that chrysophytes, along with chlorophytes, persisted throughout the summer in most of the mainstream TVA reservoirs. Cyanophytes were less dominant in mainstream than in

TVA's tributary reservoirs. The seasonal phytoplankton dynamics found for WBR were qualitatively most similar to the mainstream reservoirs (included in Placke's 1983 study): Chickamauga, which abuts Watts Bar Dam downstream, and to a lesser extent, Fort Loudoun, immediately above WBR. WBR's seasonal phytoplankton dynamics were qualitatively most similar to the tributary reservoirs: Norris and Chatuge (Placke, 1983).

4.2.2 Community Analysis

The influence of seasonal phenomena on phytoplankton in a community analysis was examined using Sørensen's and Jaccard's community similarity indices. According to Brower et al. (1990) "the value of CC_j or CC_s ranges from 0 (when no species are found in both communities) to 1.0 (when all species are found in both communities)." Six phytoplankton community comparisons resulted and are presented in order of descending similarity in Table 8. The equations were adapted to include genera (g) in place of species and are denoted as follows:

1. Sørensen coefficient of community

$$CC_s = 2c/(g)_1 + (g)_2, \text{ where}$$

c = the number of "genera" (g) common in both communities

$(g)_1$ = the number of (g) in community 1

$(g)_2$ = the number of (g) in community 2

2. Jaccard coefficient of community

$$CC_j = c / (g)_1 + (g)_2 - c, \text{ where}$$

c = the number of (g) common in both communities

$(g)_1$ = the number of (g) in community 1

$(g)_2$ = the number of (g) in community 2

Table 8 Seasonal Phytoplankton Community Similarity Indices for Watts Bar Reservoir

Seasonal Combination	$(g)_1$	$(g)_2$	c	Sørensen's Index	Jaccard's Index
Summer & Fall	75	71	49	.671	.505
Spring & Fall	55	71	42	.667	.500
Spring & Summer	55	75	39	.600	.429
Winter & Spring	19	55	16	.432	.276
Winter & Summer	19	75	17	.362	.221
Fall & Winter	71	19	16	.355	.216

Note: Data for $(g)_1$, $(g)_2$, and c were derived from Appendix A.

The number of genera that occurred in the summer and fall was probably most similar because the summer continued into the fall without any drastic changes in environmental conditions. Spring and fall assemblages possessed the next degree of similarity because temperatures and perhaps other seasonal phenomena were similar (spring temperature average was 22.9 °C and fall temperature average was 17 °C). The cyanophytes and chlorophytes seemed to respond to the similar spring and fall conditions as witnessed by the number of Divisional occurrences (Figure 5), as well as by individual genera, such as the cyanophyte *Dactylococcopsis*, and the chlorophytes,

Kirchneriella and *Quadrigula* (Appendix A). The spring and summer assemblages had a lower similarity because of prolonged benefits (to the evolving summer algal assemblages), apparent in Figure 5, of continuous higher summer temperatures (summer average temperature was 26.8 °C) and from the nutrient influx resulting from the spring pool level rise. These accumulating benefits were unattainable by the emerging spring assemblage. Winter and spring assemblages for a similar reason did not have the benefits of optimum, environmental conditions, so the winter population continued into the spring with a very similar community assemblage. Summer and winter assemblages were more similar than fall and winter assemblages, because the winter population was primarily composed of seasonal generalists that were present in every season, such as *Pediastrum*, *Merismopedia*, and *Gyrosigma*, whereas conditions incident in the fall community, as indicated in this study, offered a prime environment for seasonal specialists, such as *Sorastrum*, *Zygnema*, and *Perionella* (Appendix A). Summer and winter assemblages may have been more similar than the fall and winter assemblages due to the failure to encyst or become dormant by certain genera, usually triggered by low temperatures or unfavorable conditions; most notably, members of the Divisions Euglenophyta (*Euglena*) and Pyrrophyta (*Peridinium*) by encystment, and members of the Divisions Cyanophyta (*Anabaena* and *Nostoc*) and Chlorophyta (*Chlamydomonas*) by formation of akinetes (Bold and Wynne, 1985). *Euglena*, *Anabaena*, and *Chlamydomonas*, common to summer assemblages, were identifiably (may also have been present as unidentified akinetes/cysts) present on the January sampling day, which indicates unfavorable conditions to motivate encystment or dormancy in these genera.

4.2.3 Genera Analysis

The influence of seasonal phenomena on phytoplankton in an analysis of genera was examined in Appendix A, which contains genus-specific characterizations including, total # of occurrences over all samples per day, % of those occurrences per season, and ranges of physio-chemical conditions in which each genus was found. All the genera with more than a 50% RO (relative occurrence) thrived in all four seasons, and usually occurred abundantly in the full range of pH, conductivity, and temperature recorded in the study, and were therefore considered the dominant algae of WBR (Table 5 and Appendices A and B). The genera occurring in all four seasons were considered seasonal generalists, because they seemed to thrive across a diverse range of environmental conditions. Genera that were present in only one season were considered seasonal specialists, in that they apparently developed best in the environmental conditions characteristic of that season. For example, spring and fall occurring genera (*Kirchneriella* and *Cymbella*) probably preferred the similar temperatures and perhaps other seasonal phenomena characteristic of spring and fall, whereas those that occurred in spring, fall, and also summer (*Microcystis* and *Cosmarium*) showed a preference for higher temperatures (summer average temperature was 26.8 °C) in general, and tolerated summer temperatures reaching a maximum of 30 °C. *Caloneis* and *Microspora* were found only during the winter in lower temperatures (11 °C). According to Ruttner and Findenegg as cited in Ridley and Steel (1975), "Some classes of algae require a relatively narrow range of water temperature for maximum growth and reproduction, whilst others are tolerant to wide variations."

4.3 Influence of Habitat Dynamics

The habitat in which phytoplankton were sampled, and the physical, chemical, and biological dynamics active in those locations may be considered in different scales, such as: macroscale, mesoscale, and microscale (Thornton et al., 1990).

On the macroscale level concerning WBR, the following can be considered: climatology (reoccurring weather pattern resulting from geographic location); topography (lay-out and characteristics of reservoir due to location in reservoir system, like mainstream as opposed to tributary); geology (local soil and rock types and their contribution or hindrance to reservoir aquatic health); geography (land and water use and population distribution); and hydrology (the drainage area of the Tennessee River Basin, the drainage area above the dam, and the local watershed). WBR, on the Tennessee River, belongs to a multiple reservoir system, as do those on the Colorado, Columbia, Missouri, and White River systems (Thornton et al., 1990).

The mesoscale level involves the consideration of the reservoir on an individual level, such as longitudinal gradients within idealized reservoirs that can be divided into three zones: riverine (omitted from TVA zone descriptions), transition, and lacustrine (also referred to as forebay by TVA), as described by Thornton et al. (1990). WBR, atypical of idealized reservoirs, may possess some characteristics typical of those zones. WBR, however, receives most of its total flow (65.5%) from the Tennessee River, which is dammed upstream of WBR by Fort Loudoun Dam (Cheek et al., 1983), unlike the idealized reservoirs with "one or two major tributaries located a considerable distance from the dam" (Thornton et al., 1990). Piney River, one of Watts Bars major

adjoining tributaries, is located in the forebay area near the dam. Two other major tributaries, the Clinch River and the Emory River, account for 19% and 5% of Watts Bars total flow, respectively (Cheek et al., 1983).

The microscale level within a reservoir includes physical properties, such as temperature, conductivity, and transparency; chemical properties, such as pH and DO content; and their influence on biological entities, such as phytoplankton assemblage and associations.

Phytoplankton habitat dynamics in this study were considered mainly on the meso- and microscale levels. Specific, but empirically common habitats were selected to maximize the potential diversity of phytoplankton sampled and to be ostensibly representative of the entire reservoir. The habitats were generally classified and previously described as: embayment, cove, channel, and other. Phytoplankton community similarities from selected habitat locations were examined and ranked from most similar to least similar (Table 9), using Sørensen's and Jaccard's community similarity indices (Brower et al., 1990), whose calculation, alteration, and significance were previously described. The physio-chemical factors dynamic in those locations at the time of sampling are indicated in Table 10. The locations (from Table 3) selected for community similarity comparisons (Table 9) are indicated below:

- 1) Comparison between the two samples collected a wind-unsheltered (WUS) area and a wind-sheltered (WS) area of Lowe Branch embayment
- 2) Comparison between the two samples collected at Euchee Marina cove and embayment
- 3) Comparison between the two samples collected at Wilson Island main channel (MC) side and opposite channel (OC) side

- 4) Comparison between the three cumulative samples collected at Cave Creek embayment and three cumulative samples across the mouth of Cave Creek in the channel (C)
- 5) Comparison between the twelve cumulative samples collected at the mudflat cove and riparian channel shoreline areas
- 6) Comparison between twelve cove-embayment cumulative samples (a trawl in Euchee cove, seven barn cove trawls, and three Cave Creek embayment trawls, and a trawl in cow cove) and five channel cumulative samples (one from the main channel side of Wilson Island and the four channel trawls mentioned in Table 3 at Map Ref. # 10)
- 7) Comparison between four dock-collected channel cumulative samples and two stagnant pool cumulative samples
- 8) Comparison between four dock-collected channel cumulative samples and all five benthic and wall-dwelling periphyton samples

Table 9 Phytoplankton Community Similarity Comparisons between Selected Sample Locations on Watts Bar Reservoir

Comparisons & Rank in ()	Map Ref. #	WBR Location	(g) ₁	(g) ₂	c	CC _s	CC _i
1 (6)	1	Lowe Branch, WUS/WS	24	11	8	.457	.296
2 (5)	2	Euchee Marina, cove/embayment	31	21	18	.692	.529
3 (4)	4	Wilson Island, MC/OC	30	25	20	.727	.571
4 (2)	9/10	Cave Creek, embayment/C	48	41	34	.764	.618
5 (1)	5/6	mudflat/riparian	52	52	40	.769	.625
6 (3)	1,3,8,9/ 4,10	cove-embayment/ channel	60	54	43	.754	.606
7 (7)	7/7	dock/stagnant pool	33	21	12	.444	.286
8 (8)	7/1 + 7	dock/benthic + wall	33	22	12	.436	.279

Note: Data for (g)₁, (g)₂, and c were derived from Appendix C.

**Table 10 Habitat Dynamics at Sample Sites Selected for Phytoplankton
Community Similarity Comparisons
on Watts Bar Reservoir**

Map Ref. #	WBR Location (local reference name)	pH	Cond. ppm	Temp °C	Secchi m	Water Level ft
1	Lowe Branch, WUS/WS	7.8, 7.8	210, 185	23, 23	.63, 1.14	740
2	Euchee Marina, cove/embayment	8.2, 8.0	170, 150	19, 18	1.14, 1.14	740
4	Wilson Island, MC/OC	7.8, 7.8	150, 160	26, 26	---- ----	741.4
9/10	Cave Creek, embayment/C	7.76, 7.51	200, 153.3	26.6, 26.8	.406, .406	740.6
5/6	mudflat/riparian	7.43	138	20.5	----	738.4
1,3,8,9/ 4,10	cove-embayment/ channel	7.96, 7.7	155.5, 147.8	24.8, 22.9	.578, .406	740
7/7	dock/ stagnant pool	8.0, 7.8	133.3, 160	25.6, 11.5	.61, ----	740.4, 736

Note: Data were derived from Appendix C. The order the physio-chemical factors appear in Table 10 corresponds to the order they are described in the habitat description in Table 3, except for combined cumulative comparisons. Physio-chemical factors were not specifically measured for benthos or periphyton sample areas. Separate mudflat and riparian physio-chemical factors were not recorded for most of the study (Appendix C), so factors were averaged for the mudflat. Physio-chemical data for the mudflat is lacking for two of the twelve sample days. Water levels were included in Table 10, but were not considered to be important in influencing phytoplankton, except for the dock and stagnant pool comparison. Averages were calculated where necessary.

Nearly all compositional comparisons for which selected community comparisons were made, were almost 50% or more similar to their corresponding community. The mudflat and riparian communities were the most similar, which was expected since the sampling sites were only about 54 m apart. *Dinobryon* seemed to prefer the mudflat cove area (shallow, further from allochthonous riparian input with less shade), where it was found six times compared to the riparian near-shore channel area where it was found only twice.

The comparison shows communities in the embayment of Cave Creek and in the channel outside the embayment ranked next in similarity. This was expected because the embayment waters connected directly with the channel with no barriers, such as an island or a peninsula. The pH and conductivity averages were higher in the embayment than in the channel. The generally higher pH in the embayments (and coves) can be explained in part by some phytoplankton's ability to "successively absorb CO₂, eliminate bicarbonates, and form hydroxyl ions. All these events account for rises in pH" (Cole, 1975). Placke (1983) reports the following from studies cited below involving conductivity: strong correlations between conductivity and chlorophyll, algal biovolume, and productivity were found in North Carolina reservoirs by Weiss, 1979, and an increase of plankton, benthos, and fish production in Canadian lakes with increased conductivity was found in studies conducted by Northcote and Larkin, 1956, and Rawson, 1960. This information supports why there are usually more taxa present in embayments (and coves) than in the channel, as witnessed by the Cave Creek comparison 48:41 genera, and the cove-embayment and channel comparison 60:54

genera. As mentioned in Placke's publication (1983), "TVA experiences showing that extensive algal growths, including cyanophyte surface blooms and floating mats of filamentous algae, may occur in embayment areas while the main channel sites support very low phytoplanktonic standing crops." This study found less richness in the channel than in embayment areas, while cyanophyte blooms and floating algal mats were never observed at any location (embayment, cove, or channel) on WBR. Although, thick beds of filamentous algae, mostly of the genus *Spirogyra*, often filled the depressions (possibly caused by spawning carp or burrowing mollusks) in muddy substrate under shallow water. Placke (1983) reports:

The very short residence times of the [mainstream] reservoir may remove developing phytoplankton populations at a faster rate than they multiply so that little net accumulation of standing crop persists in the main channel. Conversely, embayment areas that are somewhat isolated from main channel flow may develop extensive algal populations with floating mats of green and blue-green algae or surface films of euglenoids.

The average residence time for WBR is 17 days, but there is often a two or three knot current in the channel (TVA, 1987).

The cove-embayment and channel combination comparison of community similarity includes for the cove-embayment combination: a trawl in Euchee cove, seven barn cove trawls, three Cave Creek embayment trawls, and a trawl in cow cove; and includes for the channel: one general channel trawl, three channel trawls across the mouth of Cave Creek embayment, and one channel trawl on the main river side of Wilson Island. Again, the combined cove-embayment measurements reflected a higher average pH and conductivity, and as well as temperature, than the combined channel measurements as illustrated in Table 10. The temperature of the cove-embayment

combination was probably higher in the summer due to the fact that they are shallower than the main channel and solar heating is more effective.

Trawls taken on each side of Wilson Island represent the next highest rank in community similarity. The physio-chemical factors were more or less the same for both sampling sites (Table 10), with the only major difference being that the main river channel site was deeper and attracted more boat traffic.

The phytoplankton communities at Euchee Marina ranked next to Wilson Island in the degree of similarity. As expected, the small cove, with warmer water and with more isolation from the channel had the higher number of genera. The pH, conductivity, and temperature were all higher in the small cove. The embayment had a wide mouth and the wind was blowing so much at sampling time that there was probably no significant distinction between embayment and channel phytoplankton due to wave motion, resulting in lower numbers of genera in the embayment compared to the higher number of genera in the small Euchee cove.

The low relative similarity between the two Lowe Branch communities in such close proximity is surprising, when considering the similarities of other nearly abutting communities. The pH and temperature of both locations were measured as the same (Table 10 and Appendix C). The conductivity at both sampling sites was higher (210 and 185 ppm), compared to the average of the study, which was around 150 ppm. The higher conductivity in the wind-unsheltered area (210 ppm) could have partially been related to the higher number of genera found there (Table 9). A more likely explanation, however, is that since the wind probably influenced the wind-unsheltered

area of the embayment more (due to its location which lacked close trees and landforms that might have served as wind breaks), causing increased turbulence throughout the water column, possibly causing higher amounts of inorganic suspended solids to rise into the photic zone, thereby reducing transparency to .63 m as compared to 1.14 m. The reduction in transparency in the wind-unsheltered area of Lowe Branch embayment may have influenced motile or buoyant phytoplankton to drift directionally [for mechanism see Placke (1983)] into the reduced photic zone, where photosynthesis could continue, which is not all that likely. The reduced amount of mixing in the wind-sheltered area resulted in a higher transparency and the phytoplankton could function deeper in the water column, where a surface trawl of the Wisconsin-style plankton net pulled behind the boat would not sample. Therefore, less phytoplankton were captured in the wind-sheltered area. Other factors, that were not measured or apparent, could also have accounted for the lower relative similarity between the two sampling sites.

Following the rank in community similarity of the Lowe Branch populations, is the comparison between samples collected at the dock and those in the stagnant pool next to the dock. One reason for lower similarity is because the samples taken at the dock (Table 9) were collected in the summer, whereas those in the stagnant pool were collected in the late fall and winter. More genera occurred in the summer in WBR than late fall and winter (Appendix A and Table 8). The pool (< 3 ft deep) was detached from the reservoir by the mudflat in the winter, which may have lead to less similarity between the two communities.

The populations with the least similarity of genera between the compared

communities were those collected at the dock and the benthic + wall-dwelling algae. The communities would be expected to be less similar, because the habitat requirements of planktonic algae (ability for prolonged buoyancy) and benthic + wall-dwelling periphyton (typically of filamentous form or consisting of creeping diatoms) are different, yet some degree of similarity still exists because all of these samples were collected in the summer or early fall. The habitat dynamics for this comparison coincide with the physio-chemical factors listed for the dock, because benthic physio-chemical measurements were not taken at the bottom of the aquatic community.

4.4 Influence of Physio-Chemical Factors

The influence of physio-chemical factors examined in this study can be considered on the microscale habitat level within WBR and include physical properties, such as temperature, conductivity, and transparency; and chemical properties, such as pH and DO content. These factors have been found to influence biological entities, such as phytoplankton assemblage and associations. Background information including TVA's analyses of physio-chemical factors as they relate to algal productivity and summaries of studies which involve the use of phytoplankton for the detection of environmental variables, are included to put this physio-chemical data analysis in perspective.

Placke (1983) reports "Nitrogen and phosphorus are present in excess and do not limit production; therefore, classification of the trophic status of these reservoirs [mainstream] based on nutrient concentrations is inappropriate." However, in a more recent study, TVA (1994) reports "the average total phosphorus concentrations observed

in Watts Bar Reservoir were among the lowest of the Tennessee River Vital Signs monitoring locations in 1993." TVA (1994) concludes:

The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly in the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The "generally low chlorophyll levels" in TVA mainstream reservoirs were not correlated with nutrient levels (Placke, 1983). Placke reports a mean summer chlorophyll a value for WBR of 5.3 (micrograms per liter) $\mu\text{g/L}$ (at forebay, 1975 study) as compared with a 7 $\mu\text{g/L}$ average at the forebay in 1993 (TVA, 1994). "The highest chlorophyll a concentrations were measured in August at the forebay (10 $\mu\text{g/L}$) and in May at the transition zone (11 $\mu\text{g/L}$ [average 8 $\mu\text{g/L}$])" (TVA, 1994).

Placke (1983) reports "Secchi depth in the [mainstream] reservoirs is not related to either chlorophyll, phosphorus, or nitrogen levels and probably reflects inorganic turbidity." The Secchi depth of 1.5 m was reported at the forebay of WBR from 1975 data (Placke, 1983) and the Secchi depth averaging 1.5 m was reported at the forebay of WBR from 1993 data (TVA, 1994). TVA (1994) concludes "these values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other [mainstream] Tennessee River reservoirs in 1993." (Refer to Table 1 for perspective).

Thermal stratification in mainstream reservoirs was reported by Placke (1983) to be generally "intermittent or nonexistent" and mixing of suspended solids extended throughout the water column. Fort Loudoun Reservoir, just above WBR, and

Chickamauga, just below WBR, (two of the four mainstream reservoirs included in the 1979 TVA study) "showed transient thermal stratification depending on weather conditions" (Placke, 1983). Cheek et al. (1983) write that WBR "is a warm-monomictic reservoir that is thermally stratified in the summer" and provide proof based on temperature and oxygen profiles dated in 1961-62. TVA (1994) reports "Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993."

If nutrients were not correlated with chlorophyll levels, and the Secchi depth was not correlated with either phytoplankton induced turbidity (chlorophyll a) or nutrients, then what primary factor does limit the productivity of algae in mainstream reservoirs? Placke (1983) reports that "Light is believed to be a controlling factor limiting the algal productivity of the [mainstream] reservoirs." The degree of light penetration through the water column may explain the lower level of similarity between the two communities compared from Lowe Branch.

The photic zone ("depth of one percent ambient light penetration") in TVA mainstream reservoirs is characteristically shallow, often less than three meters, relative to the mixed depth or thermocline ("region of temperature drop of one °C/m depth"). Placke (1983) writes:

If the depth of the mixed zone is greater than the depth of the photic zone, phytoplankton will be continually circulated into the dark where no photosynthesis and no net growth can occur. Under these conditions, the production of algal biomass may become light-limited rather than nutrient-limited.

Placke indicates that phytoplankton in the main channel are limited by shallow light penetration and also by hydraulic washout (removal of "phytoplankton populations at a faster rate than they multiply so that little net accumulation of standing crop persists in the channel"). Placke writes "hydraulics influence the apparent settling velocity of phosphorus as well as flushing large nutrient loads through the reservoirs during high flow periods."

Many studies have been conducted which involve the use of phytoplankton for the detection of various environmental variables. Summaries of pertinent studies discussed below are cited in the article by Peter A. Siver and John P. Smol (1993), titled "The Use of Scaled Chrysophytes in Long Term Monitoring Programs for the Detection of Changes in Lakewater Acidity." Studies of Kristiansen, 1986, found that "scaled chrysophytes are linked directly to lakewater pH...(and) are excellent biological indicators of pH." Three prerequisites an organism must have in order to be useful as indicators are the organism must be "taxonomically well defined," must be easily identified, and must be "distributed within a narrow ecological spectrum." Furthermore, Kristiansen states that the "occurrence of the organism must be controlled by the environmental factor in question."

