PHYTOPLANKTON OF THE BLACK WARRIOR RIVER, ALABAMA

M. Ratnasabapathy[1] and Temd R. Deason
Department of Biology, University of Alabama,
University, Alabama 35486

ABSTRACT

Most floristic and community ecology reports of freshwater algae are based only on preserved or fresh samples. In the present study, the phytoplankton of The Black Warrior river near Tuscaloosa, receiving domestic sewage and industrial wastes, was investigate- from cultured as well as natural and preserved samples. Over 380 species and varieties of algae, including some rarely reported forms, were identified. The results of Sedgwich-Rafter and diatom proportional analyses showed that a) phytoplankton density ranged from 117-488 individuals/ml.; b) among the common groups, Chlorococcales were numerically dominant, followed by the Pennales, Chrysophyceae, Centrales and Cryptomonadaceae; c) out of 36 genera of Bacillariophyceae listed, 4 genera were abundant and constant in occurrence. Some difficulties of identification and limitations of enumeration are briefly discussed. Present data confirm the pres- ence of a resident phytoplankton and provide useful data for current research on the taxonomy, ecology and possible pesticide degradation ability of the algae.

INTRODUCTION

The Warrior River, which has its source in North Alabama, and following its union with the Tombigbee, flows into the Gulf of Mexico at Mobile. It is impounded at Tuscaloosa by the Oliver Lock and Dam to form the Oliver Pool. Sewage from the City of Northport, after primary treatment, and effluents from several industries including a paper mill, a chemical plant, and a coke plant are dis- charged into the Oliver Pool. Composition and rates of discharge are available in a thesis by McClure (1968).

During the spring of 1971, thirty six algal isolates were obtained in axenic cultures by standard bacteriological methods from a station at Bennett's Marina about 500 meters upstream of the dam. These algae were studied for their possible ability to degrade pesticides. The algae are considered to be planktonic, but there are no published studies of the Warrior flora on which to base this conclusion. Further, most studies of phytoplankton populations have involved observations only of preserved materials. We felt that we might get a better picture of the algae actually present

during a period of several months if we combined three methods: 1) Observations on freshly collected smaples, 2) Observation of cultured samples, and 3) Observations of preserved samples. Organisms consistently observed by two or more methods and represented in samples from different sites and at different sites and at different times should be those which are consistently present and representative of the 'normal' population. In this sense only do we refer to resident plankton.

MATERIALS AND METHODS

Samples for our studies were taken at about three week intervals beginning in May and extending through August of 1973. The collecting stations at Tuscaloosa were chosen for ready accessibility, comparable environmental conditions, and availability of boat or barge for convenient collection of offshore plankton. Station number one was located 1.126 km (0.7 miles) upstream from Oliver Lock and Dam at the Corps of Engineers Workshop, and station two was approximately 1.287 km (0.8 miles) further upstream at Rose Towers, Tuscaloosa.

Eight to twelve liter samples were obtained for phytoplankton by pushing polyethylene containers 20-30 cm beneath the water surface before allowing them to fill. A stock solution of thimerosal-iodine (Williams, 1964) was added to the samples immediately to preserve them for later study. Unfortunately certain delicate genera such as Gonyostomum, Merotrichia, and Synura, disintegrated with the preservative. Untreated aliquots were retained for observations of living material, and small samples (0.5 L) were taken in sterile glass containers for culture work.

Periphyton growing on the sides of boats or on fallen wood were scraped into vials. Bottom mud also was obtained from the shore in the vicinity of the stations for a look at the benthic forms which might contribute to the plankton. Taxa appearing only in these collections are indicated in the tables.

Samples collected aseptically were dilution plated using three media: Bold's inorganic salt medium (Deason & Bold, 1960) BG-11 (Stanier et al., 1971), and FW-1 medium (Lewin, 1966). Other aliquots of these samples were added to liquid media, and all cultures were incubated in constant light of approximately 300 ft. c. at a temperature of 25 degrees C. The use of three media made possible the growth of a considerable variety of algae. All cultures were surveyed for algal taxa and no taxa were reported unless they were observed at least twice. Observations of the algae in culture facilitated identification of algae in the fresh and preserved samples.

The plankton of the field-preserved samples were allowed to settle out for a minimum of 2 weeks in graduated cylinders, most of the supernatant carefully withdrawn by pipette, and the remaining contents washed into smaller cylinders. This procedure was repeated. The final concentrate for each composite sample was collected in 10 ml graduated cylinders, and the level was adjusted with distilled water when necessary so that the ratio of concentrate to original raw samples was 1:1000. Quantitative analyses for phytoplankton were accomplished using 1.0 ml of the above concentrate. These analyses were largely based on methods of the Analytical Quality Control Laboratory (Weber, 1966). Useful hints also were obtained from "Standard Methods" (American Public Health Association, 1965). For the phytoplankton analysis, 1 ml concentrate was made up to 50 ml with distilled water and 1 ml aliquots were used to fill a standard Sedgwick-Rafter counting cell. Two strips were counted at a magnification of 210 X. Data were recorded on separate bench sheets for major groups and for the genera. The results were reported as numbers of individuals/ml of raw material.