Another study of 50 water bodies in the Netherlands, cited Siver and Smol (1993), determined that the water's pH controlled the occurrence of phytoplankton about 57% of the time, while the temperature of the water controlled their biomass at about 35% of the time. Other environmental factors account for the remaining eight percent. As reported in Siver and Smol (1993), Roijackers and Kessels, 1986,

concluded from the above-described study that "pH controlled the presence of scale-bearing taxa in a given waterbody whereas the water temperature controlled the resultant biomass." Similar results were found in a study conducted by Siver and Hamer in 1989 on 62 lakes, as cited in Siver and Smol (1993). They found that the pH or combination of pH and conductance accounted for the presence of phytoplankton in 23 out of 25 of the taxa tested. Water temperature and phosphorus levels were found to determine the time and intensity of the development of phytoplankton species. In yet another study cited in Siver and Smol (1993), 17 environmental characteristics were tested by Smol et al. in 1984 on 38 lakes. The influence of conductance and Secchi disc depth by themselves on the presence of phytoplankton was not found to be statistically significant. Similarly Wade (1984) concludes in his thesis that "Cyanophyta population dynamics were more influenced by specific combinations of environmental events than by long-term relationships with one or more environmental variables." Wade, however, did not include pH, alkalinity, conductivity, and Secchi disk depth as possibilities of growth controlling variables, because they "were felt to be influenced more by phytoplankton than to regulate" them.

In light of the statement in Siver and Smol (1993), "Many species of scaled chrysophytes have definitive and well documented distributions along a continuum of pH," the high, average, and low values for pH, conductivity, and temperature were identified for each of the 110 genera of phytoplankton in WBR, and Appendix B containing graphic presentations was constructed. The order of the taxa in the graphs in Appendix B coincides with the breakdown of taxa into Divisions, orders, and

sometimes families if enough taxa were identified, which is also included in Appendix B. This order was followed to see if closely related taxa thrived in similar environmental conditions. A few observations, concerning cyanophytes, were notable. The cyanophytes persisted in a higher than average pH of 7.7, in the average conductivity of the study of 150 ppm, and in a higher than average temperature of 26.6 °C, with most cyanophytes spanning the entire range of environmental factors considered (Appendix B). A statement in Placke's 1983 publication sums up the explanations for these observations:

Physiological characteristics of blue-green algae (superior phosphate and carbon uptake kinetics, tolerance of high pH, high optimum temperature, ability to fix atmospheric nitrogen, ability to regulate buoyancy, freedom from grazing pressure, etc.) make it likely that blue-green algae will dominate the summer flora of most TVA reservoirs.

An environmental variable profile including sample date averages for pH, conductivity, and temperature is provided in Appendix D. The magnitude of pH change between sample dates was more pronounced during the summer and more constant during the spring and fall. In general all Divisions tended to vary with pH in the summer, but not so much in the spring and fall (comparing Appendix D with Figure 5).

No seasonal discernible pattern for conductivity was apparent. Chrysophytes and cyanophytes tended to vary with conductivity in the spring and fall. Euglenophytes and pyrrhophytes tended to vary with conductivity most of the time. Chlorophytes did not seem to vary closely with conductivity.

The magnitude of temperature changes between sampling dates in the spring and fall tended to be more pronounced. In the summer the temperature remained more

constant (Appendix D). Chlorophytes and cyanophytes seemed to vary most closely with temperature in the spring and fall (Figure 5). Other factors than temperature were probably more influential in Divisional presence than temperature in the summer.

4.5 Comparison of Algal Taxa of WBR to Taxa of Selected Southern Reservoirs

According to Sournia (1978), "diversity is used as an unabridged expression of how a set (for instance, the community) is distributed into subsets (for instance, the [genera])." In order to compare the phytoplankton diversity of Watts Bar to phytoplankton diversity in other reservoirs from three states (Alabama, Virginia, and Texas), two types of tests were utilized: the Mann-Whitney test (to compare distribution of genera among Divisions) and Sørensen's and Jaccard's indices of community similarity (to compare the number of genera common) (Brower et al., 1990). Table 11 includes the sum of genera by Division for each reservoir, ranking descriptions (for the Mann-Whitney tests), the number of phytoplankton genera in common (c) in the reservoirs being compared (for Sørensen's and Jaccard's community similarity indices as previously described), and totals of ranks (R_1 and R_2) and genera for each reservoir. Table 11 and calculations for the Mann-Whitney tests follow:

Table 11 Mann-Whitney Test Data and Data for Community Similarity Indices for Comparison of Phytoplankton Taxa from Watts Bar Reservoir with Taxa of Selected Southern Reservoirs

Division	TN	AL	TN	VA	TN	TX
	# Rank	# Rank	# Rank	# Rank	# Rank	# Rank
Pyrrhophyta	5 3.5	4 1.5	5 4	1 1	5 3.5	3 1.5
Euglenophyta	5 3.5	4 1.5	5 4	2 2	5 3.5	3 1.5
Cyanophyta	17 7	13 5	17 8	5 4	18 8	10 5
Chrysophyta	30 8	15 6	30 9	12 6	30 9	11 6
Chlorophyta	53 10	41 9	53 10	14 7	53 10	17 7
Totals	110 32	77 23	110 35	34 20	110 34	44 21
# in common	c = 45		c = 26		c = 34	

Mann-Whitney Calculations:

$$U = (n_1)(n_2) + [(n_1)(n_1 + 1)/2] - R_1$$

$$U' = (n_1)(n_2) - U$$

TN & AL

$$R_1 = 3.5 + 3.5 + 7 + 8 + 10 = 32$$

$$U = (5)(5) + [(5)(5 + 1)/2] - 32 = 8$$

$$U' = (5)(5) - 8 = 17$$

TN & VA

$$R_1 = 4 + 4 + 8 + 9 + 10 = 35$$

$$U = (5)(5) + [(5)(5 + 1)/2] - 35 = 5$$

$$U' = (5)(5) - 5 = 20$$

TN & TX

$$R_1 = 3.5 + 3.5 + 8 + 9 + 10 = 34$$

$$U = (5)(5) + [(5)(5 + 1)/2] - 34 = 6$$

$$U' = (5)(5) - 6 = 19$$

The null hypothesis that the distribution of genera among the Divisions are the same as compared to the Divisions in three reservoirs located in the states of Alabama, Texas, and Virginia was rejected in all three cases, considering the Mann-Whitney critical values (Table 12). The Sørensen and Jaccard indices of community similarity (Table 12) indicate that of those phytoplankton communities for which data were found, the phytoplankton community of Wilson reservoir (AL) is the most similar to WBR, followed by the phytoplankton communities of Livingston (TX) and Swift Creek reservoirs (VA) (Wade, 1984; Crouch, 1978; Eckblad and Woodson, 1969), respectively.

In a Sørensen's analysis of community similarity for selected TVA reservoirs, the range of values was small varying from "0.273 (Hiwassee-Douglas) to 0.555 (Boone-Cherokee)" (Placke, 1983). Researchers for TVA found that "most reservoirs have at least a third of their species in common with other reservoirs, but that none of the reservoirs have more than about half their species in common with any other reservoir" (Placke, 1983). Again, WBR was not included in the TVA study reported by Placke.

Table 12 Phytoplankton Community Similarity Comparisons between Watts Bar Reservoir and Selected Southern Reservoirs

Reservoir, State	Duration of Study	Reservoir area (ha)	CC _s	CC _i	U	U'
Watts Bar, TN	Sep 1994- May 1996	15,783	---	---	---	---
Wilson, AL	Mar 1982-Oct 1982	6,270	.481	.317	8	17
Swift Creek, VA	Nov 1967-Apr 1968	2	.361	.220	5	20
Livingston, TX	Jun 1976-May 1977	33,428	.442	.283	6	19

Mann-Whitney Critical Values from table in Brower et al. (1990) .10_[5,5]=21 .05_[5,5]=23 .01_[5,5]=25

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- Sources:
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5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Watts Bar Reservoir (WBR) was found to support a diverse assemblage of phytoplankton comprising five algal Divisions and 110 genera. The community of phytoplankton in WBR was viewed as a system, which was surrounded by the environment. Environmental data was collected in respect to three categories: 1) season, 2) habitat, and 3) physio-chemical factors. Many of the variables considered under each category were interrelated with or the same as factors considered under the other categories. All four null hypotheses were rejected based on the analysis of the data. The presence, community composition, and diversity of WBR phytoplankton were found to be influenced by seasonal phenomena and habitat dynamics. Phytoplankton were found to be differentially distributed among the recorded minimum and maximum ranges of pH, conductivity, and temperature. When the genera among taxonomic divisions and the number of genera in common with phytoplankton taxa of selected southern reservoirs were compared, the distributions differed.

5.2 General Recommendations

Watts Bar Reservoir possesses a phytoplankton assemblage that is distinct to the degree that 50% of the assemblage is not reflected as compared with taxa of selected southern reservoirs and as generally supported by Placke's (1983) TVA reservoir comparisons. In order to preserve the high diversity of phytoplankton genera and to insure an adequate food supply for consumers in WBR, cultural eutrophication and other degrading, anthropogenically induced, stresses should be minimized primarily by

maintaining the integrity of the shorelines and by monitoring the ecological health of the reservoir and its watershed. TVA has recently prioritized and publicized the assessment of shoreline development impacts and presented alternatives in *Shoreline Management Initiative* (1996).

5.3 Recommendations for Further Study

Recommendations for further study include:

- 1) Identification of algae to species level. Crouch (1978) at Livingston Reservoir, Texas, identified 122 species of algae representing 45 genera. One-hundred and ten genera were recorded from WBR.
- 2) Determinations of current WBR phytoplankton abundance and productivity.
- 3) Quantitative evaluations of more environmental variables which might influence the phytoplankton found in WBR and applications of more advanced statistical analyses.
- 4) Integration of WBR shoreline studies, including those of Amundsen (1994), Hammons (1996), Hanahan (1996), and Loy (1994), with biotic and abiotic reservoir dynamics.

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APPENDICES

GENUS	TOT	SPR	SUM	FAL	WIN	pH	COND ppm	TEMP °C
<i>Microcystis</i>	28	17.9	60.7	21.4		7.0-8.4	120-240	12-30
<i>Nostoc</i>	1		100			8.2	140	27
<i>Oscillatoria</i>	30	20.0	46.7	30.0	3.30	7.0-8.6	120-210	11-30
<i>Schizothrix</i>	2		100			7.4-8.6	150	25-29
<i>Spirulina</i>	13	15.4	53.8	23.1	7.70	7.0-8.6	120-240	11-29
<i>Tetrapedia</i>	1			100		7.7	210	23
EUGLENOPHYTA								
<i>Euglena</i>	34	29.4	44.1	23.5	2.9	7.0-8.6	120-240	11-30
<i>Eutreptia</i>	1	100				7.0	130	27
<i>Lepocinclis</i>	1			100		7.8	140	16
<i>Phacus</i>	15	26.7	40.0	33.3		7.0-8.4	120-240	11.5- 28.5
<i>Trachelomonas</i>	10		60.0	40.0		7.4-8.6	140-240	12-30
PYRRHOPHYTA								
<i>Ceratium</i>	22	18.2	59.1	22.7		7.0-8.6	120-240	16-30
<i>Glenodinium</i>	3		66.7	33.3		7.4-8.2	150-240	19-25
<i>Gymnodinium</i>	18	16.7	55.5	27.8		7.0-8.4	120-240	16-30
<i>Oodinium</i>	1			100		7.5	140	12
<i>Peridinium</i>	1	100				7.5	150	29
16 Genera	181	$\sum ni^2 = 4161$ for this page						
110 Total Genera	946	55	75	71	19	$\sum ni^2 = 22,030$ total		

Notes: The abbreviations used in the column headings in Appendix A are:

TOL = Total SPR = Spring SUM = Summer FAL = Fall WIN = Winter

pH = potential of Hydrogen COND = Conductivity ppm = parts per million

TEMP = Temperature °C = degrees Celsius

APPENDIX A (continued)

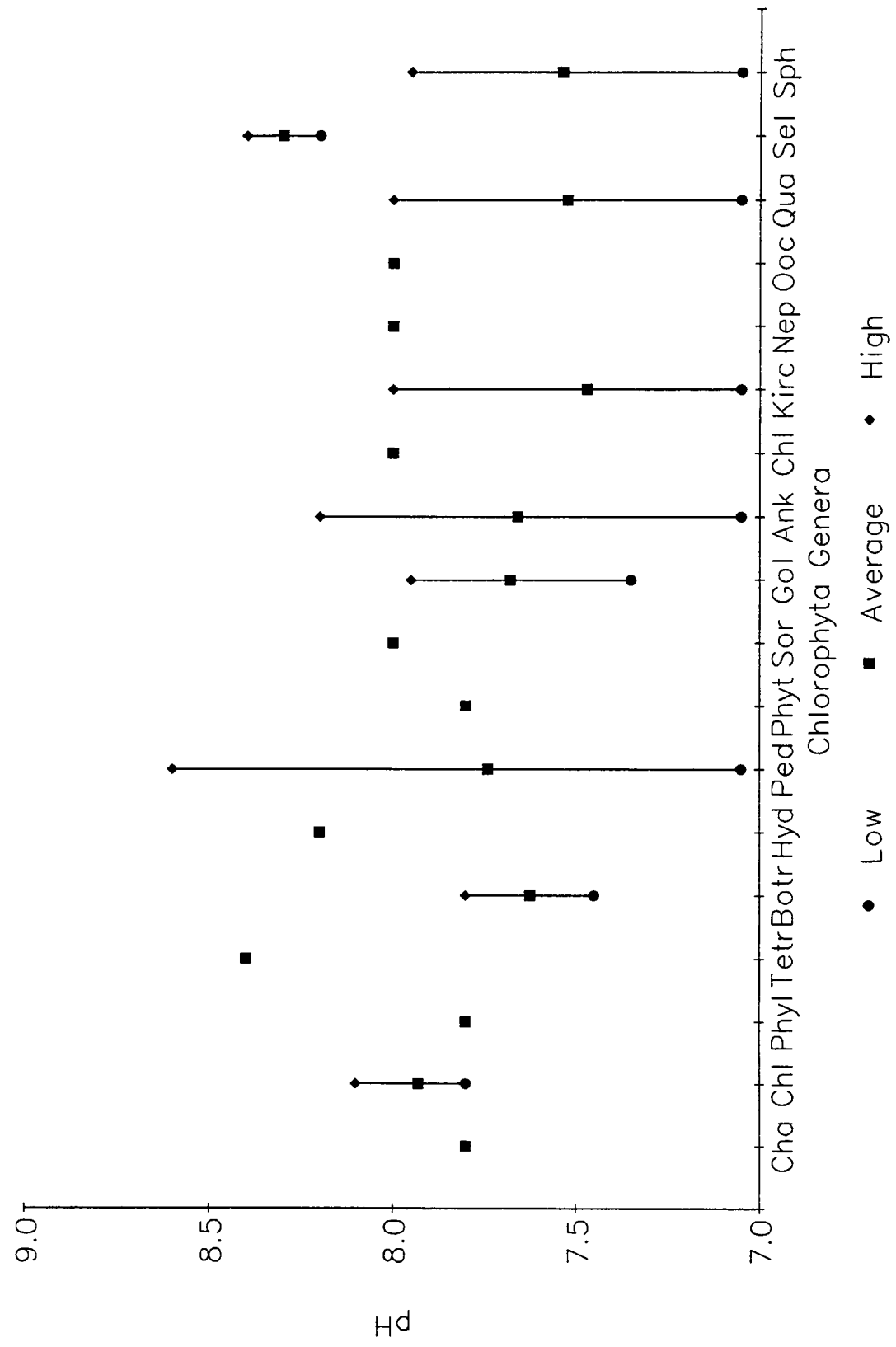
One would read the first entry addressing the genus *Actinastrum* in the following manner:

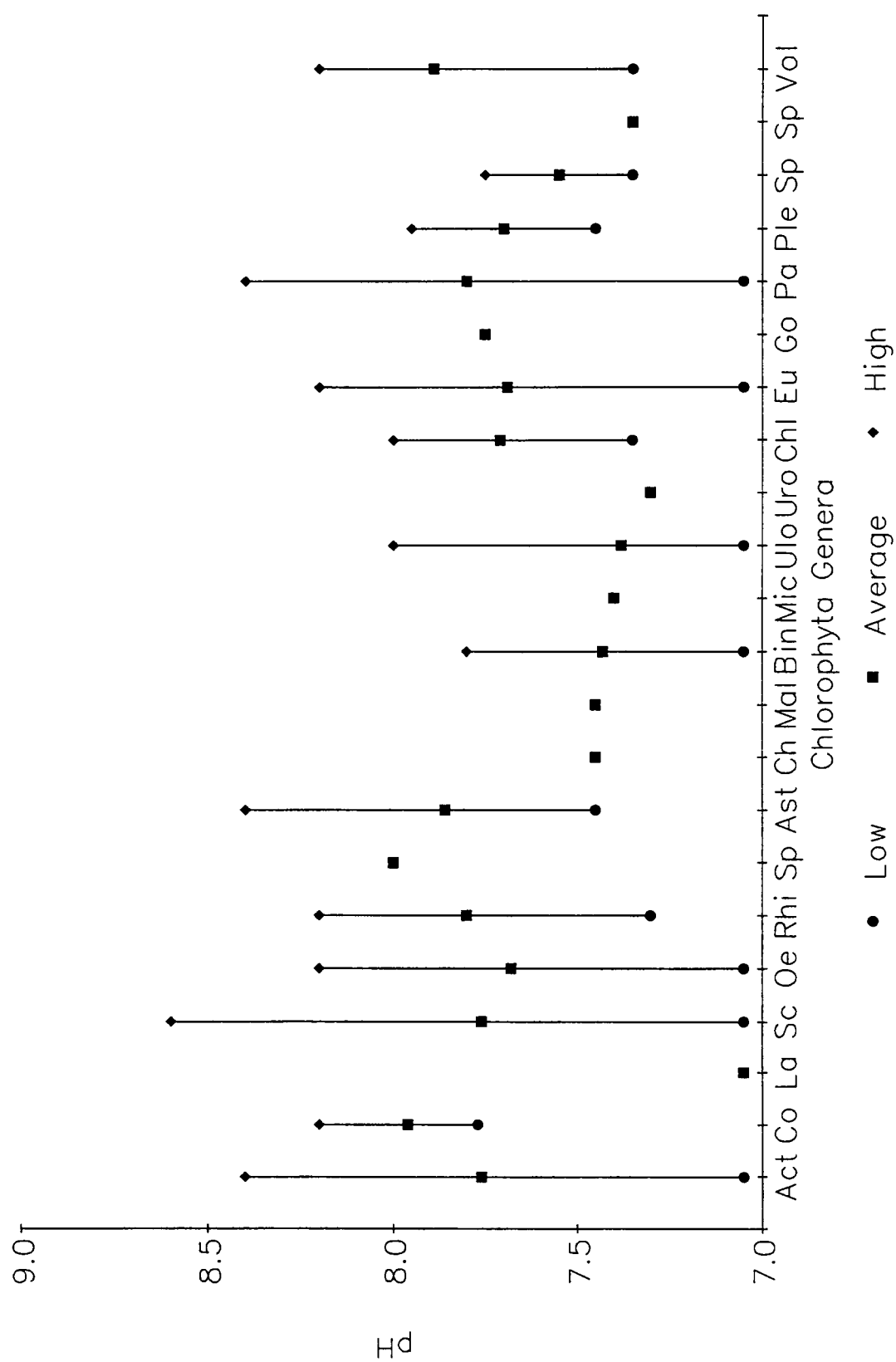
There were 28 total recorded occurrences (ni) of the alga *Actinastrum*, a member of the Division Chlorophyta, in WBR from September 10, 1994 through May 18, 1996. Of those 28 occurrences, 39.3% were found in the spring, 42.9% were found in the summer, 17.8% were found in the fall, and none were found in the winter. Members of the genus *Actinastrum* occurred in a range of physio-chemical factors; specifically a range of pH of 7.0-8.4, a range of conductivity of 120-240 ppm, and a range of temperature of 16-30 °C.