Permanent hyrax mounts for Diatom Proportional Analysis were prepared by the incineration method (Williams, 1962; Weber, 1966). Diatoms were counted at a magnification of 970 X using a binocular compound microscope containing a Whipple micrometer grid and a calibrated linear scale. The random strip counts were made until 200 cells were encountered or the scanning time reached 3 hours. Data was recorded on a bench sheet and the results reported in percentages for the four most abundant genera. The permanent slides also were used to identify the diatom species.

RESULTS AND DISCUSSION

Over 380 species or varieties of algae representing several Divisions were observed in our samples and cultures (Table VI). The Sedgwick-Rafter analysis (Table III) shows that pennate diatoms were second in abundance only to the Chlorococcales as indicated by total counts for the period of study. Chrysophycean algae were next in abundance, followed by centric diatoms and Cryptophyta. Total numbers of algae per ml of water increased as the season progressed, but only the Chlorococcales and Zygnematales showed a steady increase in numbers with time. During the period of study, water level (gauge height) remained relatively constant while the flow rate gradually decreased. The mean discharge rate in cubic feet per second was 13,550 for May, 9,639 for June, 8,585 for July and 4,465 for August.[3] Surface water temperatures for the four collecting dates (both stations), were respectively 23°C, 27°C, 29°C, and 29°C. The pH of the river was approximately 6.4 throughout the study.

The dominant genera, as indicated by the total Sedgwick-Rafter counts for the period of study (Table IV), were Synedra (including

Nitzschia), Kephyrion (including Kephyriopsis and Chrysococcus), Ankistrodesmus, and Cryptomonas. Only Cryptomonas increased steadily in numbers with time. Chlorella, although obviously numerous in fresh samples, was not listed because of the difficulty of identifying it at low magnification. Chlorococcum-like algae also were impossible to identify at low magnification particularly in preserved material. Several other genera listed may include closely related forms due to the identifications made at low magnification: Navicula may include Pinnularia, Oscillatoria may include Lyngbya and Phormidium, and Peridinium may include Glenodinium.

Our culture studies supplemented observations of raw and preserved samples. Algae which we were able to culture were much easier to recognize in the samples after we had studied them at leisure. In cultures, with or without enrichment media, certain flagellates such as Anthophysa vegetans, Paraphysomonas vestita, Spumella vivipara, Collodictyon triciliatum, Furcilia lobosa, Ochromonas sp., Chrysochromulina sp. and Entosiphon spp. developed in profusion and facilitated their identification. These and many other species which would have been overlooked in the samples were revealed by the cultures as shown in Table II indicating that 20 species appeared only in the cultures. Finally, we were able to identify in the cultures the same morphological entities isolated during 1971, including species of Chlorella, Scenedesmus, Golenkiniopsis, Carteria, Ankistrodesmus, Actinastrum, and Nitzschia. Unfortunately, time did not permit reisolation of all strains for physiological comparisons with our 1971 isolates. However, if our contention that these strains are essentially resident plankton is valid, then we should be able to reisolate the strains if time permits and if conditions in the river are not too greatly altered.

Our culture studies also confirmed the tendency of planktonic forms to be morphologically variable under different environmental conditions as reported by Trainor (1969) and others. Colonies from the samples ascribable to Tetrallantos and Nephrochlamys turned out to be Kirchneriella in culture. Scenedesmus spp. produced forms resembling Chodatella and Ourococcus. Actinastrum displayed a variety of forms resembling Tetradesmus, Didymogenes, Marthea, and Coccomyxa; an untrained observer might well have reported the occurrence of these genera.

Because our samples were large, and effectively made larger by the use of the culture technique, the identification of a large number of species in a more or less polluted river is not too surprising. Species abundance which is necessary for evaluating species diversity, was not determined because of the difficulty of determining species at Sedgwick-Rafter magnifications. When there are relatively few preserved cells, identification of most species is a difficult proposition even using a magnification of 1000 X. It is probably useful to look at the diatom proportional analysis

(Table V) to get a better idea of the diversity-abundance relationship. It is observed that almost 80% of the population consists of four genera of the 36 listed in Table I. Synedra (33%) and Nitzschia (3.8%) were most abundant among the pennate diatoms and the genera Cyclotella (23.4%) and Melosira (18%) among the centric diatoms. Of the 123 species of diatoms listed in Table I four species were the most abundant as indicated by bench data collected during the proportional analysis: Synedra acus, S. ulna, Cyclotella stelligera, and Melosira distans. A comparison of Tables III and IV shows that Synedra accounted for about 73% of the living Pennales and Ankistrodesmus for about 62% on 30 May 1973 at Station 1. Data for calculation of a species diversity index (Patten, 1962) are not available, but it appears that species diversity is low, indicating eutrophication (Williams, 1964). Eutrophication is also suggested by the dominance of the bacteria and organic detritus feeders Keratella, Codonella, and Tintinnidium among the zooplankton, and although no water blooms were observed during our study, the density of the phytoplankton (117-488 individuals/ml) indicates that the river is eutrophic.

Although species identification was facilitated, and additional species were found using the culture method, the costs in time exceeded the benefits in a study of this type.

TABLE I

Taxon	Station 1	Station 2
Division Cyanophyta		
Chroococcus rufescens (Kuetz.) Naegeli	N	
Merismopedia glauca (Ehr.) Naegeli		N
Merismopedia sp.	N	NC
Microcystis flos-aquae (Wittr.) Kuetzing		N
Microcystis sp.	NC	N
Oscillatoria amonena Gomont		N
Oscillatoria sp. 1	NCB	NC
Oscillatoria sp. 2	NCB	C
Beggiatoa sp.		N
Lyngbya epiphytica Hieronymus	P	
Lyngbya subtilis W. West	P	
Lyngbya sp.	CP	C
Phormidium sp.	C	NC
Microcoleus sp.	NCB	
Anabaena sp.	NCB	NCP
Anabaena spiroides Klebahn	N	
Aphanizomenon flos-aquae (Linn.) Ralfe	C	
Nostoc sp.	CB	C
Scytonema sp.		C
Calothrix sp.		C
Division Cryptophyta		
Chroomonas sp.	NC	
Cryptochrysis sp.		NC
Chilomonas paramaecium Ehrenberg	C	NB
Cryptomonas erosa Ehrenberg	CB	NCP
Cryptomonas obovata Skuja	NCB	NCB
Cryptomonas reflexa (Marsson) Skuja	N	
Cryptomonas sp. 1	NCB	NCB
Cryptomonas sp. 2	N	NCB
Cyathomonas truncata (Fres.) Fisch	NCB	NC
Division Chloromonadophyta		
Gonyostomum depressum Lemmermann	N	
Gonyostomum semen Diesing	N	NC
Merotrichia sp.	N	
Division Pyrrhophyta		
Glenodonium palustre Zachariasi		NP
Glenodinium spp.	N	NC
Peridinium inconspicuum Lemmermann	N	
Peridinium wisconsinense Eddy	N	N
Peridinium spp.	N	NP
Ceratium hirundinella (Muell.) Shrank	N	N

Taxon	1	2
Division Bacillariophyta		
Melosira ambiqua (Grun.) O. F. Mueller	N	N
Melosira distans (Ehr.) Kuetzing	N	N
Melosira granulata (Ehr.) Ralfs	N	NC
Melosira herzogii Lemm	NC	N
Melosira italica (Ehr.) Kuetzing	NC	N
Melosira varians C. A. Agardh	NCP	NCP
Cyclotella atomus Hustedt.	N	N
Cyclotella antiqua Wm. Smith	N	N
Cyclotella bodanica Eulenstein	N	N
Cyclotella meneghiniana Kuetzing	NC	NC
Cyclotella stelligera (Cleve et Grun.) van Heurck	N	NC
Cyclotella pseudostelligera Hustedt.	N	N
Cyclotella glomerata Bachmann	N	N
Stephanodiscus sp.		N
Attheya zachariasi Brunthaler	N	N
Rhizosolenia eriensis H. L. Smith	NC	N
Rhizosolenia sp.	NC	N
Chaetoceros sp.	N	
Asterionella formosa Hass. var. formosa Patrick et Reimer	N	N
Diatoma vulgare Bory var. vulgare Patrick et Reimer	N	
Fragilaria brevistriata Grun. var. brevistriata Patrick et Reimer		N
Fragilaria capucina (Desm.) var. capucina Patrick et Reimer	N	N
Fragilaria construens (Ehr.) Grun. var. construens Patrick et Reimer	N	
Fragilaria crotonensis Kitton var. crotonensis Patrick et Reimer	NCB	NC
Fragilaria vaucheriae (Kuetz.) Peters var. vaucheriae Patrick et Reimer	NCB	NP
Fragilaria spp.	N	N
Synedra acus Kuetz. var. acus Patrick et Reimer	N	NP
Synedra rumpens Kuetz. var rumpens Patrick et Reimer		NP
Synedra rumpens var. meneghiniana Grunow		N
Synedra ulna (Nitz.) Ehr. var. ulna Patrick et Reimer	NC	NCP
Synedra spp.	NC	N
Tabellaria fenestrata (Lyng.) Kuetz. var fenestrata Patrick et Reimer	N	NP
Tabellaria flocculosa (Roth) Kuetz. var. flocculosa Patrick et Reimer	N	NP
Meridion circulare (Grev.) C. A. Ag. var. circulare Patrick et Reimer		N
Eunotia curvata (Kuetz.) Lagerst. var. curvata Patrick et Reimer		N
Eunotia incisa W. Sm. ex Greg. var. incisa Patrick et Reimer	N	
Eunotia pectinalis (O. F. Muell.) Rabh. var. pectinalis Patrick et Reimer	N	NP