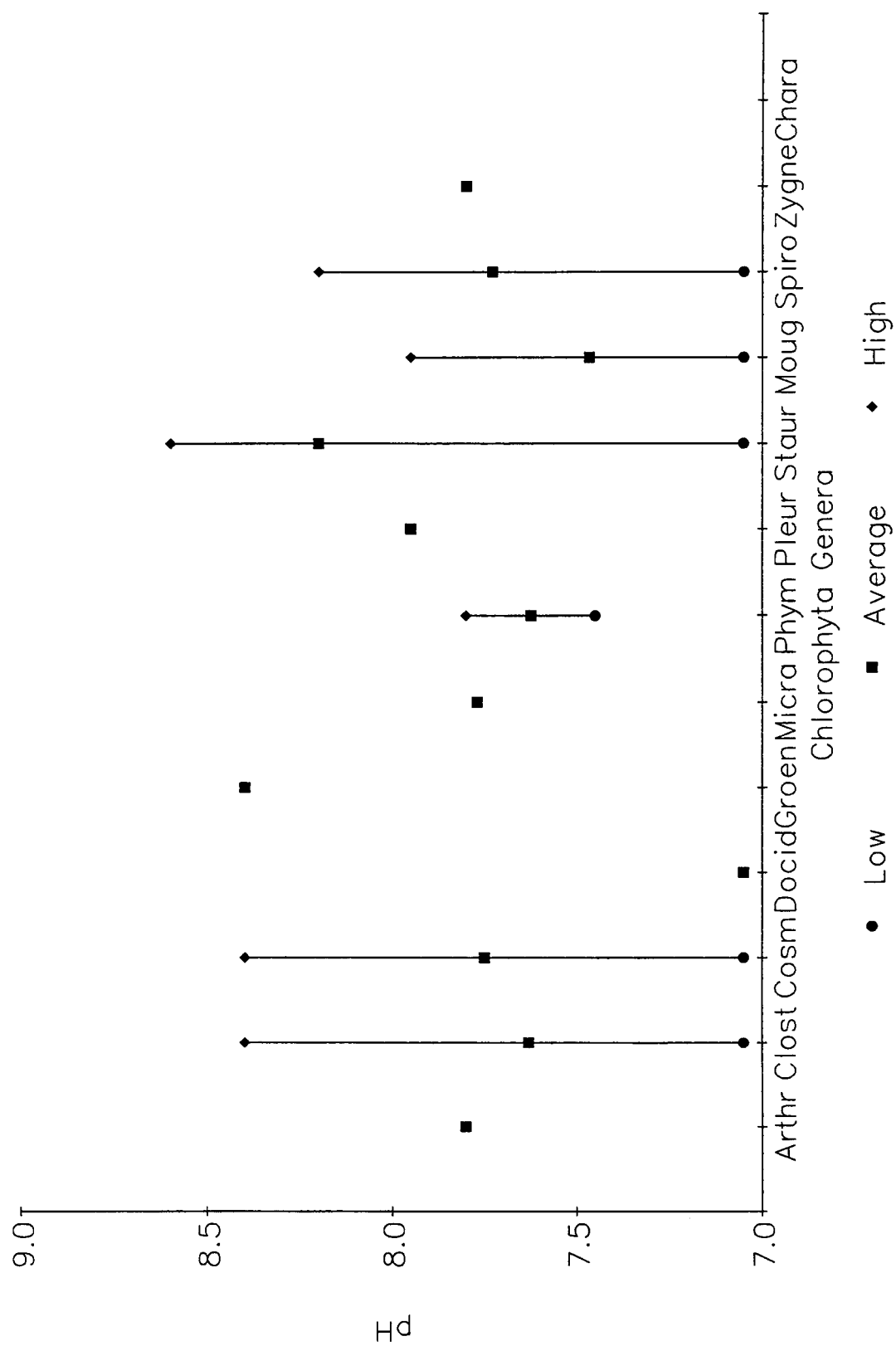
Totals at the bottom of each page are given for the number of genera (g) listed, the total number of occurrences (O), and the sum of each occurrence squared ($\sum ni^2$) for that page. Totals at the end of Appendix A are the sum of the page totals and include totals for the number of genera that were recorded as present in each season, as combined over the study.

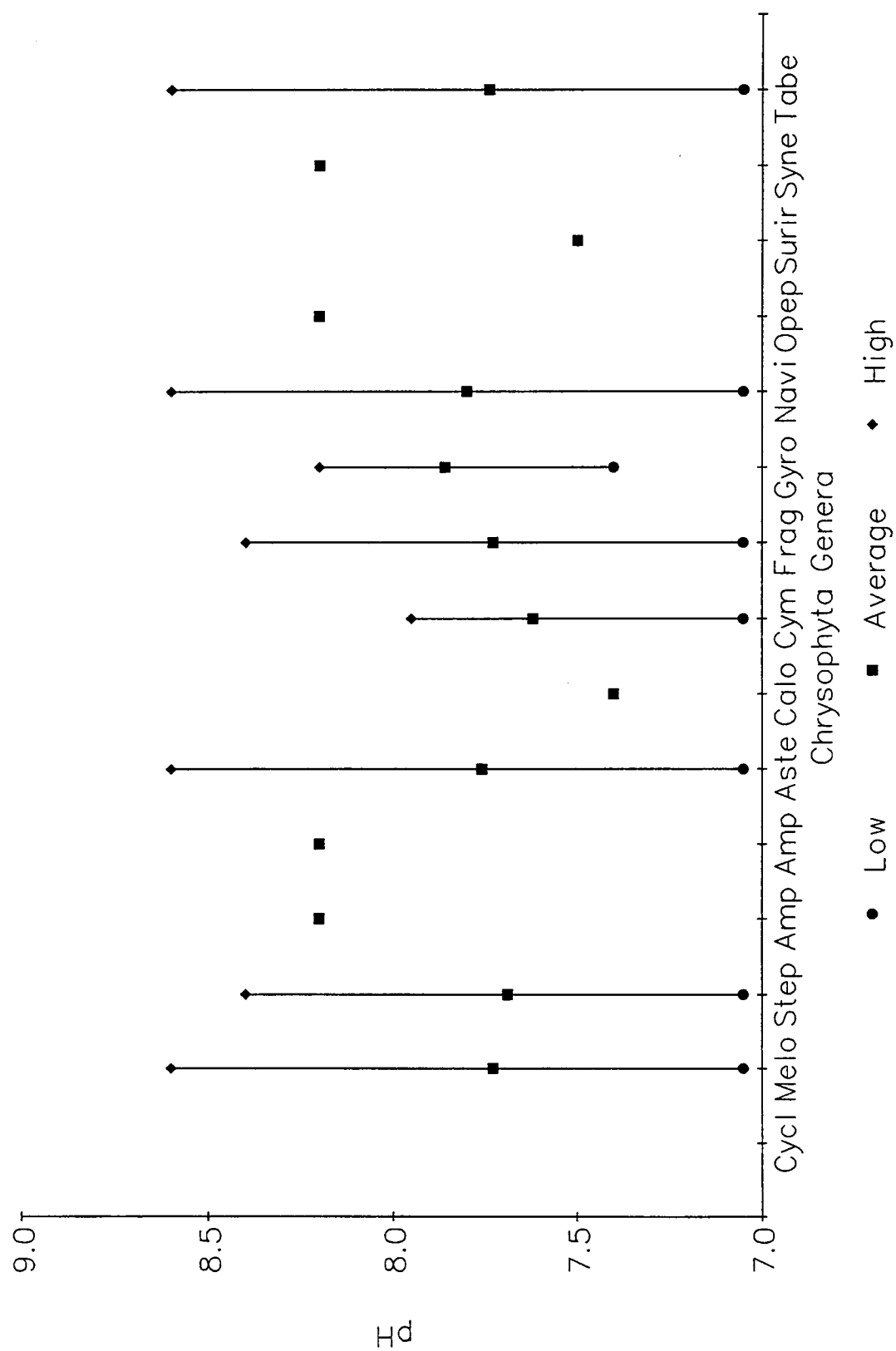
APPENDIX B

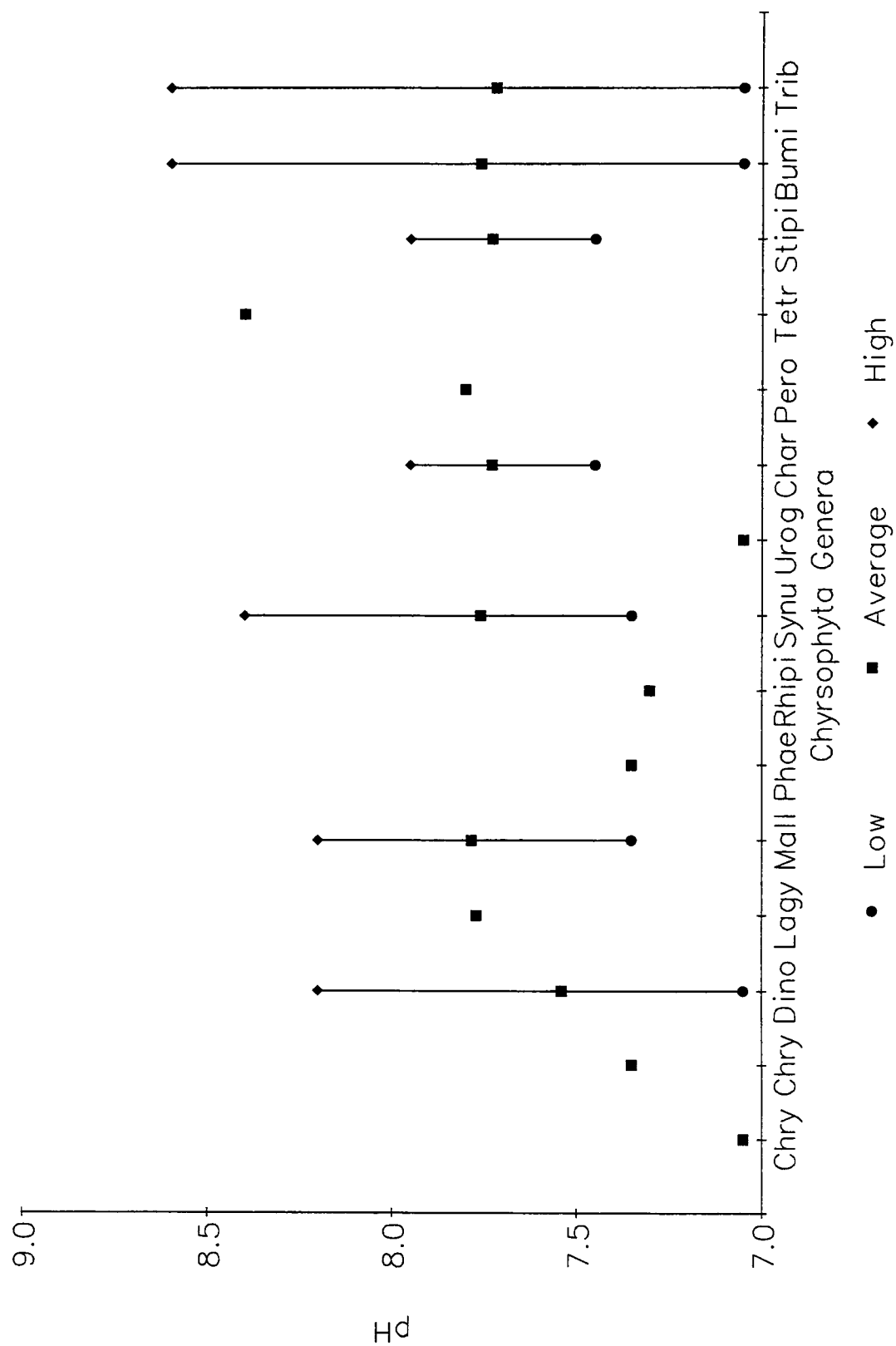
Phytoplankton Genera of Watts Bar Reservoir along Three Continua between the Recorded Study Minimum and Maximum Ranges of the Physio-Chemical Factors of pH, Conductivity, and Temperature as Arranged by Divisions, Orders, and/or Families Provided in List Form, also in Appendix B