Taxon	1	2
Eunotia pectinalis var. undulata (Ralfs) Rabenhorst		N
Eunotia spp.	N	NP
Achnanthes clevei Grun. var. clevei Patrick et Reimer	N	
Achnanthes exigua Grun. var. exigua Patrick et Reimer	N	
Achananthes lanceolata (Breb.) Grunow var. dubia Grunow	N	N
Achnanthes lanceolata var. omissa Reimer		N
Achnanthes linearis (W. Sm.) Grun. var. linearis Patrick et Reimer		N
Achnanthes minutissima Kuetzing var. minutissima Patrick et Reimer	NC	NBP
Achnanthes sp.		N
Cocconeis fluviatilis Wallace var. fluviatilis Patrick et Reimer	N	
Cocconeis sp.	N	N
Amphipleura pellucida Kuetz var. pellucida Patrick et Reimer	P	NP
Anomoeoneis vitrea (Grun.) Ross var. vitrea Patrick et Reimer		
Caloneis bacillum (Grun.) Cleve	N	
Capartogramma crucicula (Grun. ex Cl.) Ross var. crucicula Patrick et Reimer	N	N
Diploneis puella (Schum.) Cl. var. puella Patrick et Reimer	N	
Diploneis sp.	N	N
Frustulia rhomboides var. capitata (A. Mayer) Patrick		N
Frustulia rhomboides var. crassinervia (Breg. ex W. Sm.) Ross		NP
Frustulia rhomboides (Ehr.) DeToni var. rhomboides Patrick et Reimer	N	NP
Frustulia rhomboides var. saxonica (Rabh.) De Toni		N
Frustulia vulgaris (Thwaites) De T. var. vulgaris Patrick et Reimer	N	N
Frustulia weinholdii Hust. var. weinholdii Patrick et Reimer		N
Gyrosigma nodiferum (Grun.) Reim. var. nodiferum Patrick et Reimer		N
Gyrosigma spencerii (Quek.) Griff. et Henfr. var. spencerii Patrick et Reimer	N	NCP
Gyrosigma sp.		
Navicula atomus (Kuetz.) Grun. var. atomus Patrick et Reiner		N
Navicula crucicula (W. Sm.) Donk. var. crucicula Patrick et Reiner	N	N
Navicula exigua (Greg. ex. Grun.) var. capitata Patrick et Reiner	N	
Navicula gottlandica Grun. var gottlandica Patrick et Reiner	N	N
Navicula gregaria Donk. var. gregaria Patrick et Reiner	N	
Navicula heufleri (Grun.) var. leptocephala (Breb. ex Grun.) Patrick	N	

Taxon	1	2
Navicula mobiliensis Boyer var. minor Patrick		N
Navicula mutica Kuetz. var. mutica Patrick et Reimer	N	
Navicula mutica var. tropica Hustedt	N	N
Navicula notha Wall. var. notha Patrick et Reimer		N
Navicula pupula Kuetz. var. capitata Skvortzov et Meyer	N	
Navicula pupula Kuetz. var. pupula Patrick et Reimer	N	
Navicula pupula Kuetz. var. rectangularis (Greg.) Grunow		N
Navicula pygmaea (Kuetz.) var. pygmaea Patrick et Reimer	N	
Navicula radiosa Kuetz. var. tenella (Breb. et Kuetz.) Grunow	N	
Navicula rhynchocephala var. germainii (Wall.) Patrick	N	N
Navicula viridula (Kuetz.) var. rostellata Patrick et Reimer	N	
Navicula spp.	NB	BP
Neidium affine (Ehr.) Pfitz. var. affine Patrick et Reimer	N	
Neidium affine var. ceylonicum (Skv.) Reimer	N	N
Neidium bisulcatum (Lagerst.) Cl. var. bisulcatum Patrick et Reimer		N
Pinnularia appendiculata (Ag.) Cl. var. appendiculata Patrick et Reimer		N
Pinnularia biceps Greg. var. biceps Patrick et Reimer	N	
Pinnularia borealis Ehr. var. rectangularis Carlson		N
Pinnularia braunii (Grun.) Cl. var. amphicephala (A. Mayer) Hustedt		N
Pinnularia brebissonii (Kuetz.) Rabh. var. brebissonii Patrick et Reimer	N	
Pinnularia microstauron (Ehr.) Cl. var. microstauron Patrick et Reimer	N	
Pinnularia obscura Krasske var. obscura Patrick et Reimer	N	
Pinnularia subcapitata Greg. var. subcapitata Patrick et Reimer		N
Pinnularia substomatophora Hust. var. substomatophora Patrick et Reimer		N
Pinnularia viridis (Nitz.) Ehr. var. viridis Patrick et Reimer	N	
Pinnularia spp.	N	NCP
Stauroneis anceps Ehr. var. anceps Patrick et Reimer	N	
Stauroneis sp.	N	N
Gomphonema acuminatum Ehrenberg	N	N
Gomphonema acuminatum var. coronata (Ehr.) Cleve		N
Gomphonema angustatum (Kuetz.) Grunow	N	CP
Gomphonema sp.	N	N
Amphora sp.	N	N
Cymbella gracilis (Rabh.) Cleve	N	N

Taxon	1	2
Cymbella tumida (Breb.) van Heurck	NP	NP
Cymbella turgida Gregory	P	NP
Cymbella ventricosa Kuetzing	NP	NP
Cymbella sp.	N	N
Denticula elegans Kuetzing	N	N
Denticula sp.		N
Epithemia ocellata (Ehr.) Kuetzing	N	
Epithemia sp.	N	N
Rhophalodia gibba (Ehr.) O. F. Mueller	N	N
Bacillaria paradoxa Gmelin	N	P
Hantzschia amphioxys (Ehr.) Grunow	N	N
Nitzschia acicularis W. Smith	NC	NC
Nitzschia amphibia Grunow	N	N
Nitzschia closterium (Ehr.) W. Smith	N	N
Nitzschia filiformis (W. Smith) Hustedt	NC	NP
Nitzschia holsatica Hustedt		N
Nitzschia longissima (Breb.) Ralfs	N	N
Nitzschia lorenziana Grunow	N	NP
Nitzschia palea (Kuetz.) W. Smith	NC	CBP
Nitzschia sigma (Kuetz.) W. Smith		N
Nitzschia sinuata var. tabellaria Grunow	N	
Nitzschia tryblionella Hantzsch	N	N
Nitzschia spp.	N	N
Surirella elegans Ehrenberg		N
Surirella didyma Kuetzing		NB
Surirella linearis W. Smith	N	N
Surirella tenuissima Hustedt	N	
Surirella spp.	N	NB
Division Chrysophyta		
Chrysamoeba sp.	NC	
Lagynion scherfelii Pascher		N
Kephyrion cupuliforme Conrad	N	N
Kephyrion cyclindricum (Lack.) Conrad	N	N
Kephyrion doliolum Conrad	N	N
Kephyrion rubri-claustri Conrad		
Kephyrion spp.	N	N
Codonodendron sp.	N	
Chrysococcus porifer Lemmermann	N	N
Chrysococcus rufescens Klebs	N	N
Chrysococcus spp.	N	N
Ochromonas sp. 1	C	CP
Ochromonas sp. 2	NC	NCB
Paraphysomonas vestita (Stokes) De Saedeleer	NC	NC
Spumella vivipara	NC	
Chrysochromulina sp.	NC	
Anthophysa steinii Senn		N
Anthophysa vegetans (O. F. M.) Stein	N	NP
Dinobryon bavaricum Imhof	N	N
Dinobryon cylindricum Imhof		N

Taxon	1	2
Dinobryon divergens Imhof	N	N
Pseudokephyrion ellipsoideum (Pasch.) Schm.		N
Pseudokephyrion spp.	N	N
Mallomonas acaroides Perty		N
Mallomonas tonsurata Teiling		N
Mallomonas spp.	N	N
Synura uvella Ehrenberg	NCP	N
Codosiga sp. 1	NP	N
Codosiga sp. 2	P	
Salpingoeca sp.	N	N
Division Xanthophyta		
Botrydiopsis sp.	N	
Chlorocloster sp.	N	N
Leuvenia natans Gardner	NC	
Chlorobotrys sp.	C	
Gloeobotrys sp.	NC	C
Characiopsis sp.		P
Centritractus belanophorus Lemmermann		N
Ophiocytium bicuspidatum (Borge) Lemmermann	N	N
Ophiocytium parvulum (Perty) A. Braun	N	N
Heterothrix sp.	NC	NC
Botrydium granulatum (L.) Greville	C	
Division Euglenophyta		
Euglena acus Ehrenberg	NCB	
Euglena ehrenbergii Klebs	N	
Euglena oxyuris Schmarda		N
Euglena pisciformis Klebs	NCB	NC
Euglena viridis Ehrenberg		
Euglena spp.	N	N
Lepocinclis fusiformis (Carter) Lemmermann	NC	
Lepocinclis ovum (Ehrenb.) Lemmermann	NC	N
Lepocinclis steinii Lemmermann	NC	N
Phacus agilis Skuja	N	N
Phacus longicauda (Ehrenb.) Dujardin	N	
Phacus orbicularis Huebner		N
Phacus oscillans Klebs	N	
Phacus tortus (Lemm.) Skvortzow	N	
Phacus sp.	N	N
Trachelomonas bernardinensis W. Vischer em. Deflandre	N	
Trachelomonas granulata Swirenko	N	N
Trachelomonas hispida (Perty) Stein	N	N
Trachelomonas oblonga Lemmermann	N	N
Trachelomonas obovata Stokes em. Deflandre	N	
Trachelomonas similis Stokes	N	
Trachelomonas superba (Swir.) Deflandre	N	N
Trachelomonas volvocinopsis Swirenko	N	N
Trachelomonas spp.	N	N
Strombomonas giradiana (Playf.) Deflandre	N	N