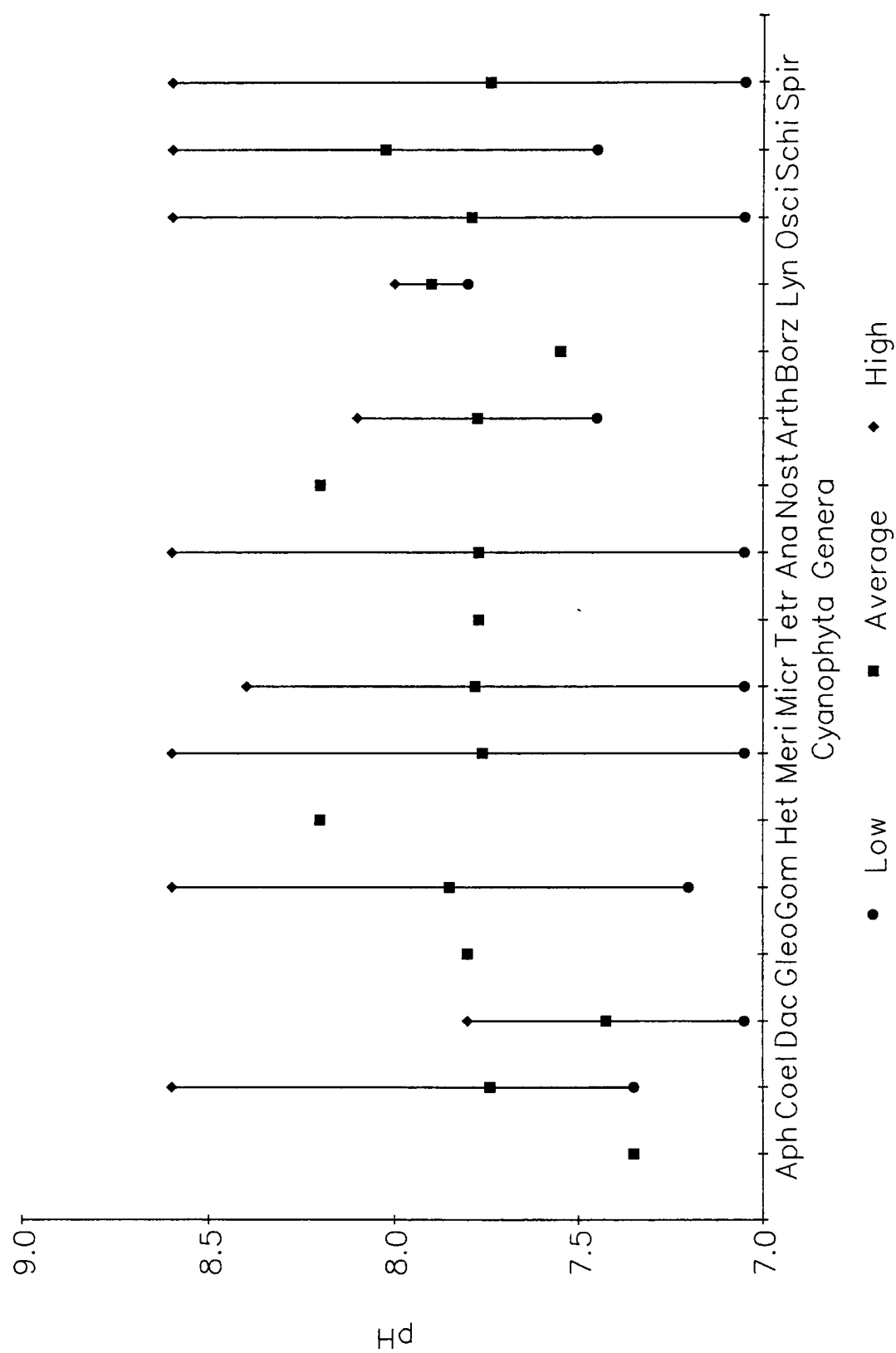


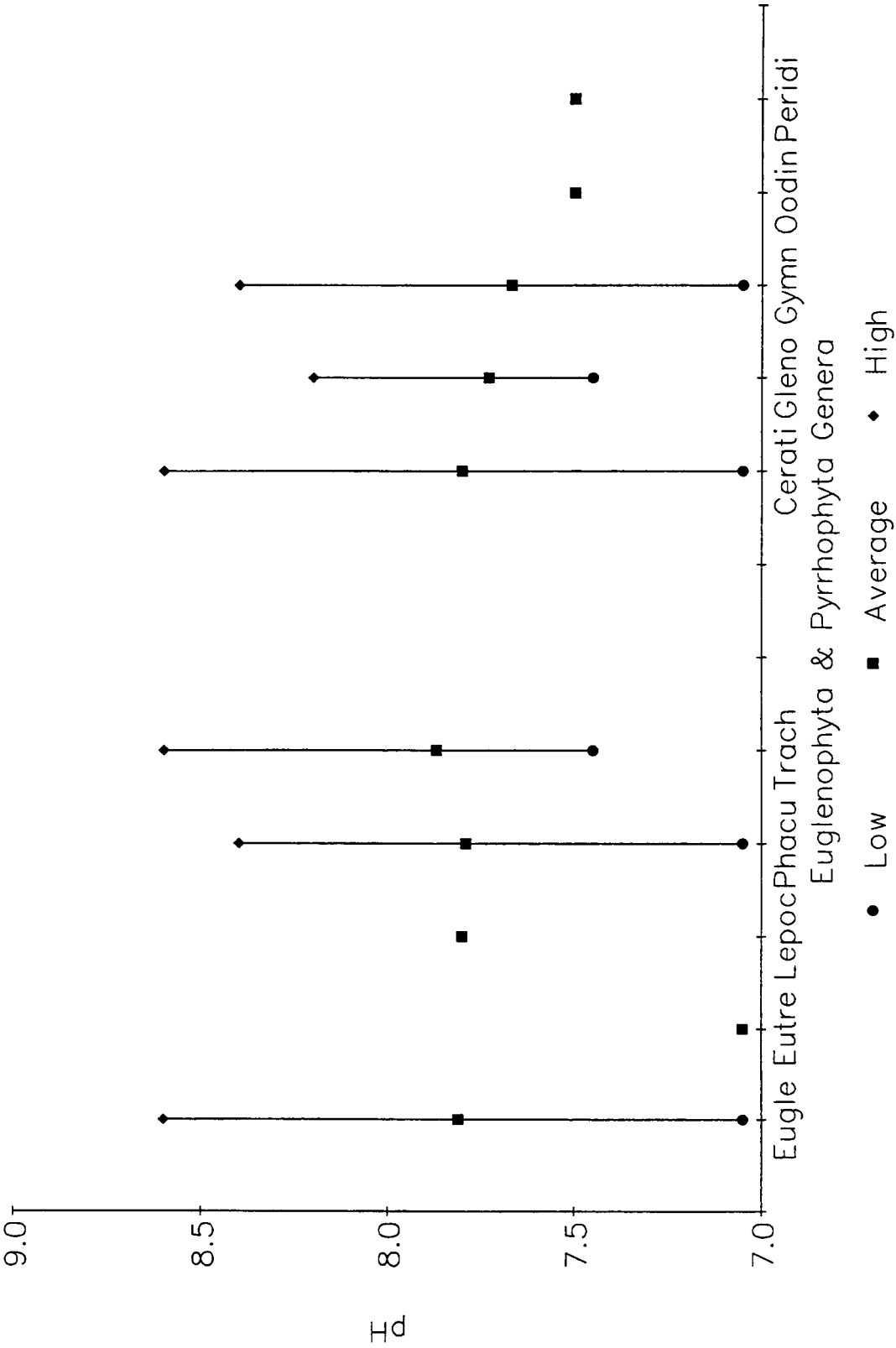


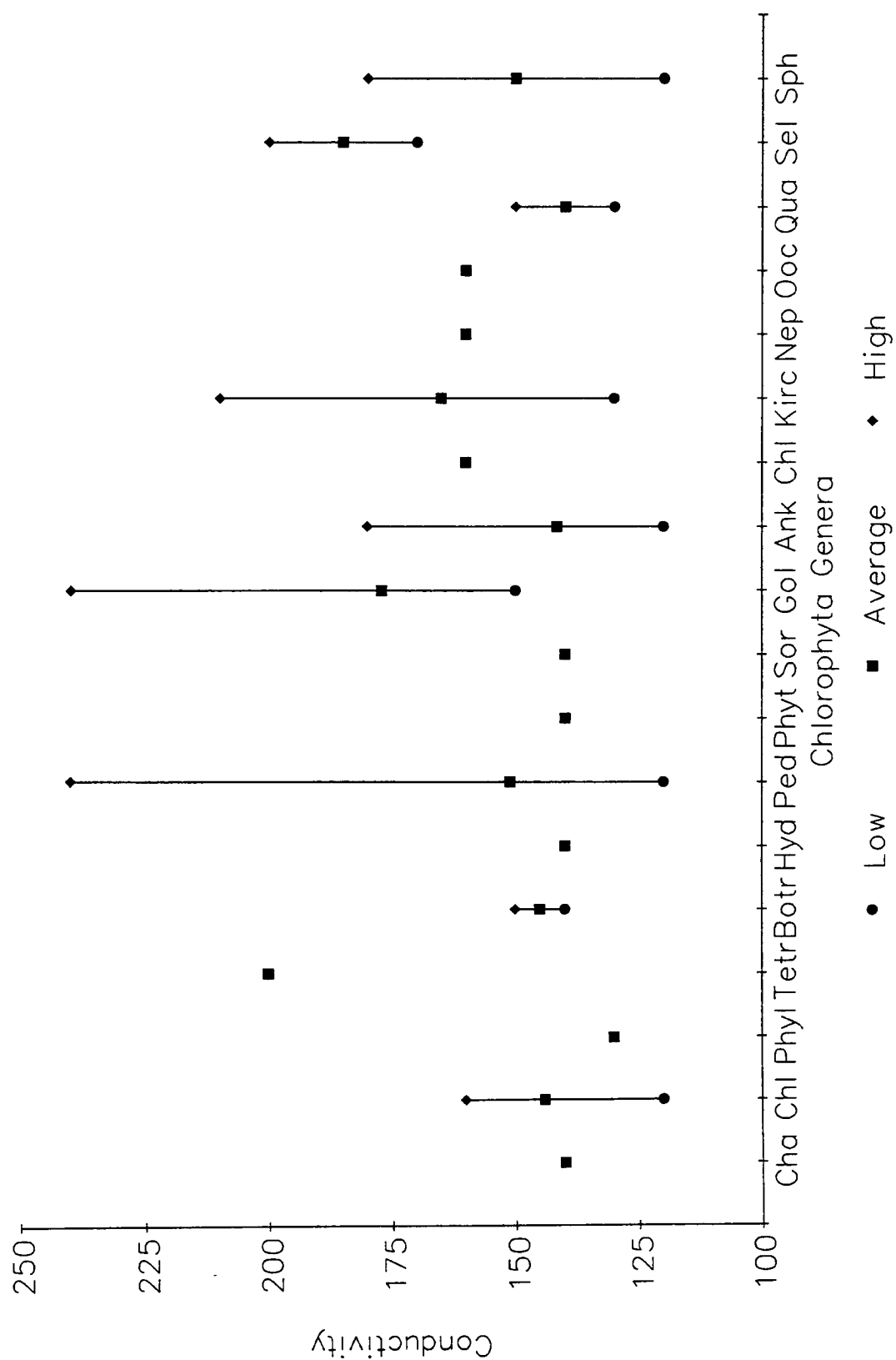


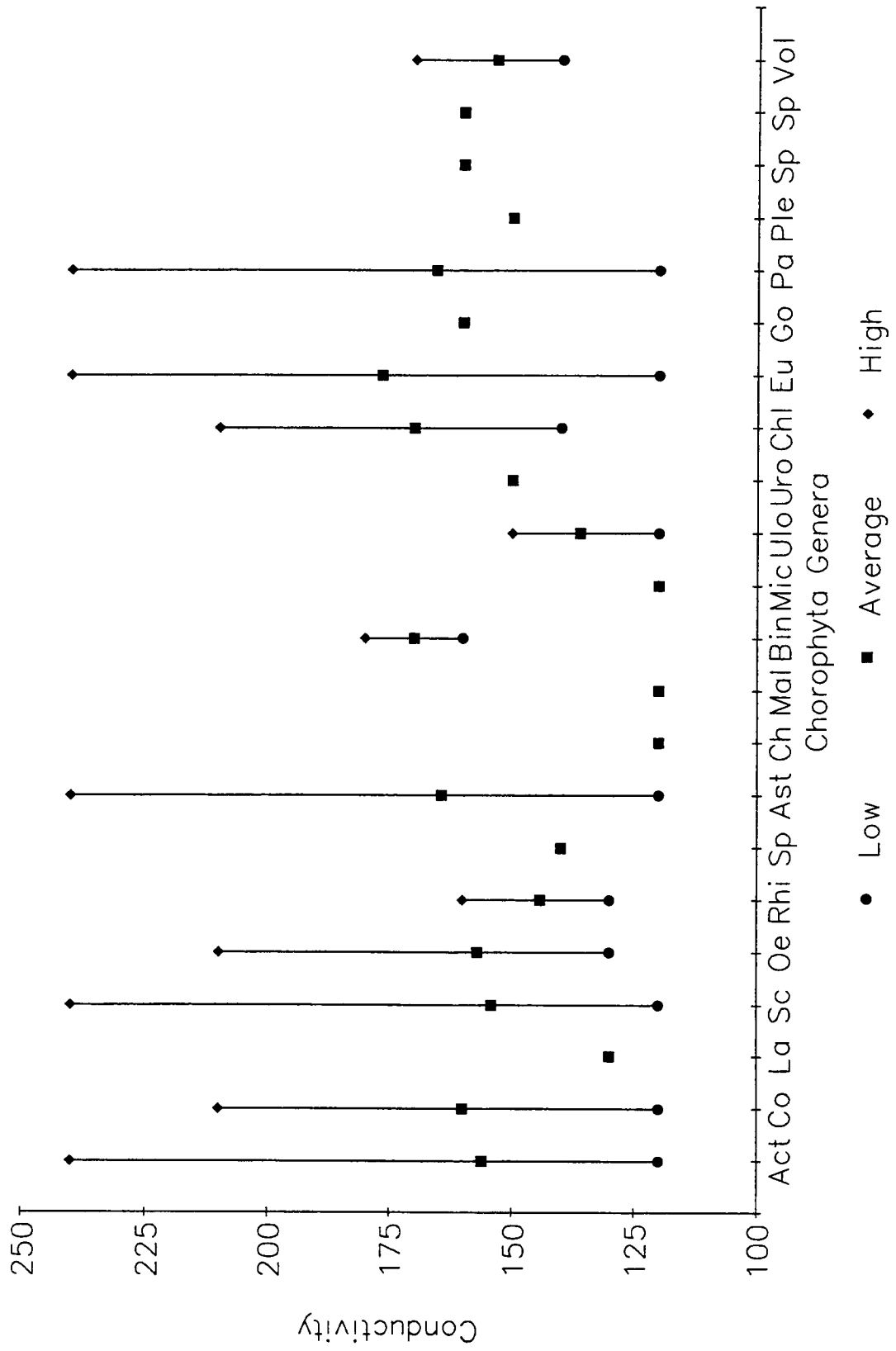


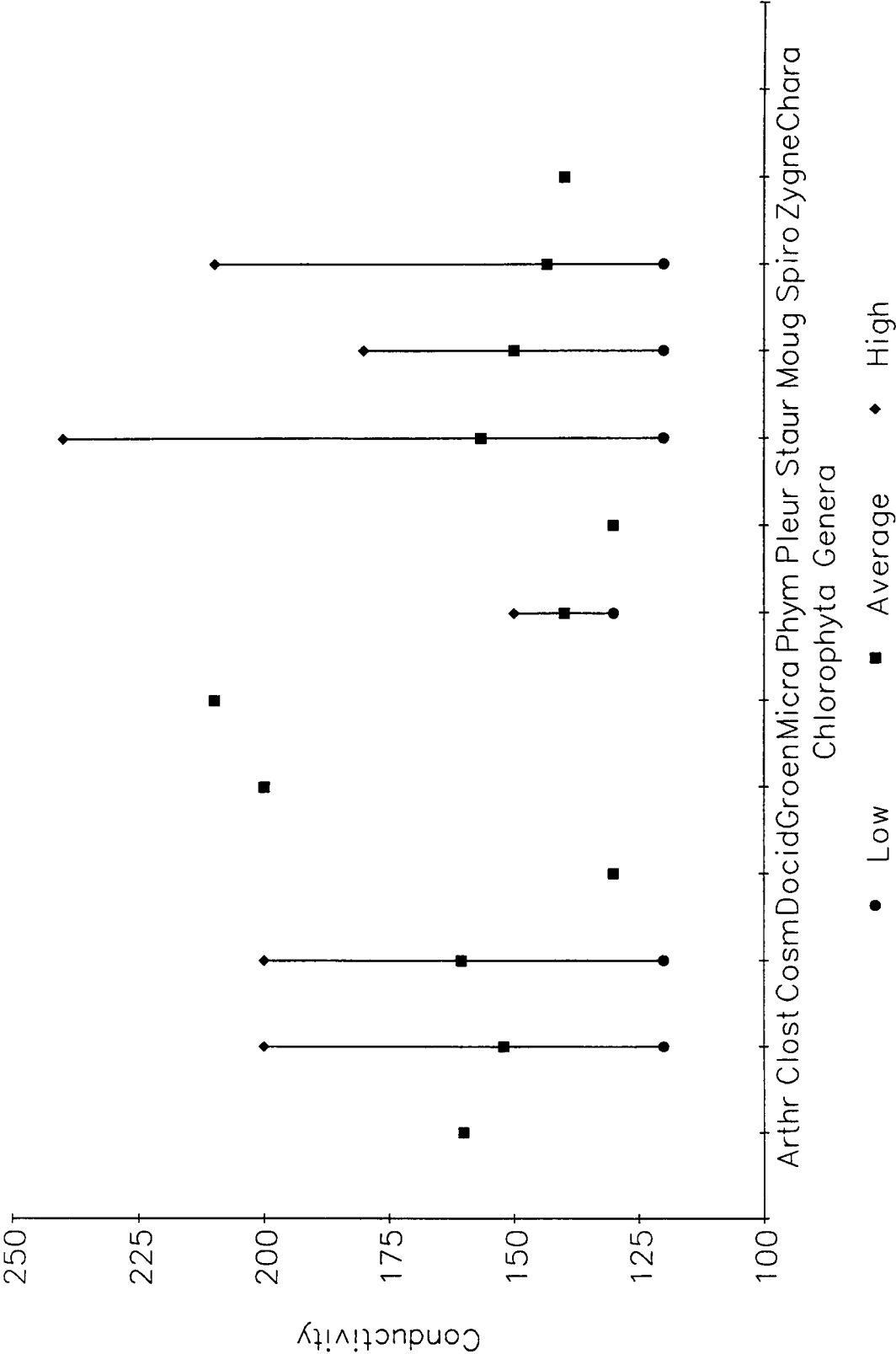


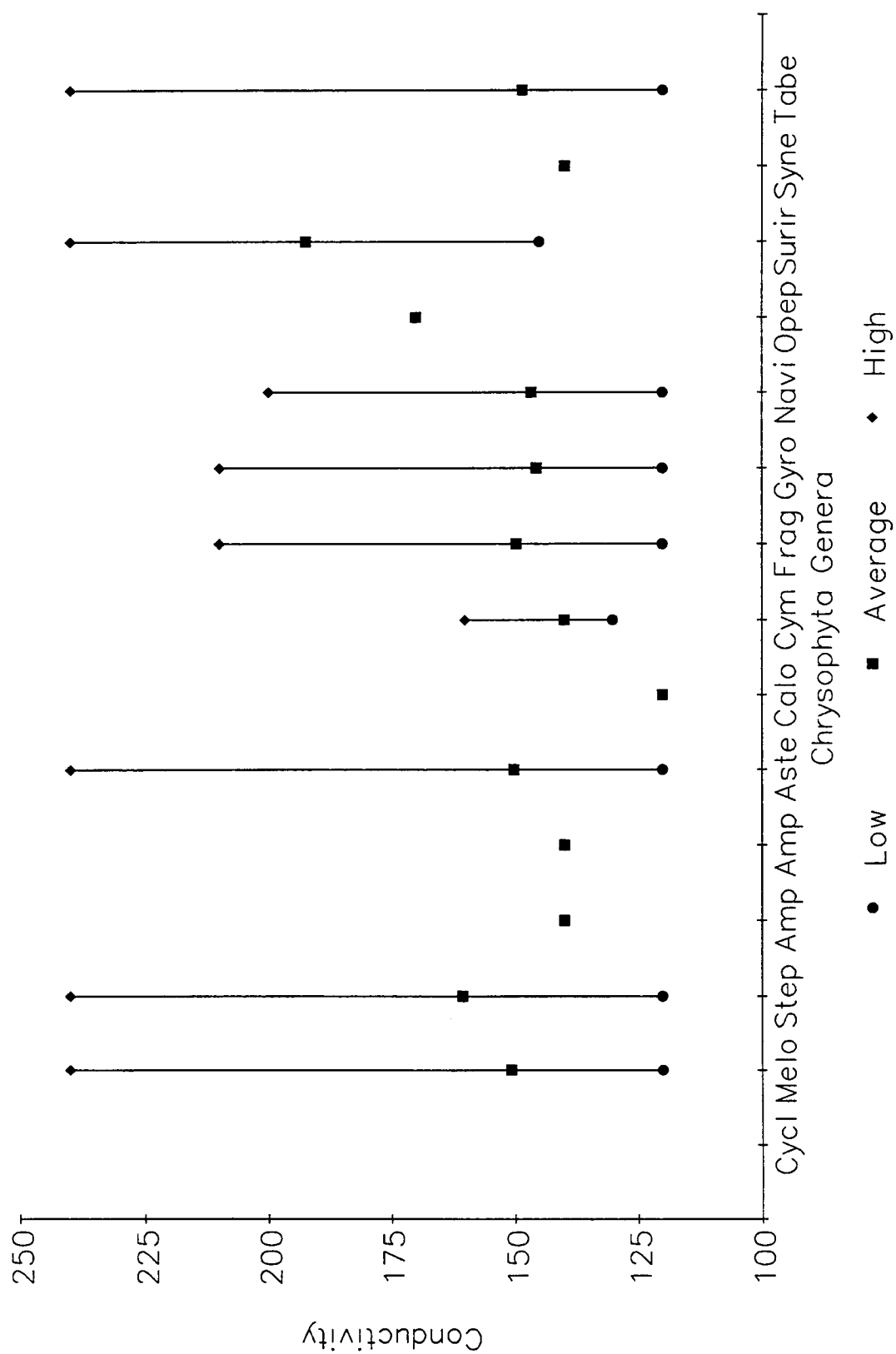


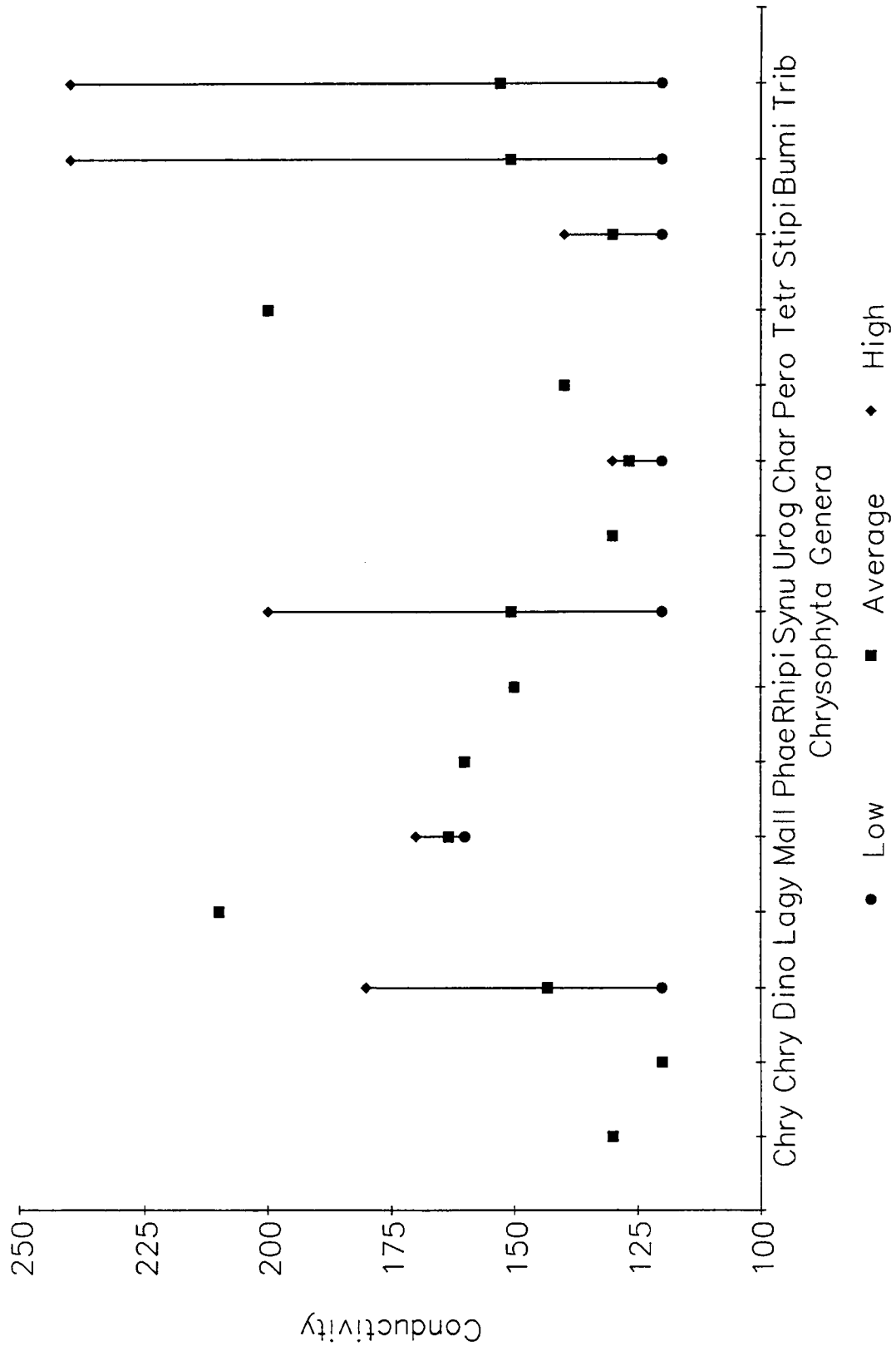


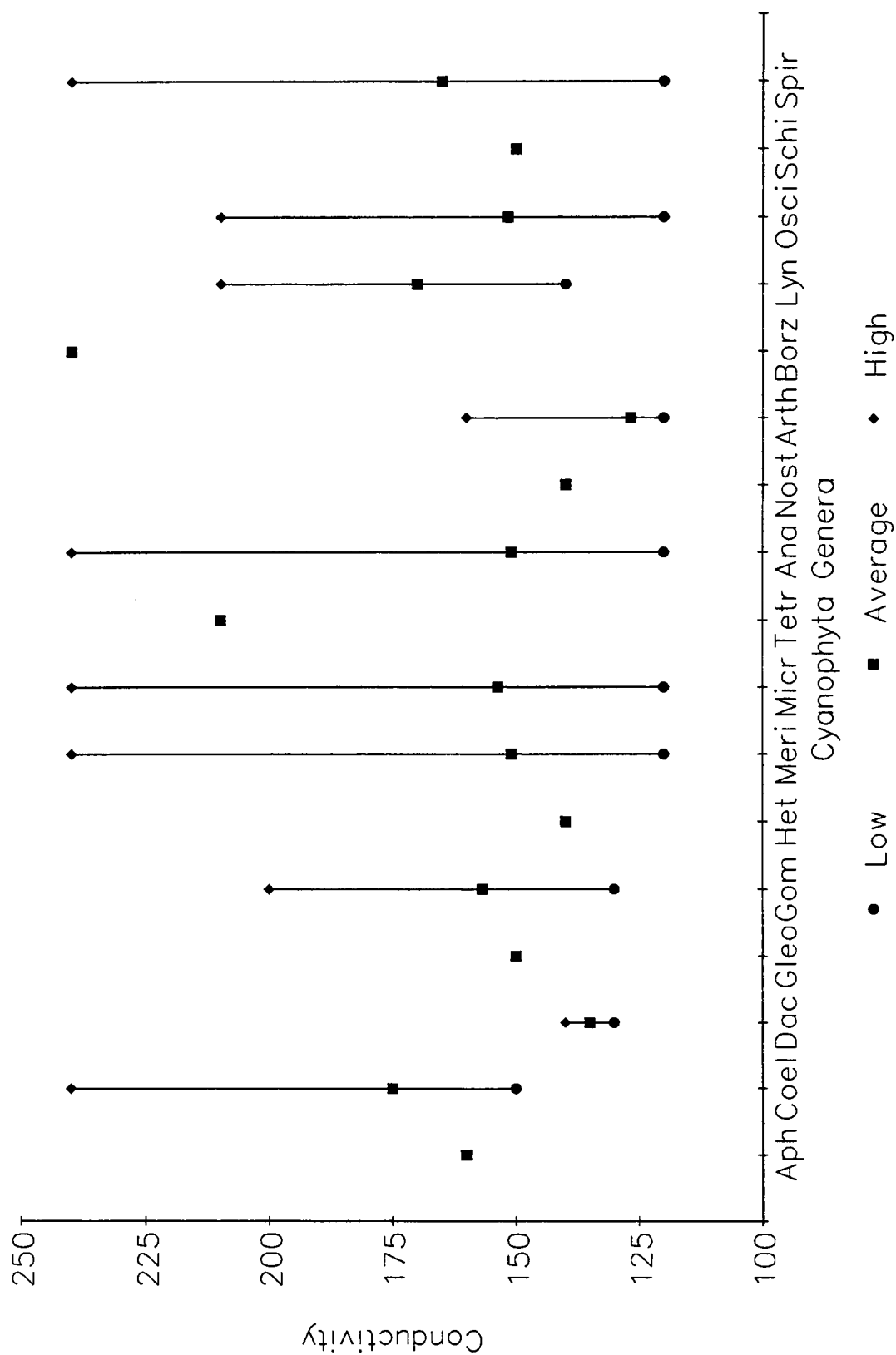


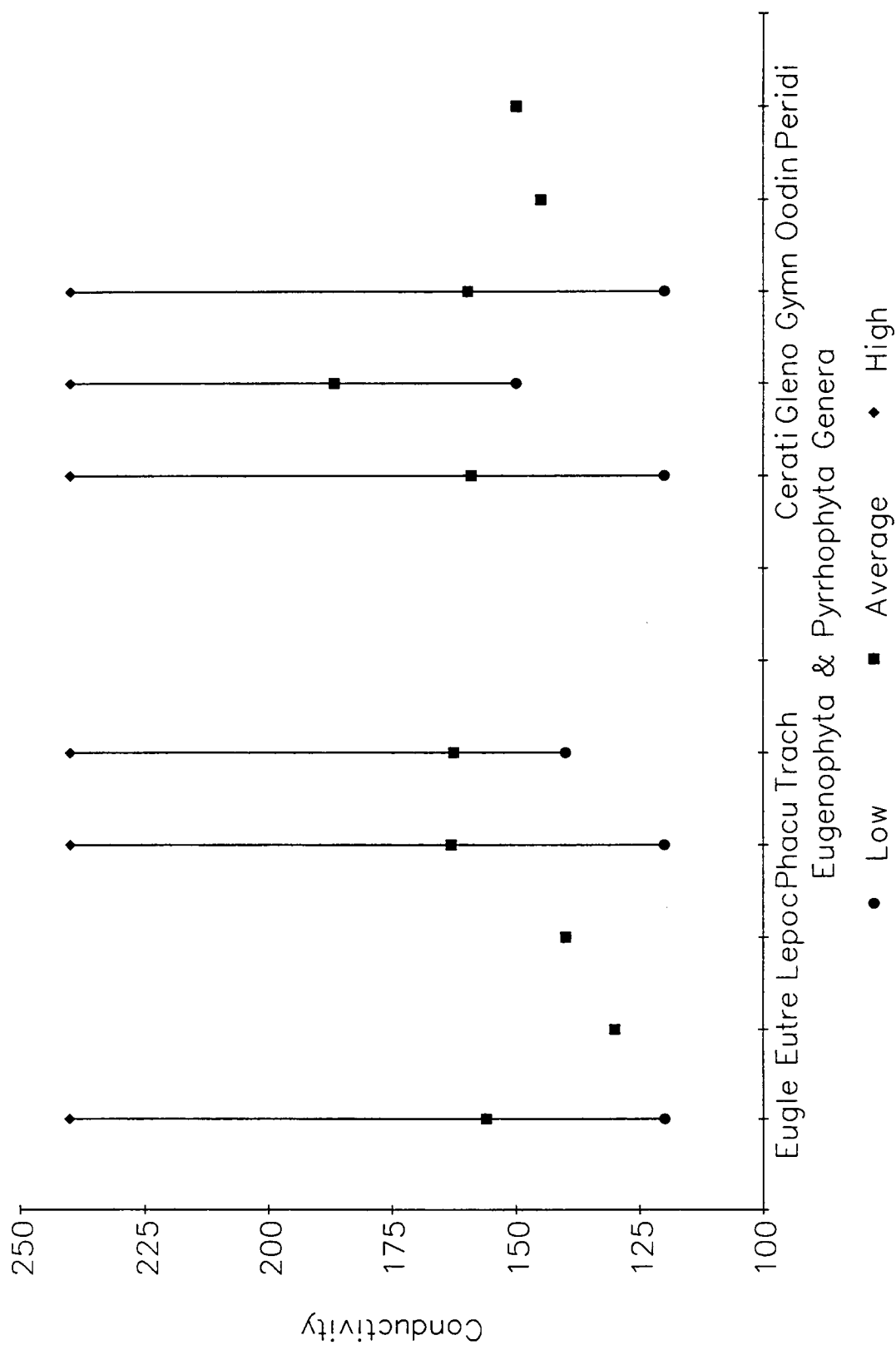


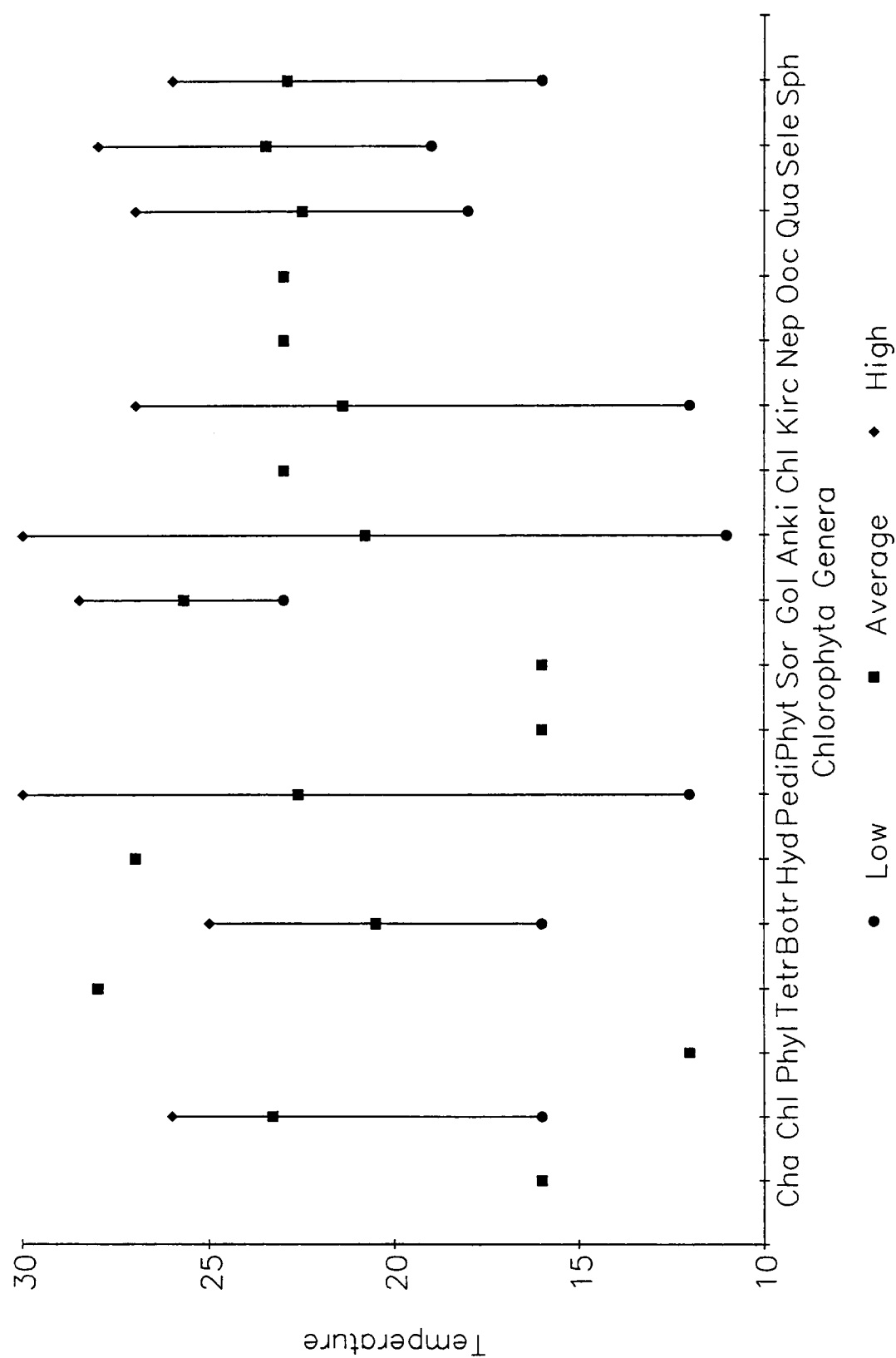


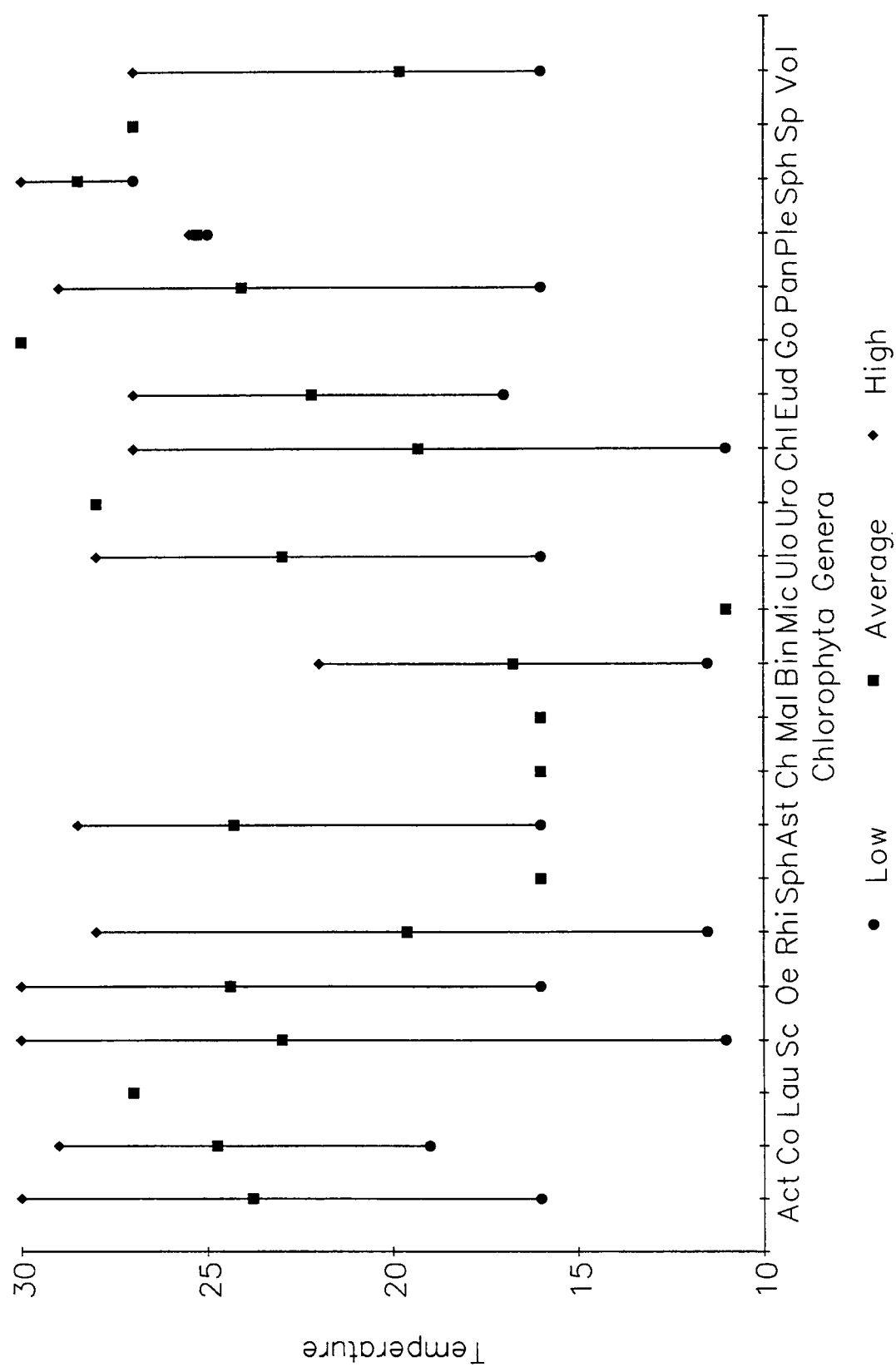


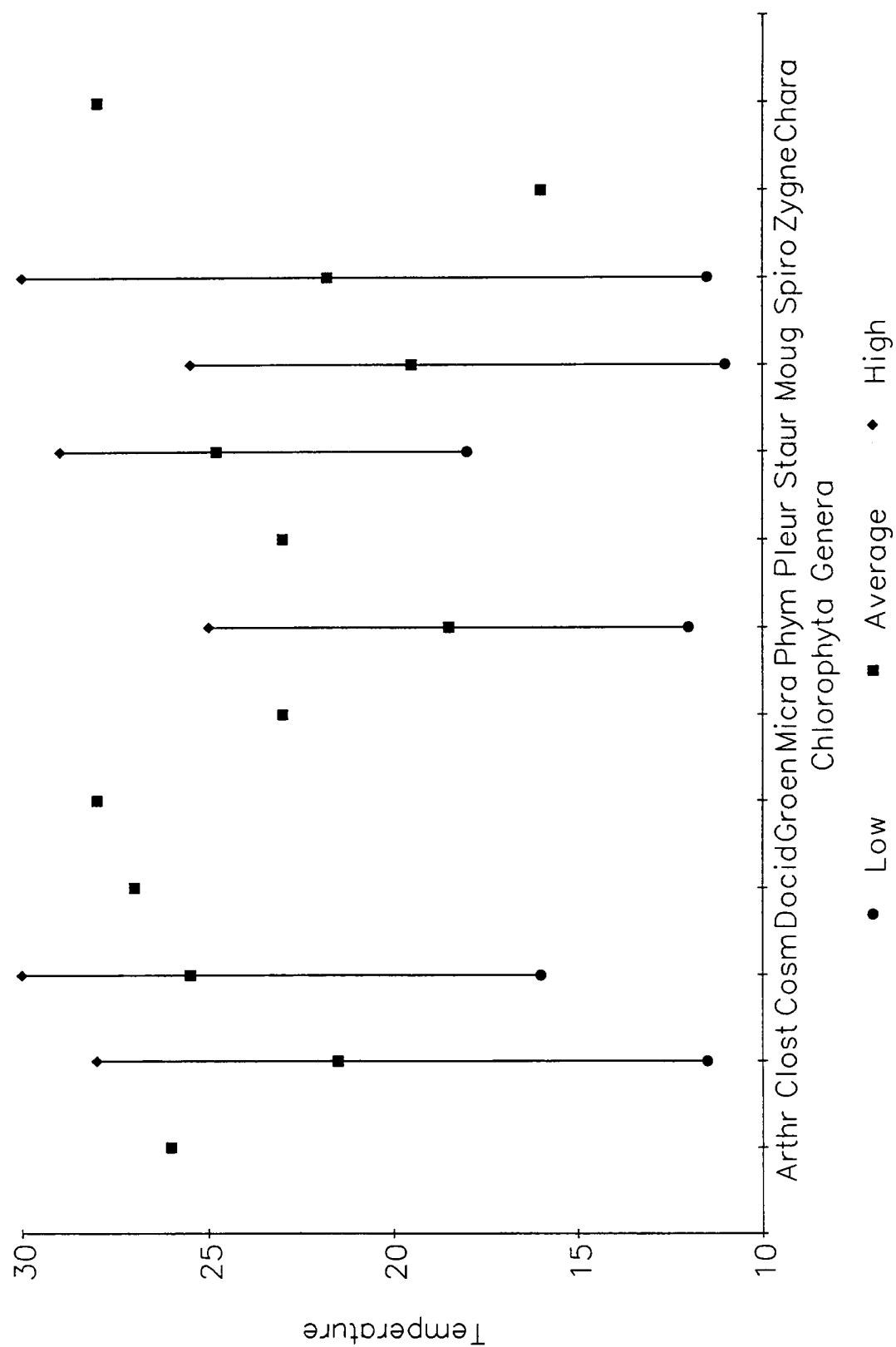


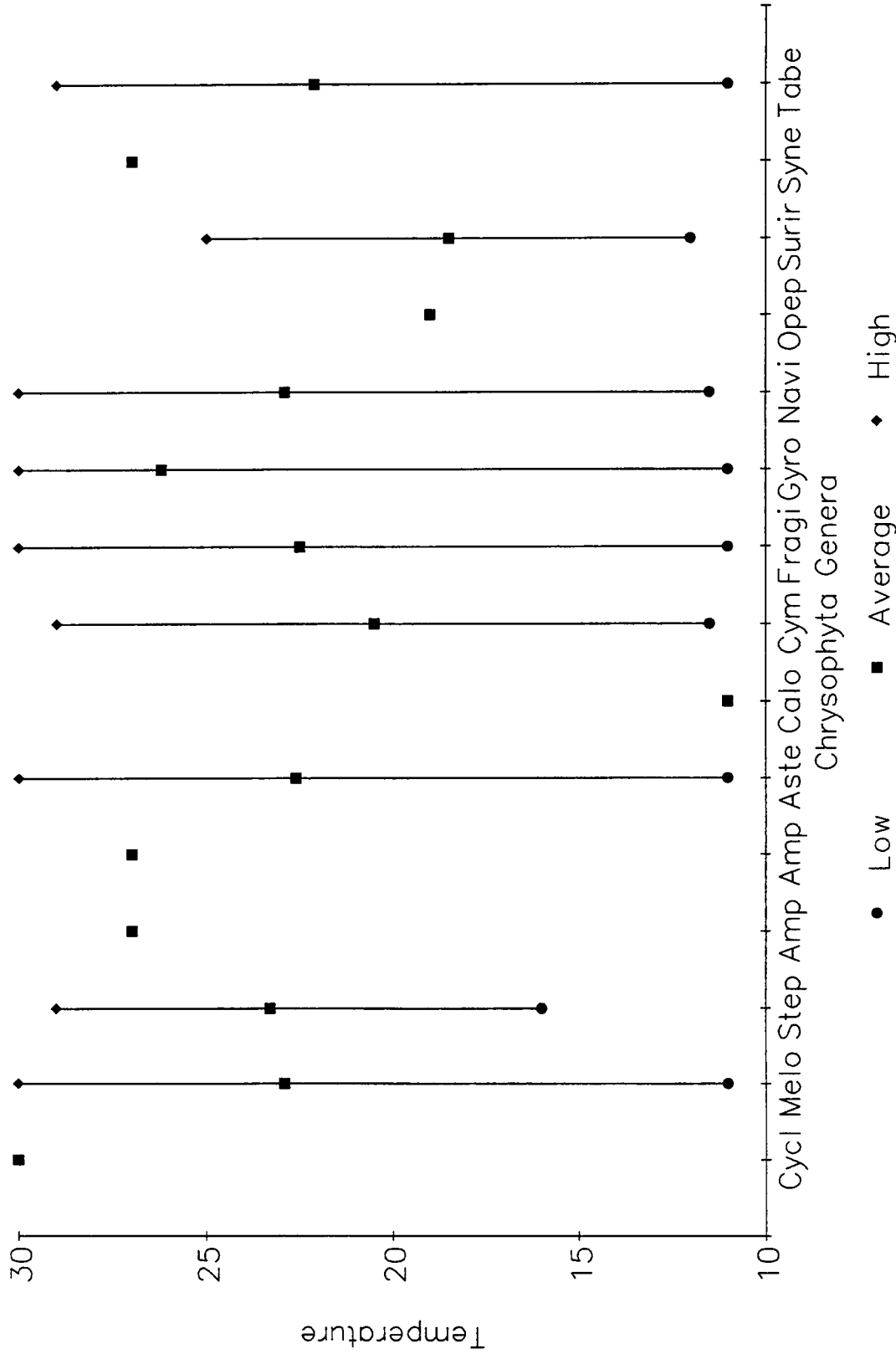


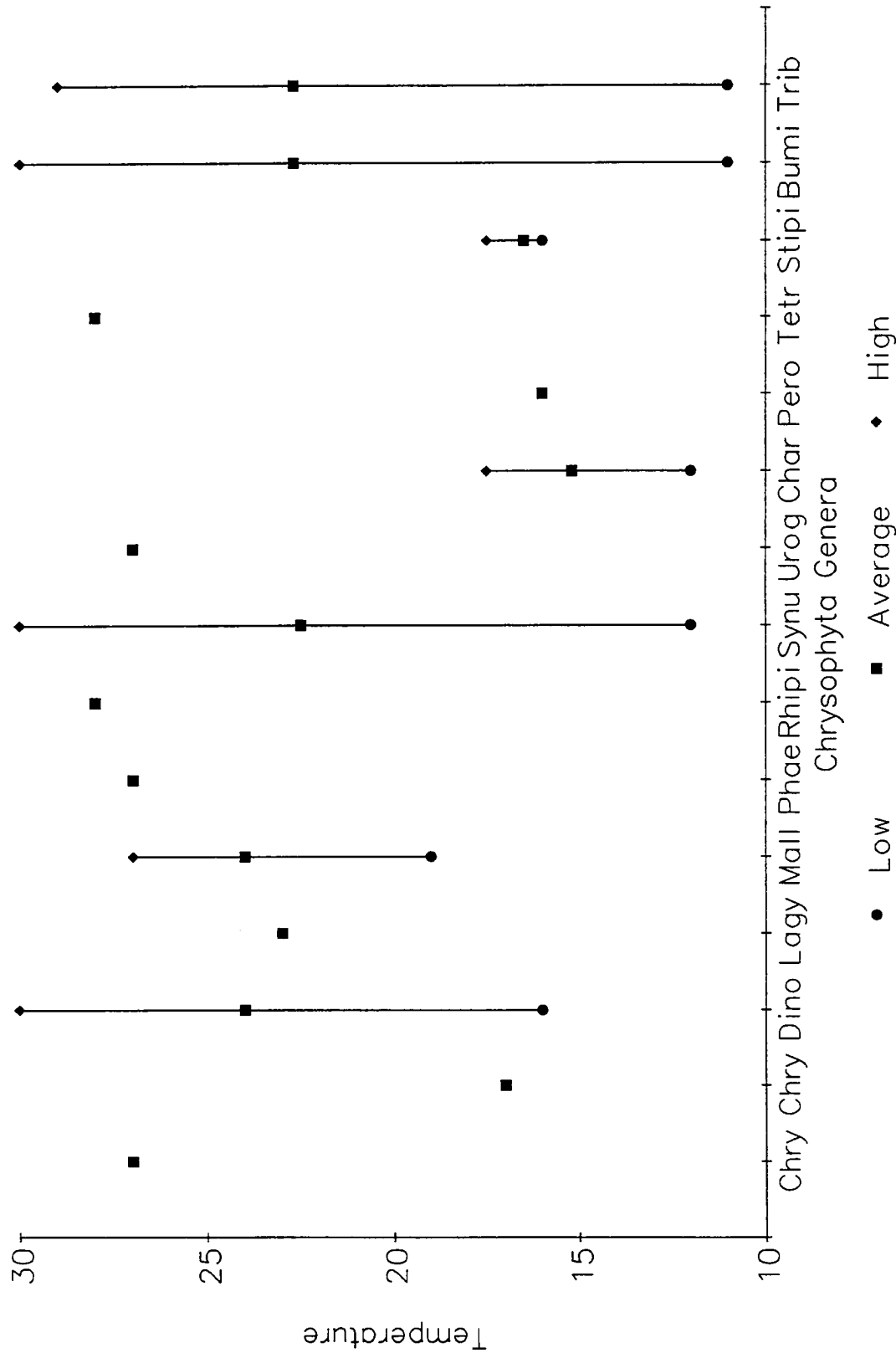


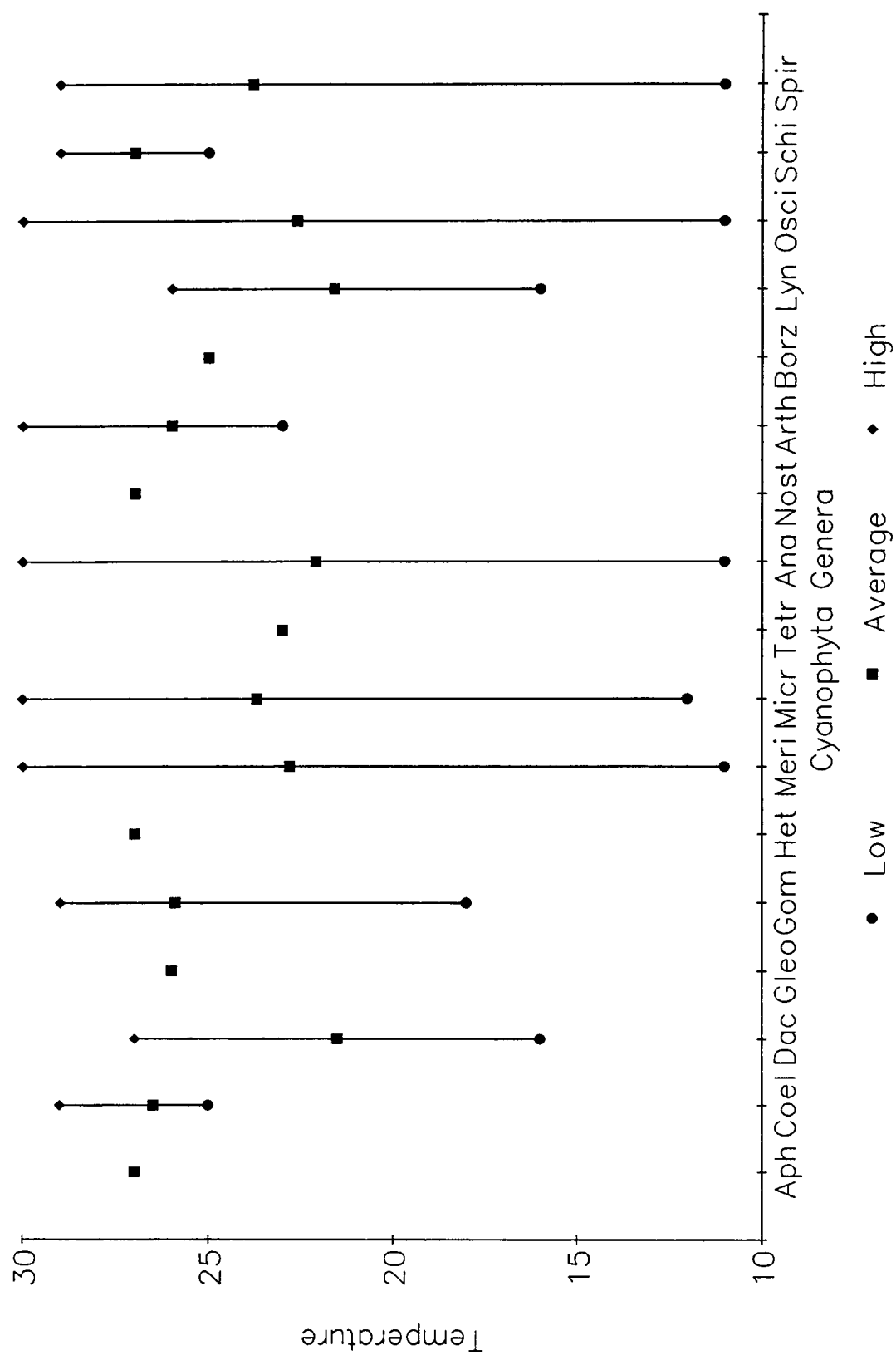


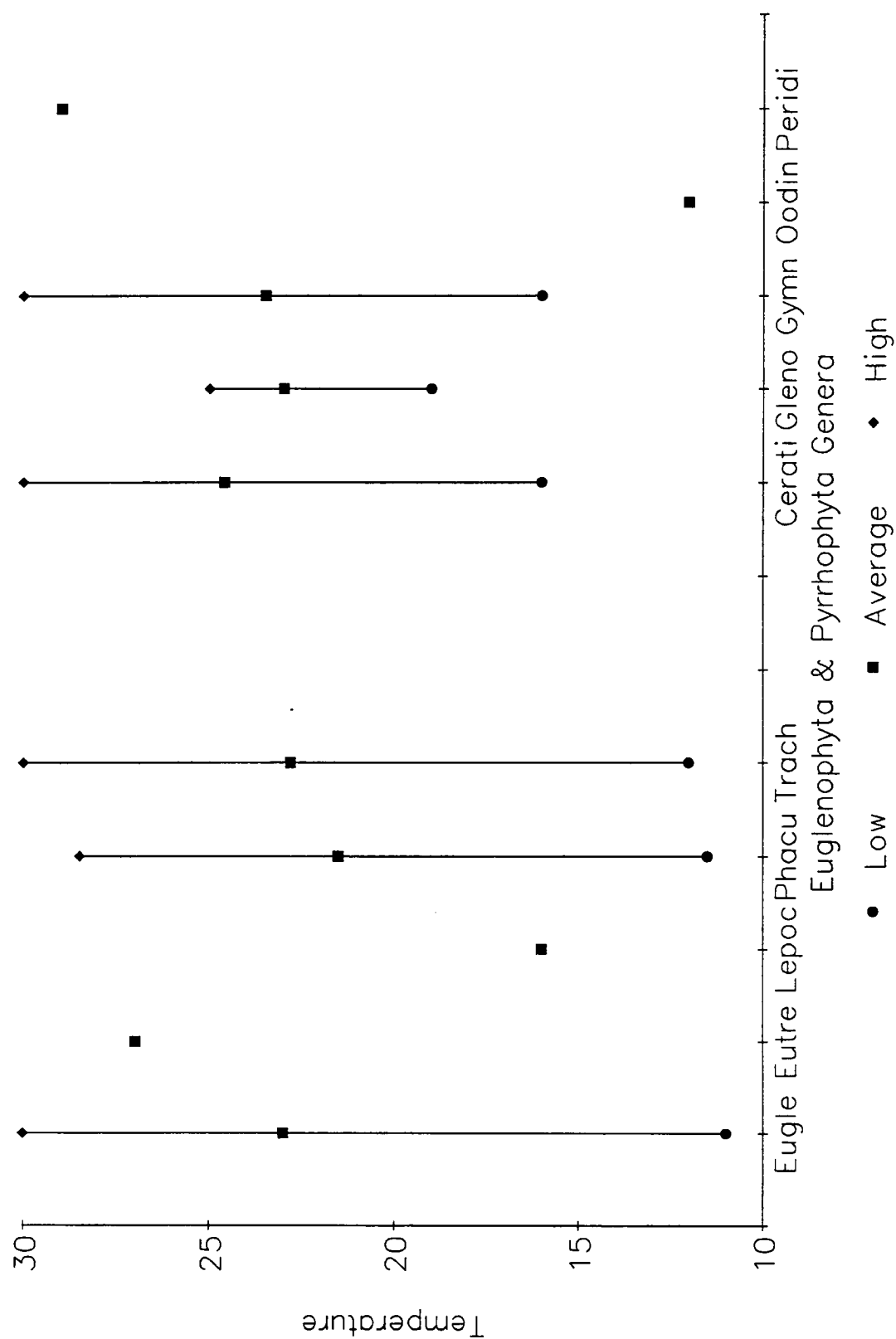












APPENDIX B (continued)**List of Phytoplankton Genera Identified in Watts Bar Reservoir, Tennessee
from September 10, 1994 through May 18, 1996****DIVISION CHLOROPHYTA****Order Chaetophorales**

Chaetosphaeridium
Chlorosarcina

Order Chlorococcales**Family Chlorococcaceae**

Phyllobium
Tetraedron

Family Dictyosphaeriaceae

Botryococcus

Family Hydrodictyaceae

Hydrodictyon
Pediastrum
Sorastrum

Family Micractiniaceae

Golenkinia

Family Oocystaceae

Ankistrodesmus
Chlorella (Inc. Palmellocooccus)
Kirchneriella
Nephrocytium
Oocystis
Quadrigula
Selenastrum

Family Palmellaceae

Sphaerocystis

Family Scenedesmaceae

Actinastrum

Coelastrum

Lauterborniella

*Phytomorula*³

Scenedesmus

Order Oedogoniales

Oedogonium

Order Siphonocladales

Rhizoclonium

Order Sphaeropleales

Sphaeroplea

Order Tetrasporales

Asterococcus

Characiochloris

Malleleochloris

Order Ulotrichales

Binuclearia

Microspora

Ulothrix

Uronema

Order Volvocales

Chlamydomonas

Eudorina

Gonium

Pandorina

Pleodorina

Sphaerellopsis

Spondylomorum

Volvox

Order Zygnematales

Family Desmidiaceae

Arthrodesmus

Closterium

Cosmarium

Docidium

Groenbladia

Micrasterias

Phymatodocis

Pleurotaenium

Staurastrum

Family Zygnemataceae

Mougeotia

Spirogyra

Zygnema

SUB-DIVISION CHAROPHYCEAE

Chara

DIVISION CHRYSOPHYTA

SUB-DIVISION BACILLARIOPHYCEAE

Order Centrales

Cyclotella

Melosira

Stephanodiscus

Order Pennales

Amphipleura

Amphora

Asterionella

Caloneis

Cymbella

Fragilaria

Gyrosigma
Navicula
Opephora
Surirella
Synedra
Tabellaria

SUB-DIVISION CHRYSOPHYCEAE

Chrysamoeba
Chrysosphaerella
Dinobryon
Lagynion
Mallomonas
Phaeoplaca
*Rhipidodendron*²
Synura
Uroglenopsis

SUB-DIVISION XANTHOPHYCEAE (HETEROKONTAE)

Order Mischococcales

Characiopsis
Peroniella
Tetraedriella

Order Rhizochloridales

Stipitococcus

Order Tribonematales

Bumilleria
Tribonema

DIVISION CYANOPHYTA

Order Chroococcales

Aphanocapsa
Coelosphaerium
Dactylococcopsis
Gloeotheca

Gomphosphaeria
Heterohormogonium
Merismopedia
Microcystis
Tetrapedia

Order Nostocales

Anabaena
Nostoc

Order Oscillatoriales

Arthrospira
Borzia
Lyngbya
Oscillatoria
Schizothrix
Spirulina

DIVISION EUGLENOPHYTA

Euglena
Eutreptia
Lepocinclis
Phacus
Trachelomonas

DIVISION PYRRHOPHYTA

Ceratium
Glenodinium
Gymnodinium
Oodinium
Peridinium

Primary Source: Prescott, G.W. 1970. *How to Know the Freshwater Algae*, 2nd ed. Wm. C. Brown Publishers, Dubuque, Iowa.

Secondary Sources: ²Smith, G.M. 1933. *The Freshwater Algae of the United States*. McGraw-Hill Book Co., New York, New York.

³Whitford L.A. and G.J. Schumacher. 1969. *A Manual of the Freshwater Algae in North Carolina*. The North Carolina Agricultural Experiment Station, Raleigh, North Carolina. Technical Bulletin No. 188.

APPENDIX C

**Field Sample Sheets for Watts Bar Reservoir Study on Phytoplankton
Community Composition from September 10, 1994 through May 18, 1996**

Date: 9/10/94

Samples: 1

Weather: Clear, calmLocation: Barn Cove #8

Location: _____

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions*

Environmental Conditions

Environmental Conditions

pH 7.5

pH _____

pH _____

Cond. 170 ppm

Cond. _____

Cond. _____

Temp. 24 - 27 °C

Temp. _____

Temp. _____

Water level 740 ft

Water level _____

Water level _____

Transparency 1.40 m

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Dinobryon*
- 4) *Eudorina*
- 5) *Gymnodinium*
- 6) *Lyngbya*
- 7) *Melosira*
- 8) *Oscillatoria*
- 9) *Pediastrum*
- 10) *Scenedesmus*
- 11) *Tabellaria*
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- 15) **TVA Env. Cond.*
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Date 10/29/94 # Samples: 1 Weather: Clear sky

Location: Barn Cove #8 Location: _____ Location: _____
 Sample 1 Sample 2 Sample 3
 Environmental Conditions Environmental Conditions Environmental Conditions

pH	<u>8.0</u>	pH	_____	pH	_____
Cond.	<u>140 ppm</u>	Cond.	_____	Cond.	_____
Temp.	<u>16 °C</u>	Temp.	_____	Temp.	_____
Water level	<u>740.2 ft</u>	Water level	_____	Water level	_____
Transparency	_____	Transparency	_____	Transparency	_____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Ankistrodesmus*
- 3) *Asterionella*
- 4) *Ceratium*
- 5) *Chlamydomonas*
- 6) *Cosmarium*
- 7) *Dinobryon*
- 8) *Euglena*
- 9) *Fragilaria*
- 10) *Gymnodinium*
- 11) *Lyngbya*
- 12) *Melosira*
- 13) *Merismopedia*
- 14) *Oedogonium*
- 15) *Oscillatoria*
- 16) *Pandorina*
- 17) *Pediastrum*
- 18) *Phacus*
- 19) *Scenedesmus*
- 20) *Sorastrum*
- 21) *Sphaeroplea*
- 22) *Spirogyra*
- 23) *Stephanodiscus*
- 24) *Synura*
- 25) *Tabellaria*
- 26) *Tribonema*
- 27) *Ulothrix*
- 28) *Volvox*
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Date: 11/12/94 # Samples: 1 Weather: Sunny, clear, breezy

Location: Channel other #10 Location: _____ Location: _____

Sample 1 Sample 2 Sample 3
Environmental Conditions Environmental Conditions Environmental Conditions

pH	<u>7.8</u>	pH	_____	pH	_____
Cond.	<u>140 ppm</u>	Cond.	_____	Cond.	_____
Temp.	<u>16 °C</u>	Temp.	_____	Temp.	_____
Water level	<u>738 ft</u>	Water level	_____	Water level	_____
Transparency	_____	Transparency	_____	Transparency	_____

GENUS

GENUS

GENUS

- | | | | | | |
|-----|--------------------------|-----|--|-----|--|
| 1) | <i>Actinastrum</i> | 1) | | 1) | |
| 2) | <i>Anabaena</i> | 2) | | 2) | |
| 3) | <i>Ankistrodesmus</i> | 3) | | 3) | |
| 4) | <i>Asterionella</i> | 4) | | 4) | |
| 5) | <i>Asterococcus</i> | 5) | | 5) | |
| 6) | <i>Botryococcus</i> | 6) | | 6) | |
| 7) | <i>Ceratium</i> | 7) | | 7) | |
| 8) | <i>Chaetosphaeridium</i> | 8) | | 8) | |
| 9) | <i>Chlorosarcina</i> | 9) | | 9) | |
| 10) | <i>Dactylococcopsis</i> | 10) | | 10) | |
| 11) | <i>Euglena</i> | 11) | | 11) | |
| 12) | <i>Fragilaria</i> | 12) | | 12) | |
| 13) | <i>Gymnodinium</i> | 13) | | 13) | |
| 14) | <i>Lepocinclis</i> | 14) | | 14) | |
| 15) | <i>Melosira</i> | 15) | | 15) | |
| 16) | <i>Merismopedia</i> | 16) | | 16) | |
| 17) | <i>Oedogonium</i> | 17) | | 17) | |
| 18) | <i>Pediastrum</i> | 18) | | 18) | |
| 19) | <i>Perionella</i> | 19) | | 19) | |
| 20) | <i>Phacus</i> | 20) | | 20) | |
| 21) | <i>Phytomorula</i> | 21) | | 21) | |
| 22) | <i>Scenedesmus</i> | 22) | | 22) | |
| 23) | <i>Spirogyra</i> | 23) | | 23) | |
| 24) | <i>Stipitococcus</i> | 24) | | 24) | |
| 25) | <i>Synura</i> | 25) | | 25) | |
| 26) | <i>Tabellaria</i> | 26) | | 26) | |
| 27) | <i>Trachelomonas</i> | 27) | | 27) | |
| 28) | <i>Volvox</i> | 28) | | 28) | |
| 29) | <i>Zygnema</i> | 29) | | 29) | |
| 30) | | 30) | | 30) | |

Date: 1/14/95

Samples: 3

Weather: Rainy, cloudy, foggyLocation: Mudflat #5

Sample 1

Environmental Conditions

pH 7.4Cond. 120 ppmTemp. 11 °CWater level 736 ftTransparency

GENUS

1) *Asterionella*2) *Bumilleria*3) *Fragilaria*4) *Gyrosigma*5) *Microspora*6) *Mougeotia*7) *Spirulina*8) *Tabellaria*

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Location: Riparian #6

Sample 2

Environmental Conditions

pH Cond. Temp. Water level Transparency

GENUS

1) *Anabaena*2) *Ankistrodesmus*3) *Asterionella*4) *Caloneis*5) *Euglena*6) *Fragilaria*7) *Merismopedia*8) *Microspora*9) *Pediastrum*

10)

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Location: Stagnant Pool #7

Sample 3

Environmental Conditions

pH Cond. Temp. Water level Transparency

GENUS

1) *Chlamydomonas*2) *Melosira*3) *Oscillatoria*4) *Scenedesmus*5) *Tribonema*

6)

7)

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Date: 3/22/95

Samples: 2

Weather: Cloudy, windyLocation: Mudflat #5Location: Riparian #6

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.4

pH _____

pH _____

Cond. 130 ppm

Cond. _____

Cond. _____

Temp. 19 °C

Temp. _____

Temp. _____

Water level 735 ft

Water level _____

Water level _____

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Anabaena*
- 2) *Ankistrodesmus*
- 3) *Asterionella*
- 4) *Dinobryon*
- 5) *Euglena*
- 6) *Fragilaria*
- 7) *Gymnodinium*
- 8) *Melosira*
- 9) *Oscillatoria*
- 10) *Stephanodiscus*
- 11) *Tabellaria*
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- 1) *Anabaena*
- 2) *Ankistrodesmus*
- 3) *Asterionella*
- 4) *Euglena*
- 5) *Melosira*
- 6) *Oscillatoria*
- 7) *Tabellaria*
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Date: 3/31/95

Samples: 2

Weather: Sunny, clearLocation: Mudflat #5Location: Riparian #6