Taxon	1	2
Strombomonas sp.		N
Menoidium pellucidum Perty	N	
Notosolenus apocamptus Stokes		C
Notosolenus obliquus Stokes		NP
Notosolenus orbicularis Stokes		N
Anisonema acinus Dujardin	NC	NC
Anisonema sp. 1		NC
Entosiphon obliquum Klebs	N	N
Entosiphon ovatum Stokes	N	NP
Entosiphon sulcatum (Duj.) Stein	N	NC
Entosiphon sp. 1	N	P
Petalomonas sp.	C	NC
Heteronema cryptocercum Skuja	N	
Peranema furcatum Skvortzow		NC
Peranema trichophorum (E.) Stein	C	NCP
Peranema sp.	NC	P
Division Chlorophyta		
Collodictyon triciliatum Carter	NC	NC
Furcilia lobosa Stokes	NC	NC
Furcilia trifurca Pascher	C	
Carteria sp. 1	N	N
Carteria sp. 2		N
Carteria sp. 3		N
Chlamydomonas sp. 1	CB	NC
Chlamydomonas sp. 2	C	NC
Chlamydomonas sp. 3	C	C
Chlamydomonas sp. 4		B
Chlamydomonas sp. 5	C	
Sphaerellopsis sp. 1	C	C
Dysmorphococcus variabilis Takeda	NC	NCB
Coccomonas sp.	N	N
Gonium pectorale Mueller	C	NC
Pandorina morum Bory	N	NCB
Eudorina elegans Ehrenberg	NC	NV
Pedinomonas rotundata Korshikov	NC	N
Nephroselmis sp.	N	
Characium sp.		P
Chlorococcum sp.	C	NC
Schroederia setigera Lemmermann	NC	NC
Tetraedron gracile (Reinch) Hansgirg	N	
Tetraedron regulare Kuetzing		C
Sphaerocystis schroeteri Chodat	NB	NC
Ankistrodesmus convolutus var. minutus (Naeg.)		
Ankistrodesmus falcatus (Corda) Ralfs	NCB	NC
Ankistrodesmus falcatus var. stipitatus (Chorda) Lemmermann	C	
Ankistrodesmus sp. 1	NCB	NC
Ankistrodesmus sp. 2	NCB	N
Ankistrodesmus sp. 3	NC	C

Taxon	1	2
Chlorella sp.	NCB	C
Chodatella ciliate (Lagerh.) Chodat	N	N
Chodatella quadriseta Lemmermann	NC	
Chodatella subsalsa Lemmermann	N	
Closteriopsis longissima Lemmermann	NB	N
Franceia droescheri (Lemm.) G. M. Smith	N	N
Franceia ovalis (France) Lemmermann	N	N
Kirchneriella contorta (Schmidle) Bohlin	NC	NC
Kirchneriella lunaris (Kirch.) Moebius	NC	NC
Kirchneriella obesa (W. West) Schmidle	NC	NC
Kirchneriella obesa var. major (Bernard) G. M. Smith	N	N
Kirchneriella subsolitaria G. S. West	N	N
Nephrocytium sp.		NC
Oocystis borgei Snow		N
Oocystis parva West et West	N	C
Oocystis sp.	N	NC
Quadrigula sp.		N
Rayssiella hemisphaerica Edelstein et Prescott	N	
Selenastrum bibraianum Reinch	NC	NC
Selenastrum westii G. M. Smith	NC	C
Selenastrum sp. 1	C	
Treubaria crassispina G. M. Smith	N	N
Eutetramorus globosus Walton		N
Radiococcus sp.		N
Errerella bornhemiensis Conrad	N	N
Golenkiniopsis solitaria Korshikov	NC	C
Micractinium pusillum Fresenius	NCB	NC
Micractinium quadrisetum (Lemm.) G. M. Smith	NC	
Dictyosphaerium ehrenbergianum Naegeli	NC	N
Dictyosphaerium pulchellum Wood	NCBP	NCP
Quadricoccus verrucosus Fott	NC	
Westella botrydioides (W. West) de Wildeman	NC	NC
Actinastrum hantzschii Lagerheim	NCB	NC
Coelastrum cambricum Archer	NC	NC
Coelastrum microporum Naegeli	NCB	NC
Coelastrum reticulatum (Dang.) Senn	C	NCP
Coelastrum sphaericum Naegeli	N	C
Nautococcus sp.	C	C
Coronastrum aestivale Thompson		C
Crucigenia apiculata (Lemm.) Schmidle	NC	NC
Crucigenia fenestrata Schmidle	NC	N
Crucigenia quadrata Morren		N
Crucigenia tetrapedia (Kirch.) West et West	N	NC
Scenedesmus abundans (Kirch.) Chodat	NC	NC
Scenedesmus acuminatus (Lagerh.) Chodat	N	N
Scenedesmus armatus (Chod.) G. M. Smith	NC	NC
Scenedesmus arcuatus Lemmermann	C	NC
Scenedesmus bernadii G. M. Smith		N
Scenedesmus bijuga (Turp.) Lagerheim	NC	C
Scenedesmus brasiliensis Bohlin	N	C