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.3/7.4

pH _____

pH _____

Cond. 120 ppm

Cond. _____

Cond. _____

Temp. 17 °C

Temp. _____

Temp. _____

Water level 737 ft

Water level _____

Water level _____

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Ankistrodesmus*
- 4) *Asterionella*
- 5) *Chrysosphaerella*
- 6) *Dinobryon*
- 7) *Eudorina*
- 8) *Melosira*
- 9) *Navicula*
- 10) *Oscillatoria*
- 11) *Pediastrum*
- 12) *Phacus*
- 13) *Stephanodiscus*
- 14) *Tabellaria*
- 15) *Tribonema*
- 16) *Ulothrix*
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- 1) *Actinastrum*
- 2) *Ankistrodesmus*
- 3) *Asterionella*
- 4) *Cosmarium*
- 5) *Melosira*
- 6) *Scenedesmus*
- 7) *Stephanodiscus*
- 8) *Tabellaria*
- 9) *Tribonema*
- 10) *Ulothrix*
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Date: 5/18/95 # Samples: 2 Weather: Cloudy, windy

Location: Mudflat #5 Location: Riparian #6 Location: _____
 Sample 1 Sample 2 Sample 3
 Environmental Conditions Environmental Conditions Environmental Conditions

pH	<u>7.0/7.1</u>	pH	_____	pH	_____
Cond.	<u>180 ppm</u>	Cond.	_____	Cond.	_____
Temp.	<u>22 °C</u>	Temp.	_____	Temp.	_____
Water level	<u>740.5 ft</u>	Water level	_____	Water level	_____
Transparency	_____	Transparency	_____	Transparency	_____

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Asterionella*
- 4) *Binuclearia*
- 5) *Ceratium*
- 6) *Cosmarium*
- 7) *Dinobryon*
- 8) *Eudorina*
- 9) *Fragilaria*
- 10) *Kirchneriella*
- 11) *Melosira*
- 12) *Mougeotia*
- 13) *Oedogonium*
- 14) *Oscillatoria*
- 15) *Pediastrum*
- 16) *Sphaerocystis*
- 17) *Stephanodiscus*
- 18) *Tabellaria*
- 19) *Tribonema*
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GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Ankistrodesmus*
- 4) *Asterionella*
- 5) *Binuclearia*
- 6) *Euglena*
- 7) *Fragilaria*
- 8) *Gymnodinium*
- 9) *Kirchneriella*
- 10) *Melosira*
- 11) *Oedogonium*
- 12) *Pandorina*
- 13) *Pediastrum*
- 14) *Phacus*
- 15) *Scenedesmus*
- 16) *Sphaerocystis*
- 17) *Spirulina*
- 18) *Staurastrum*
- 19) *Stephanodiscus*
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Date: 5/25/95

Samples: 3

Weather: SunnyLocation: Mudflat #5Location: Riparian #6Location: Barn Cove #8

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH _____

pH _____

pH 8.0

Cond. _____

Cond. _____

Cond. 160 ppm

Temp. _____

Temp. _____

Temp. 23 °C

Water level _____

Water level _____

Water level 740.8 ft

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

1) *Ankistrodesmus*1) *Ankistrodesmus*1) *Actinastrum*2) *Asterionella*2) *Asterionella*2) *Asterionella*3) *Cosmarium*3) *Euglena*3) *Chlorella*4) *Euglena*4) *Fragilaria*4) *Chlorosarcina*5) *Fragilaria*5) *Microcystis*5) *Cosmarium*6) *Melosira*6) *Pediastrum*6) *Euglena*7) *Oedogonium*7) *Phacus*7) *Fragilaria*8) *Pediastrum*8) *Sphaerocystis*8) *Kirchneriella*9) *Phacus*9) *Stephanodiscus*9) *Microcystis*10) *Spirogyra*

10)

10) *Nephrocytium*11) *Stephanodiscus*

11)

11) *Oocystis*12) *Volvox*

12)

12) *Pandorina*

13)

13)

13) *Pediastrum*

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14)

14) *Scenedesmus*

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15) *Staurostrum*

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16) *Stephanodiscus*

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17) *Volvox*

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Date: 6/9/95 # Samples: 3

Weather: Cloudy past two weeksLocation: Mudflat #5Location: Riparian #6Location: Barn Cove #8

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH _____

pH _____

pH 7.5

Cond. _____

Cond. _____

Cond. 150 ppm

Temp. _____

Temp. _____

Temp. 29 °C

Water level _____

Water level _____

Water level 741 ft

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Ankistrodesmus*
- 3) *Asterionella*
- 4) *Coelastrum*
- 5) *Cosmarium*
- 6) *Cymbella*
- 7) *Dinobryon*
- 8) *Fragilaria*
- 9) *Melosira*
- 10) *Pediastrum*
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- 15) **No Daphnia*
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- 1) *Pediastrum*
- 2) *Spirogyra*
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- 15) **Daphnia*
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- 1) *Actinastrum*
- 2) *Asterionella*
- 3) *Ceratium*
- 4) *Fragilaria*
- 5) *Oedogonium*
- 6) *Pediastrum*
- 7) *Peridinium*
- 8) *Scenedesmus*
- 9) *Staurastrum*
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Date: 6/17/95 # Samples: 2 Weather: Sunny