Taxon	1	2
Scenedesmus denticulatus Lagerheim		N
Scenedesmus dimorphus (Turp.) Brebisson	NC	NC
Scenedesmus longus Meyen	C	C
Scenedesmus opoliensis p. Richter	C	C
Scenedesmus obliquus (Turp.) Kuetzing	C	
Scenedesmus quadricauda (Turp.) Brebisson	NC	
Scenedesmus serratus (Corda) Bohlin	NC	N
Scenedesmus smithii Teiling	NC	NC
Scenedesmus sp.	C	
Tetrallantos lagerheimii Teiling	NC	N
Tetrastrum heteracanthum (Nordst.) Chodat	N	N
Pediastrum duplex Meyen	NC	NC
Pediastrum duplex var. gracilimum West et West	N	NC
Pediastrum duplex var. rotundatum Lucks		N
Pediastrum tetras (Ehrenb.) Ralfs	N	NC
Pediastrum tetras var. tetraodon (Corda) Ralfs		N
Dactylothece sp.	C	C
Dispora sp.	NC	
Elakatothrix sp.	N	N
Ulothrix fimbriata Bold	NC	
Ulothrix sp. 1	N	P
Ulothrix sp. 2	C	NCP
Ulothrix sp. 3	N	N
Microthamnion strictissimum Rabenhorst	N	
Stigeoclonium sp.	CB	P
Aphanochaete repens A. Braun		P
Oedogonium sp. 1	P	CP
Oedogonium sp. 2	P	P
Rhizoclonium sp.		P
Mougeotia sp.		P
Spirogyra sp. 1	C	P
Spirogyra sp. 2		P
Spirogyra sp. 3		NP
Cylindrocystis brebissonii Meneghini	N	
Closterium gracile Brebisson	NC	NCBP
Closterium moniliferum (Bory) Ehrenberg		NCP
Closterium sp. 1	NC	N
Closterium sp. 2	N	N
Cosmarium phaseolus Brebisson	N	
Cosmarium sp. 1		N
Cosmarium sp. 2		N
Cosmarium sp. 3		B
Cosmarium sp. 4		NP
Euastrum denticulatum (Kirch.) Gay	N	N
Euastrum sp. 1	C	NC
Euastrum sp. 2		N
Pleurotaenium ehrenbergii (Breb.) Debary	N	N
Pleurotaenium sp. 1		NBP
Staurastrum arachne Ralfs		NC
Staurastrum chaetoceros (Schroed.) G. M. Smith	N	N

Taxon	1	2
Staurastrum corniculatum Lundell		N
Staurastrum depressiceps Scott et Groenblad		N
Staurastrum megacanthum Lundell	N	N
Staurastrum paradoxum Meyen	NC	N
Staurastrum sp. 1	C	N
Staurastrum sp. 2	N	
Spondylosium planum (Wolle) West et West	N	N
Teilingia granulata (Roy et Biss.) Bourrelly	N	NC

TABLE II

Division	Totals	Chlorophyta	Euglenophyta	Xanthophyta	Chrysophyta	Bacillariophyta	Pyrrhophyta	Chloromonadophyta	Cryptophyta	Cyanophyta
Genera	164	66	13	10	16	36	3	2	5	13
Species	381	137	43	11	30	122	6	3	9	20
NB	35	15	2	-	1	7	-	-	5	5
B	1	1	-	-	-	-	-	-	-	-
NP	49	11	4	-	5	25	2	-	1	1
P	8	6	-	1	1	-	-	-	-	-
C	20	15	1	1	-	-	-	-	-	3
N	203	43	25	5	20	98	3	2	1	6
CC	127	67	12	3	7	19	1	1	8	9
Photosynthetic Flagellate spp.	84	18	27	-	22	-	6	3	8	-
Non-photosynthetic Flagellate spp.	29	3	16	-	8	-	-	-	2	-
Total Flagellates	113	21	43	-	30	-	6	3	10	-