Location: Mudflat #5 Location: Riparian #6 Location: _____
 Sample 1 Sample 2 Sample 3
 Environmental Conditions Environmental Conditions Environmental Conditions

pH	<u>7.0/7.1</u>	pH	_____	pH	_____
Cond.	<u>130 ppm</u>	Cond.	_____	Cond.	_____
Temp.	<u>27 °C</u>	Temp.	_____	Temp.	_____
Water level	<u>740 ft</u>	Water level	_____	Water level	_____
Transparency	_____	Transparency	_____	Transparency	_____

GENUS

GENUS

GENUS

- | | | |
|----------------------------|---------------------------|-----|
| 1) <i>Actinastrum</i> | 1) <i>Actinastrum</i> | 1) |
| 2) <i>Ankistrodesmus</i> | 2) <i>Ankistrodesmus</i> | 2) |
| 3) <i>Asterionella</i> | 3) <i>Asterionella</i> | 3) |
| 4) <i>Bumilleria</i> | 4) <i>Ceratium</i> | 4) |
| 5) <i>Ceratium</i> | 5) <i>Closterium</i> | 5) |
| 6) <i>Chrysamoeba</i> | 6) <i>Cymbella</i> | 6) |
| 7) <i>Cosmarium</i> | 7) <i>Dinobryon</i> | 7) |
| 8) <i>Cymbella</i> | 8) <i>Docidium</i> | 8) |
| 9) <i>Dactylococcopsis</i> | 9) <i>Euglena</i> | 9) |
| 10) <i>Euglena</i> | 10) <i>Eutreptia</i> | 10) |
| 11) <i>Fragilaria</i> | 11) <i>Fragilaria</i> | 11) |
| 12) <i>Lauterborniella</i> | 12) <i>Gymnodinium</i> | 12) |
| 13) <i>Navicula</i> | 13) <i>Kirchneriella</i> | 13) |
| 14) <i>Oedogonium</i> | 14) <i>Melosira</i> | 14) |
| 15) <i>Pediastrum</i> | 15) <i>Merismopedia</i> | 15) |
| 16) <i>Scenedesmus</i> | 16) <i>Microcystis</i> | 16) |
| 17) <i>Spirogyra</i> | 17) <i>Oedogonium</i> | 17) |
| 18) <i>Staurastrum</i> | 18) <i>Pediastrum</i> | 18) |
| 19) <i>Ulothrix</i> | 19) <i>Quadrigula</i> | 19) |
| 20) | 20) <i>Scenedesmus</i> | 20) |
| 21) | 21) <i>Spirogyra</i> | 21) |
| 22) | 22) <i>Spirulina</i> | 22) |
| 23) | 23) <i>Staurastrum</i> | 23) |
| 24) | 24) <i>Stephanodiscus</i> | 24) |
| 25) | 25) <i>Tabellaria</i> | 25) |
| 26) | 26) <i>Uroglenopsis</i> | 26) |
| 27) | 27) <i>Volvox</i> | 27) |
| 28) | 28) | 28) |
| 29) | 29) | 29) |
| 30) | 30) | 30) |

Date: 7/1/95

Samples: 3

Weather: Partly cloudyLocation: Mudflat #5Location: Riparian #6Location: Benthic #7

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.3pH pH Cond. 150 ppmCond. Cond. Temp. 28 °CTemp. Temp. Water level 739.5 ftWater level Water level Transparency Transparency Transparency

GENUS

GENUS

GENUS

- 1) *Asterionella*
- 2) *Bumilleria*
- 3) *Merismopedia*
- 4) *Microcystis*
- 5) *Pediastrum*
- 6) *Ulothrix*
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- 10) *Many daphnia
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- 1) *Bumilleria*
- 2) *Fragilaria*
- 3) *Melosira*
- 4) *Microcystis*
- 5) *Navicula*
- 6) *Pediastrum*
- 7) *Spirogyra*
- 8)
- 9)
- 10) *Few daphnia
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- 1) *Chara*
- 2) *Cosmarium*
- 3) *Hydrodictyon*
- 4) *Oscillatoria*
- 5) *Rhipidodendron*
- 6) *Rhizoclonium*
- 7) *Spirogyra*
- 8) *Uronema*
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Date: 7/9/95

Samples: 3

Weather: SunnyLocation: Mudflat #5Location: Riparian #6Location: Dock #7

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.7, 7.8pH pH Cond. 160 ppmCond. Cond. Temp. 30 °CTemp. Temp. Water level 739.8 ftWater level Water level Transparency Transparency Transparency

GENUS

GENUS

GENUS

- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Bumilleria*
- 4) *Ceratium*
- 5) *Cosmarium*
- 6) *Dinobryon*
- 7) *Fragilaria*
- 8) *Gymnodinium*
- 9) *Melosira*
- 10) *Merismopedia*
- 11) *Microcystis*
- 12) *Navicula*
- 13) *Oedogonium*
- 14) *Oscillatoria*
- 15) *Pediastrum*
- 16) *Sphaerocystis*
- 17) *Spirogyra*
- 18) *Trachelomonas*
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- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Ankistrodesmus*
- 4) *Bumilleria*
- 5) *Cosmarium*
- 6) *Euglena*
- 7) *Fragilaria*
- 8) *Gonium*
- 9) *Melosira*
- 10) *Merismopedia*
- 11) *Microcystis*
- 12) *Navicula*
- 13) *Oedogonium*
- 14) *Pediastrum*
- 15) *Scenedesmus*
- 16) *Sphaerellopsis*
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- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Chlamydomonas*
- 4) *Cyclotella*
- 5) *Gyrosigma*
- 6) *Merismopedia*
- 7) *Microcystis*
- 8) *Sphaerocystis*
- 9) *Spirogyra*
- 10) *Synura*
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Date: 7/29/95

Samples: 3

Weather: SunnyLocation: Cave Creek #9Location: Channel #10Location: Barn Cove #8

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.3/7.4pH 7.2pH 7.5Cond. 160 ppmCond. 140 ppmCond. 160 ppmTemp. 27 °CTemp. 27 °CTemp. 29 °CWater level 740.4 ftWater level 740.4 ftWater level 740.4 ft

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Aphanocapsa*
- 4) *Arthrospira*
- 5) *Asterionella*
- 6) *Bumilleria*
- 7) *Ceratium*
- 8) *Chlamydomonas*
- 9) *Coelosphaerium*
- 10) *Cosmarium*
- 11) *Dinobryon*
- 12) *Euglena*
- 13) *Fragilaria*
- 14) *Golenkinia*
- 15) *Gomphosphaeria*
- 16) *Gymnodinium*
- 17) *Mallomonas*
- 18) *Melosira*
- 19) *Merismopedia*
- 20) *Microcystis*
- 21) *Navicula*
- 22) *Oedogonium*
- 23) *Oscillatoria*
- 24) *Pandorina*
- 25) *Pediastrum*
- 26) *Phaeoplaca*
- 27) *Scenedesmus*
- 28) *Sphaerellopsis*
- 29) *Spondylium*
- 30) *Stephanodiscus*

- 1) *Bumillaria*
- 2) *Cosmarium*
- 3) *Dinobryon*
- 4) *Fragilaria*
- 5) *Gomphosphaeria*
- 6) *Gymnodinium*
- 7) *Melosira*
- 8) *Oedogonium*
- 9) *Pediastrum*
- 10) *Scenedesmus*
- 11) *Tabellaria*
- 12) *Tribonema*
- 13) *Ulothrix*
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- 1) *Anabaena*
- 2) *Cosmarium*
- 3) *Euglena*
- 4) *Fragilaria*
- 5) *Gomphosphaeria*
- 6) *Melosira*
- 7) *Merismopedia*
- 8) *Microcystis*
- 9) *Oedogonium*
- 10) *Pandorina*
- 11) *Pediastrum*
- 12) *Scenedesmus*
- 13) *Stephanodiscus*
- 14) *Tabellaria*
- 15) *Tribonema*
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31)	<i>Synura</i>	31)	31)
32)	<i>Tabellaria</i>	32)	32)
33)	<i>Tribonema</i>	33)	33)
34)	<i>Volvox</i>	34)	34)

Date: 8/5/95 # Samples: 2

Weather: Mostly cloudy, windyLocation: Dock #7Location: Wall #7

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 8.2

pH _____

pH _____

Cond. 140 ppm

Cond. _____

Cond. _____

Temp. 27 °C

Temp. _____

Temp. _____

Water level 740.5 ft

Water level _____

Water level _____

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Ceratium*
- 4) *Cosmarium*
- 5) *Dinobryon*
- 6) *Euglena*
- 7) *Fragilaria*
- 8) *Gyrosigma*
- 9) *Hydrodictyon*
- 10) *Melosira*
- 11) *Microcystis*
- 12) *Navicula*
- 13) *Oedogonium*
- 14) *Pediastrum*
- 15) *Scenedesmus*
- 16) *Spirogyra*
- 17) *Tabellaria*
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- 1) *Oscillatoria*
- 2) *Rhizoclonium*
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Date: 8/9/95 # Samples: 3

Weather: CloudyLocation: Behind Wilson #4Location: Chnl Wilson #4Location: Cow Cove #3

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.8pH 7.8pH 8.1Cond. 160 ppmCond. 150 ppmCond. 120 ppmTemp. 26 °CTemp. 26 °CTemp. 26 °CWater level 741.4 ftWater level 741.4 ftWater level 741.4 ftTransparency Transparency Transparency

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Arthrodesmus*
- 4) *Arthrospira*
- 5) *Asterionella*
- 6) *Asterococcus*
- 7) *Bumilleria*
- 8) *Ceratium*
- 9) *Cosmarium*
- 10) *Fragilaria*
- 11) *Golenkinia*
- 12) *Gomphosphaeria*
- 13) *Lyngbya*
- 14) *Mallomonas*
- 15) *Melosira*
- 16) *Merismopedia*
- 17) *Microcystis*
- 18) *Navicula*
- 19) *Oscillatoria*
- 20) *Pediastrum*
- 21) *Scenedesmus*
- 22) *Staurastrum*
- 23) *Stephanodiscus*
- 24) *Tabellaria*
- 25) *Tribonema*
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- 1) *Anabaena*
- 2) *Arthrospira*
- 3) *Asterionella*
- 4) *Asterococcus*
- 5) *Bumilleria*
- 6) *Ceratium*
- 7) *Chlorosarcina*
- 8) *Coelastrum*
- 9) *Cosmarium*
- 10) *Euglena*
- 11) *Fragilaria*
- 12) *Gleotheca*
- 13) *Gomphosphaeria*
- 14) *Gyrosigma*
- 15) *Melosira*
- 16) *Merismopedia*
- 17) *Microcystis*
- 18) *Navicula*
- 19) *Oedogonium*
- 20) *Oscillatoria*
- 21) *Pandorina*
- 22) *Pediastrum*
- 23) *Phacus*
- 24) *Scenedesmus*
- 25) *Sphaerocystis*
- 26) *Spirogyra*
- 27) *Staurastrum*
- 28) *Stephanodiscus*
- 29) *Tabellaria*
- 30) *Tribonema*

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Arthrospira*
- 4) *Asterionella*
- 5) *Asterococcus*
- 6) *Bumilleria*
- 7) *Ceratium*
- 8) *Chlorosarcina*
- 9) *Coelastrum*
- 10) *Cosmarium*
- 11) *Euglena*
- 12) *Fragilaria*
- 13) *Melosira*
- 14) *Microcystis*
- 15) *Oscillatoria*
- 16) *Pediastrum*
- 17) *Scenedesmus*
- 18) *Staurastrum*
- 19) *Stephanodiscus*
- 20) *Tabellaria*
- 21) *Tribonema*
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Date: 8/19/95

Samples: 3

Weather: SunnyLocation: Cave Creek #9

Sample 1

Environmental Conditions

Location: Channel #10

Sample 2

Environmental Conditions

Location: Barn Cove #8

Sample 3

Environmental Conditions

pH 8.4
 Cond. 200 ppm
 Temp. 28 °C
 Water level 740.0 ft
 Transparency 0.432 m

pH 7.9
 Cond. 170 ppm
 Temp. 28.5 °C
 Water level 740.0 ft
 Transparency 1.17 m

pH 8.6
 Cond. 150 ppm
 Temp. 29 °C
 Water level 740.0 ft
 Transparency 0.432 m

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Asterionella*
- 4) *Asterococcus*
- 5) *Bumilleria*
- 6) *Ceratium*
- 7) *Closterium*
- 8) *Cosmarium*
- 9) *Euglena*
- 10) *Fragilaria*
- 11) *Gomphosphaeria*
- 12) *Groenbladia*
- 13) *Gymnodinium*
- 14) *Melosira*
- 15) *Merismopedia*
- 16) *Microcystis*
- 17) *Navicula*
- 18) *Oscillatoria*
- 19) *Pandorina*
- 20) *Pediastrum*
- 21) *Phacus*
- 22) *Scenedesmus*
- 23) *Selenastrum*
- 24) *Spirulina*
- 25) *Staurastrum*
- 26) *Stephanodiscus*
- 27) *Synura*
- 28) *Tabellaria*
- 29) *Tetradriella*
- 30) *Tetraedron*

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Asterionella*
- 4) *Asterococcus*
- 5) *Bumilleria*
- 6) *Ceratium*
- 7) *Cosmarium*
- 8) *Euglena*
- 9) *Fragilaria*
- 10) *Golenkinia*
- 11) *Gomphosphaeria*
- 12) *Gymnodinium*
- 13) *Gyrosigma*
- 14) *Melosira*
- 15) *Merismopedia*
- 16) *Microcystis*
- 17) *Navicula*
- 18) *Pandorina*
- 19) *Pediastrum*
- 20) *Phacus*
- 21) *Scenedesmus*
- 22) *Spirulina*
- 23) *Staurastrum*
- 24) *Tabellaria*
- 25) *Trachelomonas*
- 26) *Tribonema*
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GENUS

- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Bumilleria*
- 4) *Ceratium*
- 5) *Coelosphaerium*
- 6) *Euglena*
- 7) *Gomphosphaeria*
- 8) *Melosira*
- 9) *Merismopedia*
- 10) *Navicula*
- 11) *Oscillatoria*
- 12) *Pediastrum*
- 13) *Scenedesmus*
- 14) *Schizothrix*
- 15) *Spirulina*
- 16) *Staurastrum*
- 17) *Tabellaria*
- 18) *Trachelomonas*
- 19) *Tribonema*
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Date: 8/26/95

Samples: 3

Weather: Cloudy, rainyLocation: Cave Creek #9Location: Channel #10Location: Barn Cove #8

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.5, 7.6pH 7.4, 7.5pH 7.9, 8.0Cond. 240 ppmCond. 150 ppmCond. 150 ppmTemp. 25 °CTemp. 25 °CTemp. 25.5 °CWater level 739.5 ftWater level 739.5 ftWater level 739.5 ftTransparency 0.406 mTransparency 0.406 mTransparency 0.33 m

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Asterionella*
- 4) *Asterococcus*
- 5) *Bumilleria*
- 6) *Borzia*
- 7) *Ceratium*
- 8) *Coelosphaerium*
- 9) *Eudorina*
- 10) *Euglena*
- 11) *Glenodinium*
- 12) *Golenkinia*
- 13) *Gymnodinium*
- 14) *Melosira*
- 15) *Merismopedia*
- 16) *Microcystis*
- 17) *Pandorina*
- 18) *Pediastrum*
- 19) *Phacus*
- 20) *Scenedesmus*
- 21) *Spirulina*
- 22) *Staurastrum*
- 23) *Stephanodiscus*
- 24) *Surirella*
- 25) *Tabellaria*
- 26) *Trachelomonas*
- 27) *Tribonema*
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- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Arthrospira*
- 4) *Asterionella*
- 5) *Asterococcus*
- 6) *Botryococcus*
- 7) *Bumilleria*
- 8) *Ceratium*
- 9) *Closterium*
- 10) *Coelosphaerium*
- 11) *Cosmarium*
- 12) *Dinobryon*
- 13) *Euglena*
- 14) *Fragilaria*
- 15) *Glenodinium*
- 16) *Golenkinia*
- 17) *Gomphosphaeria*
- 18) *Gymnodinium*
- 19) *Melosira*
- 20) *Merismopedia*
- 21) *Oscillatoria*
- 22) *Pandorina*
- 23) *Pediastrum*
- 24) *Phacus*
- 25) *Phymatodocis*
- 26) *Pleodorina*
- 27) *Scenedesmus*
- 28) *Schizothrix*
- 29) *Sphaerocystis*
- 30) *Spirulina*

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Asterionella*
- 4) *Bumilleria*
- 5) *Ceratium*
- 6) *Chlorosarcina*
- 7) *Coelastrum*
- 8) *Cosmarium*
- 9) *Euglena*
- 10) *Fragilaria*
- 11) *Golenkinia*
- 12) *Gomphosphaeria*
- 13) *Gymnodinium*
- 14) *Melosira*
- 15) *Merismopedia*
- 16) *Mougeotia*
- 17) *Navicula*
- 18) *Pandorina*
- 19) *Pediastrum*
- 20) *Phacus*
- 21) *Pleodorina*
- 22) *Scenedesmus*
- 23) *Sphaerocystis*
- 24) *Spirulina*
- 25) *Staurastrum*
- 26) *Synura*
- 27) *Tabellaria*
- 28) *Trachelomonas*
- 29) *Tribonema*
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31)	31)	<i>Staurastrum</i>	31)
32)	32)	<i>Stephanodiscus</i>	32)
33)	33)	<i>Synura</i>	33)
34)	34)	<i>Tabellaria</i>	34)
35)	35)	<i>Trachelomonas</i>	35)
36)	36)	<i>Tribonema</i>	36)

Date: 9/7/95 # Samples: 3

Weather: SunnyLocation: Dock #7Location: Benthic #7Location: Wall #7

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 8.2pH pH Cond. 140 ppmCond. Cond. Temp. 27 °CTemp. Temp. Water level 740 ftWater level Water level Transparency Transparency Transparency

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Amphipluera*
- 3) *Ankistrodesmus*
- 4) *Asterionella*
- 5) *Bumilleria*
- 6) *Eudorina*
- 7) *Euglena*
- 8) *Fragilaria*
- 9) *Gomphosphaeria*
- 10) *Gyrosigma*
- 11) *Melosira*
- 12) *Merismopedia*
- 13) *Microcystis*
- 14) *Navicula*
- 15) *Oedogonium*
- 16) *Oscillatoria*
- 17) *Pandorina*
- 18) *Pediastrum*
- 19) *Scenedesmus*
- 20) *Spirogyra*
- 21) *Synedra*
- 22) *Tabellaria*
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- 1) *Amphora*
- 2) *Anabaena*
- 3) *Cosmarium*
- 4) *Euglena*
- 5) *Heterohormogonium*
- 6) *Merismopedia*
- 7) *Microcystis*
- 8) *Navicula*
- 9) *Nostoc*
- 10) *Oscillatoria*
- 11) *Rhizoclonium*
- 12) *Scenedesmus*
- 13) *Spirulina*
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- 1) *Amphora*
- 2) *Bumilleria*
- 3) *Euglena*
- 4) *Golenkinia*
- 5) *Gyrosigma*
- 6) *Merismopedia*
- 7) *Navicula*
- 8) *Oscillatoria*
- 9) *Rhizoclonium*
- 10) *Scenedesmus*
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Date: 9/16/95

Samples: 1

Weather: Cloudy, rainy

Location: Dock #7
 Sample 1
 Environmental Conditions

Location: _____
 Sample 2
 Environmental Conditions

Location: _____
 Sample 3
 Environmental Conditions

pH 7.6
 Cond. 120 ppm
 Temp. 23 °C
 Water level 740.8 ft
 Transparency 0.61 m

pH _____
 Cond. _____
 Temp. _____
 Water level _____
 Transparency _____

pH _____
 Cond. _____
 Temp. _____
 Water level _____
 Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Asterionella*
- 3) *Bumilleria*
- 4) *Ceratium*
- 5) *Fragilaria*
- 6) *Gymnodinium*
- 7) *Gyrosigma*
- 8) *Melosira*
- 9) *Merismopedia*
- 10) *Microcystis*
- 11) *Navicula*
- 12) *Pandorina*
- 13) *Pediastrum*
- 14) *Scenedesmus*
- 15) *Spirogyra*
- 16) *Synura*
- 17) *Tabellaria*
- 18) *Tribonema*
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Date: 9/23/95

Samples: 3

Weather: Cloudy, windyLocation: Lowes Br #1 WUS Location: Lowes Br #1 WS Location: Benthic #1

Sample 1 Wind-unshelt.

Sample 2 Wind-shelt.

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.8pH 7.8pH Cond. 210 ppmCond. 185 ppmCond. Temp. 23 °CTemp. 23 °CTemp. Water level 740 ftWater level 740 ftWater level Transparency 0.635 mTransparency 1.14 mTransparency

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Ceratium*
- 3) *Chlamydomonas*
- 4) *Coelastrum*
- 5) *Eudorina*
- 6) *Euglena*
- 7) *Fragilaria*
- 8) *Golenkinia*
- 9) *Gyrosigma*
- 10) *Kirchneriella*
- 11) *Lagynion*
- 12) *Melosira*
- 13) *Micrasterias*
- 14) *Microcystis*
- 15) *Oedogonium*
- 16) *Oscillatoria*
- 17) *Pandorina*
- 18) *Pediastrum*
- 19) *Scenedesmus*
- 20) *Spirulina*
- 21) *Staurastrum*
- 22) *Stephanodiscus*
- 23) *Tetrapedia*
- 24) *Tribonema*
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- 1) *Bumilleria*
- 2) *Euglena*
- 3) *Fragilaria*
- 4) *Gomphosphaeria*
- 5) *Gymnodinium*
- 6) *Melosira*
- 7) *Oedogonium*
- 8) *Oscillatoria*
- 9) *Pediastrum*
- 10) *Spirulina*
- 11) *Staurastrum*
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- 1) *Lyngbya*
- 2) *Scenedesmus*
- 3) *Spirogyra*
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Date: 10/21/95

Samples: 2

Weather: Partly cloudy, windyLocation: Euchee Cove #2Location: Euchee Emb. #2

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 8.2pH 8.0

pH _____

Cond. 170 ppmCond. 150 ppm

Cond. _____

Temp. 19 °CTemp. 18 °C

Temp. _____

Water level 740 ftWater level 740 ft

Water level _____

Transparency 1.14 mTransparency 1.14 m

Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Ankistrodesmus*
- 4) *Asterionella*
- 5) *Bumilleria*
- 6) *Ceratium*
- 7) *Coelastrum*
- 8) *Cosmarium*
- 9) *Eudorina*
- 10) *Euglena*
- 11) *Fragilaria*
- 12) *Glenodinium*
- 13) *Gymnodinium*
- 14) *Mallomonas*
- 15) *Melosira*
- 16) *Microcystis*
- 17) *Navicula*
- 18) *Oedogonium*
- 19) *Opephora*
- 20) *Oscillatoria*
- 21) *Pandorina*
- 22) *Pediastrum*
- 23) *Phacus*
- 24) *Scenedesmus*
- 25) *Selenastrum*
- 26) *Staurastrum*
- 27) *Stephanodiscus*
- 28) *Tabellaria*
- 29) *Trachelomonas*
- 30) *Tribonema*
- 31) *Volvox*

- 1) *Actinastrum*
- 2) *Asterionella*
- 3) *Asterococcus*
- 4) *Bumilleria*
- 5) *Ceratium*
- 6) *Euglena*
- 7) *Fragilaria*
- 8) *Gomphosphaeria*
- 9) *Gymnodinium*
- 10) *Melosira*
- 11) *Oscillatoria*
- 12) *Pandorina*
- 13) *Pediastrum*
- 14) *Phacus*
- 15) *Quadrigula*
- 16) *Scenedesmus*
- 17) *Staurastrum*
- 18) *Stephanodiscus*
- 19) *Tabellaria*
- 20) *Trachelomonas*
- 21) *Volvox*
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Date: 10/28/95

Samples: 2

Weather: Partly cloudy, windyLocation: Mudflat #5Location: Riparian #6

Location: _____

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.4, 7.5pH 7.9, 8.0

pH _____

Cond. 120 ppmCond. 130 ppm

Cond. _____

Temp. 16 °CTemp. 17.5 °C

Temp. _____

Water level 739 ftWater level 739 ft

Water level _____

Transparency _____

Transparency _____

Transparency _____

GENUS

GENUS

GENUS

- 1) *Anabaena*
- 2) *Bumilleria*
- 3) *Characiochloris*
- 4) *Characiopsis*
- 5) *Closterium*
- 6) *Fragilaria*
- 7) *Malleleochloris*
- 8) *Melosira*
- 9) *Microcystis*
- 10) *Navicula*
- 11) *Oscillatoria*
- 12) *Pediastrum*
- 13) *Scenedesmus*
- 14) *Sphaerocystis*
- 15) *Spirogyra*
- 16) *Spirulina*
- 17) *Stipitococcus*
- 18) *Tabellaria*
- 19) *Tribonema*
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- 1) *Anabaena*
- 2) *Bumilleria*
- 3) *Characiopsis*
- 4) *Euglena*
- 5) *Fragilaria*
- 6) *Gyrosigma*
- 7) *Melosira*
- 8) *Merismopedia*
- 9) *Microcystis*
- 10) *Navicula*
- 11) *Pediastrum*
- 12) *Spirogyra*
- 13) *Stipitococcus*
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Date: 12/2/95

Samples: 3

Weather: SunnyLocation: Mudflat #5Location: Riparian #6Location: Stag. Pool #7

Sample 1

Sample 2

Sample 3

Environmental Conditions

Environmental Conditions

Environmental Conditions

pH 7.8pH 7.5pH 7.8Cond. 130 ppmCond. 140 ppmCond. 160 ppmTemp. 12 °CTemp. 12 °CTemp. 11.5 °CWater level 736 ftWater level 736 ftWater level Transparency Transparency Transparency

GENUS

GENUS

GENUS

- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Bumilleria*
- 4) *Characiopsis*
- 5) *Cymbella*
- 6) *Fragilaria*
- 7) *Melosira*
- 8) *Merismopedia*
- 9) *Microcystis*
- 10) *Navicula*
- 11) *Oscillatoria*
- 12) *Phyllobium*
- 13) *Phymatodocis*
- 14) *Rhizoclonium*
- 15) *Scenedesmus*
- 16) *Spirogyra*
- 17) *Tabellaria*
- 18) *Tribonema*
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- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Bumilleria*
- 4) *Fragilaria*
- 5) *Kirchneriella*
- 6) *Melosira*
- 7) *Merismopedia*
- 8) *Microcystis*
- 9) *Navicula*
- 10) *Oodinium*
- 11) *Oscillatoria*
- 12) *Pediastrum*
- 13) *Rhizoclonium*
- 14) *Spirogyra*
- 15) *Surirella*
- 16) *Synura*
- 17) *Tabellaria*
- 18) *Trachelomonas*
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- 1) *Anabaena*
- 2) *Asterionella*
- 3) *Binuclearia*
- 4) *Bumilleria*
- 5) *Closterium*
- 6) *Cymbella*
- 7) *Euglena*
- 8) *Fragilaria*
- 9) *Merismopedia*
- 10) *Navicula*
- 11) *Oscillatoria*
- 12) *Pediastrum*
- 13) *Phacus*
- 14) *Phyllobium*
- 15) *Rhizoclonium*
- 16) *Scenedesmus*
- 17) *Spirogyra*
- 18) *Tabellaria*
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Date: 5/18/96 # Samples: 2 Weather: Sunny

Location: <u>Mudflat #5</u>	Location: <u>Riparian #6</u>	Location: _____
Sample 1	Sample 2	Sample 3
Environmental Conditions	Environmental Conditions	Environmental Conditions
pH <u>7.7, 7.8</u>	pH <u>7.9, 8.0</u>	pH _____
Cond. <u>140 ppm</u>	Cond. <u>130 ppm</u>	Cond. _____
Temp. <u>23 °C</u>	Temp. <u>23 °C</u>	Temp. _____
Water level <u>741.3 ft</u>	Water level <u>741.3 ft</u>	Water level _____
Transparency _____	Transparency _____	Transparency _____

GENUS

GENUS

GENUS

- 1) *Actinastrum*
- 2) *Ankistrodesmus*
- 3) *Arthrospira*
- 4) *Asterionella*
- 5) *Bumilleria*
- 6) *Dinobryon*
- 7) *Euglena*
- 8) *Fragilaria*
- 9) *Melosira*
- 10) *Merismopedia*
- 11) *Microcystis*
- 12) *Navicula*
- 13) *Oscillatoria*
- 14) *Pediastrum*
- 15) *Pleurotaenium*
- 16) *Spirogyra*
- 17) *Tabellaria*
- 18) *Tribonema*
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- 1) *Actinastrum*
- 2) *Anabaena*
- 3) *Ankistrodesmus*
- 4) *Asterionella*
- 5) *Bumilleria*
- 6) *Cosmarium*
- 7) *Cymbella*
- 8) *Dinobryon*
- 9) *Euglena*
- 10) *Fragilaria*
- 11) *Gomphosphaeria*
- 12) *Gyrosigma*
- 13) *Melosira*
- 14) *Merismopedia*
- 15) *Microcystis*
- 16) *Navicula*
- 17) *Oscillatoria*
- 18) *Pediastrum*
- 19) *Pleurotaenium*
- 20) *Spirogyra*
- 21) *Surirella*
- 22) *Tabellaria*
- 23) *Tribonema*
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APPENDIX D

Physio-Chemical Factor Profile on Watts Bar Reservoir from September 10, 1994 through May 18, 1996

The physio-chemical factors were averaged over all samples per sample day (Appendix C) and were manipulated for graphing as described below.

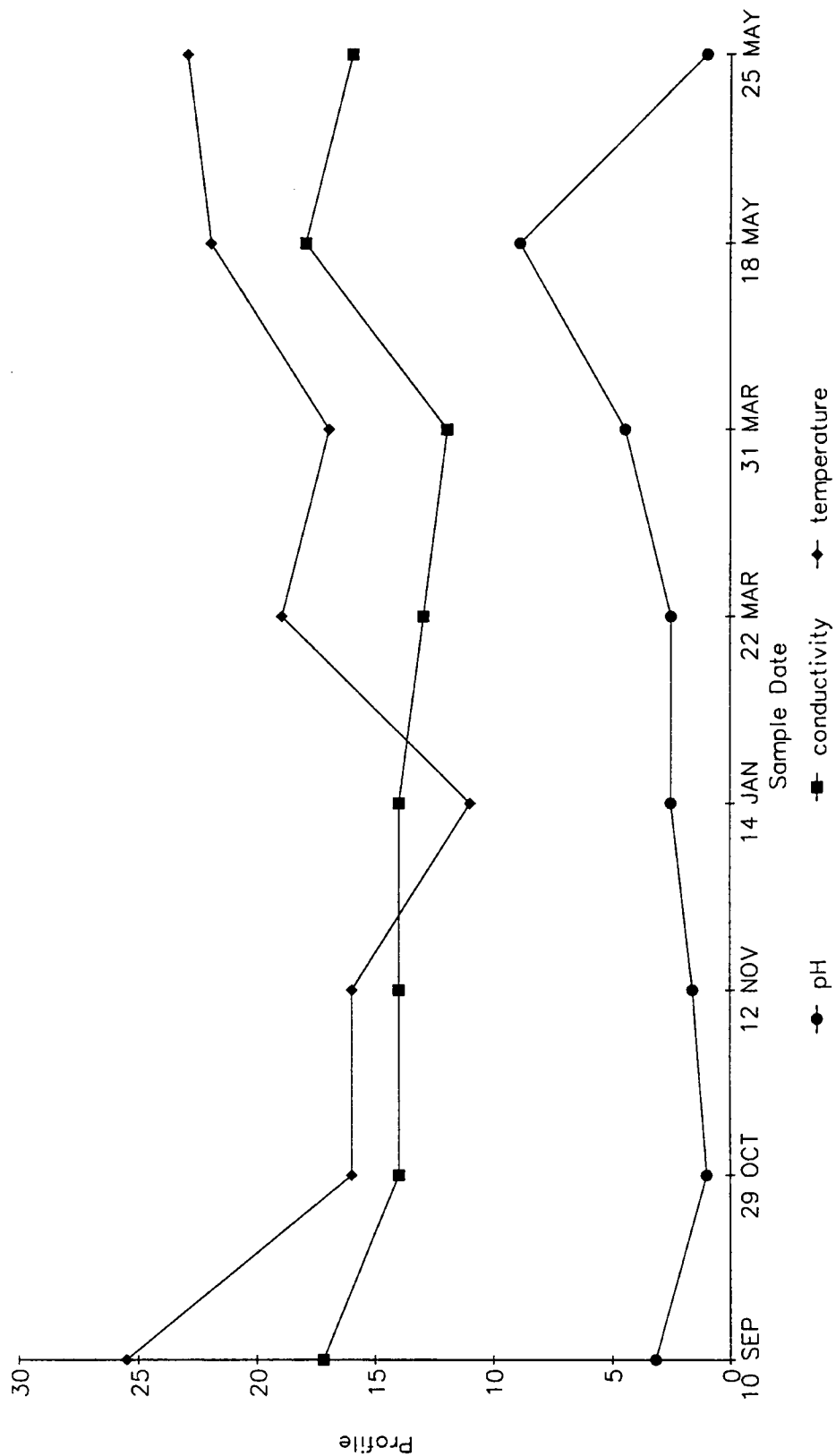
pH measurements ranging from 7.0 to 8.6 (Appendix A) and averaging 7.7, have been converted (described in Brower et al., 1990) using the following method on a calculator:

$$\begin{aligned}\text{pH} &= \log (1/[\text{H}^+]) \\ [\text{H}^+] &= 1/(\text{antilog pH})\end{aligned}$$

For example: $[\text{H}^+] = (\text{antilog } 7.05)$ found on a Casio Scientific Calculator fx-115N as 10^x . Type in 7.05 and push shift log, then store the number in Min. Type one and the division button, then retrieve the stored number from MR and push =. The result should be 8.91×10^{-8} . Calculations that resulted in powers other than 10^{-8} , like $8.2 = 6.31 \times 10^{-9}$, were converted to 10^{-8} by moving the decimal accordingly.

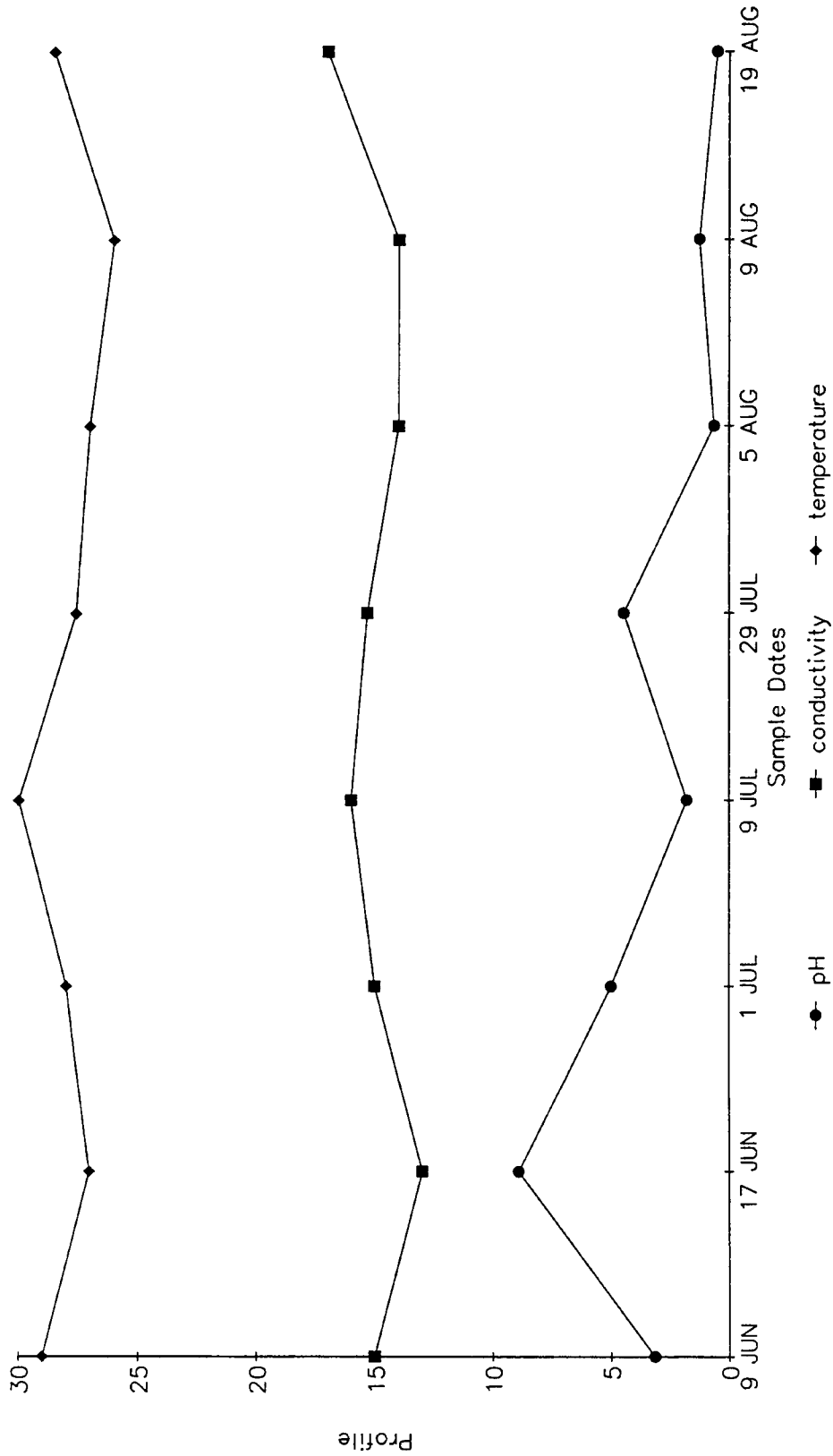
Conductivity measurements in parts per million (ppm), ranging from 120 - 240 (Appendix A) and averaging 150, were scaled to the graph by dividing each average per sample day by ten.

Temperature measurements in degrees Celsius ($^{\circ}\text{C}$), ranging from 11 - 30 (Appendix A), were not manipulated for the graph other than the average per sample day.



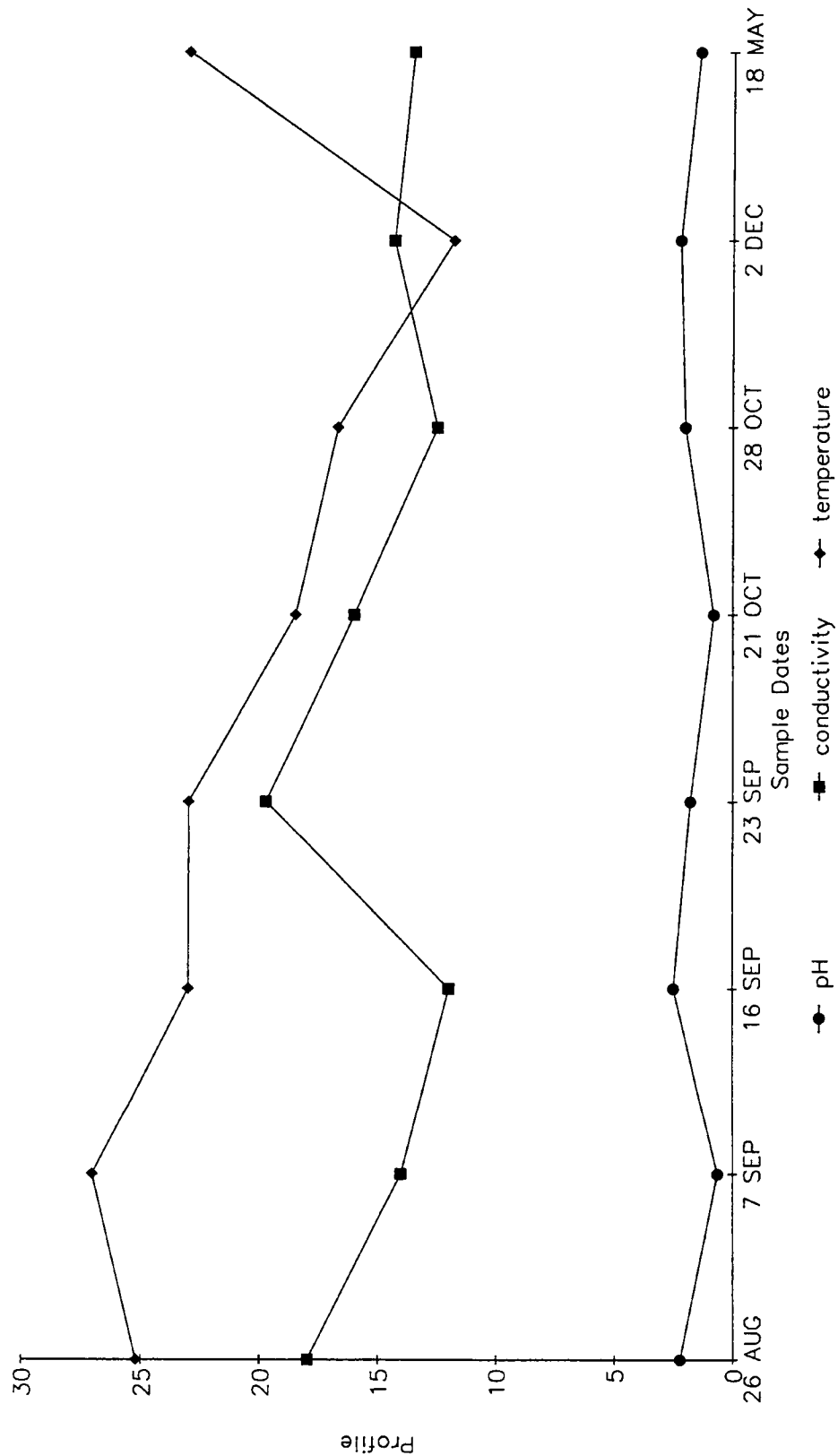
Appendix D Physio-Chemical Factor Profile on Watts Bar Reservoir from September 10, 1994 through May 18, 1996

Note: The Y-axis profile is explained in the Appendix D title page (141).



Appendix D (continued)

Note: The Y-axis profile is explained in the Appendix D title page (141).



Appendix D (continued)

Note: The Y-axis profile is explained in the Appendix D title page (141).

VITA

Pamela L. Bruce Inklebarger was born in Knoxville, Tennessee on March 14, 1972. She attended schools in the public system of Knox County, including Brickey Elementary, Halls Middle, and Halls High Schools. She graduated from Halls in 1990 with an Honors Diploma and was a member of the following: National Honor Society, Math Honor Society, and the Spanish Honor Club. She published four entries in her high school's literary magazine, Libre.

Pam attended Carson-Newman College in Jefferson City, Tennessee, where she was a member of the following: Alpha Chi, Alpha Lambda Delta - Phi Eta Sigma, Beta Beta Beta Biological Honor Society, Blue Key National Honor Fraternity. She was recognized in the Who's Who Among Students in American Universities and Colleges in 1994. She graduated with a Magna Cum Laude in May 1994, and married two weeks later at the amphitheater at Norris Dam State Park with a southern-style wedding to Mr. Jimmy Dewayne Inklebarger.

Pam was accepted to the University of Tennessee's Graduate Program in Botany for the Master's Program and graduated in May 1997. During her time at the University of Tennessee, she taught eleven sections of general biology labs and two general botany labs as a Teaching Assistant and taught a course in general botany as a Teaching Associate. Pam was granted the Award of Teaching Excellence in General Biology in the Fall of 1996. Besides her Teaching Assistantship, Pam worked part-time at RBM Company, an industrial-petroleum equipment handling and distribution business, in Knoxville starting in 1990.