TABLE III

Date	30-5-73		22-6-73		16-7-73		6-8-73	
Station	1	2	1	2	1	2	1	2
Group:								
Cyanophyta, coccoid	-	0.6	1.9	-	1.2	-	2.5	6.2
Cyanophyta, filamentous	2.5	1.9	0.6	0.6	5.6	4.3	9.3	29.1
Cryptophyta	4.3	7.4	8.7	16.1	20.5	8.1	26.0	29.1
Pyrrhophyta	5.6	1.9	3.6	9.3	9.9	1.2	18.0	18.0
Bacillariophyta								
Centrales, live	5.0	12.4	6.8	4.3	19.8	13.0	13.0	21.7
Centrales, dead	4.3	5.6	2.5	3.1	4.3	2.5	-	2.5
Pennales, live	37.8	46.5	15.5	14.9	109.1	85.6	26.0	32.2
Pennales, dead	8.1	7.4	2.5	6.2	11.2	5.0	2.5	3.7
Chrysophyta	9.3	3.7	22.3	43.4	55.2	23.6	47.1	71.9
Euglenophyta	1.9	2.5	3.7	3.1	4.3	3.1	1.9	5.0
Chlorophyta								
Volvocales	1.9	2.5	10.5	6.2	12.8	6.9	16.7	9.3
Chlorococcales	31.6	45.9	42.2	64.5	75.0	59.5	115.9	244.9
Ulotrichales	-	-	-	0.6	0.6	-	-	-
Zygnematales	-	0.6	0.6	-	0.6	1.9	3.1	5.6
Unidentified cells	3.1	5.5	2.5	4.9	1.8	7.4	4.3	6.2
Unidentified filaments	1.2	5.0	0.6	1.9	5.6	1.2	0.6	2.5
Total individuals per milliliter	117	149	125	179	338	223	287	488

TABLE IV

Date	30-5-73		22-6-73		16-7-73		6-8-73	
Station	1	2	1	2	1	2	1	2
Genus:								
Ankistrodesmus	19.7	24.2	5.6	9.9	24.2	13.0	40.3	26.0
Asterionella	-	-	-	-	1.2	1.2	-	-
Attheya	-	-	-	-	-	-	-	0.6
Chlamydomonas	-	0.6	1.9	3.7	2.5	-	2.5	1.2
Closterium	-	-	-	-	-	0.6	0.6	0.6
Coccomonas	0.6	0.6	6.2	3.2	3.7	3.7	8.1	6.8
Coelastrum	-	-	-	-	-	-	6.2	10.5
Cryptomonas	5.6	3.1	8.1	16.1	19.0	8.1	24.8	26.7
Dictyosphaerium	-	-	-	-	-	-	1.2	2.5
Dinobryon	-	0.6	3.1	3.7	49.6	-	1.2	0.6
Dysmorphococcus	-	1.2	-	0.6	1.2	3.1	2.5	1.4
Euglena	0.6	0.6	-	0.6	1.2	1.2	-	1.2
Kephyrion	2.5	2.5	18.0	49.2	48.2	17.4	39.1	57.6
Kirchneriella	-	-	-	-	-	-	-	1.2
Lepocinclis	-	-	1.2	-	-	0.6	-	0.6
Mallomonas	3.1	2.5	1.9	2.5	3.7	3.7	7.4	11.8
Merismopedia	-	-	1.2	-	1.9	-	2.5	5.0
Navicula	3.7	7.5	5.6	4.3	5.0	3.7	3.1	1.9
Oscillatoria	-	-	0.6	0.6	4.3	3.1	24.8	26.7
Peridinium	3.1	0.6	-	0.6	4.3	3.1	24.8	26.7
Phacus	-	0.6	-	-	-	-	0.6	0.6
Rhizosolenia	-	-	-	-	-	-	1.2	5.0
Scenedesmus	6.8	4.3	3.1	1.9	0.6	3.1	2.5	7.4
Staurastrum	-	-	0.6	-	0.6	0.6	1.9	0.6
Synedra	27.8	34.5	12.4	9.9	35.5	91.3	39.1	40.3
Trachelomonas	0.6	0.6	2.7	2.5	3.1	0.6	1.2	1.4
Totals/ml	74.1	94.0	72.2	109.3	210.0	158.0	235.6	264.9

TABLE V

Date	30-5-73		22-6-73		16-7-73		6-8-73	
Station	1	2	1	2	1	2	1	2
Genus:								
Cyclotella	6	35(31)	79(76)	32	46(45)	40(39)	41(36)	33(31)
Melosira	25(13)	65(36)	80(42)	48(27)	52(28)	34(18)	46(31)	54(34)
Rhizosolenia	-	-	-	-	-	-	-	-
Stephanodiscus	-	2	-	-	-	-	-	-
Unidentified Centrales	1	5	2	4(2)	15(9)	3(2)	2	-
Achnanthes	1	6	11	7	1	3	4	17
Amphipleura	-	-	1	-	-	-	-	-
Amphora	-	-	-	-	-	-	1	-
Asterionella	-	1	6(1)	-	3(1)	4(2)	3(1)	12(3)
Cocconeis	-	-	1	-	-	-	-	-
Cymbella	1	2	3	1	2	2	1	2
Denticula	-	-	-	-	-	-	-	1
Diatoma	-	-	1	-	-	-	-	-
Diploneis	-	-	-	-	1	-	-	-
Eunotia	1	3	1	-	1	-	-	-
Fragilaria	3(2)	11(6)	6	7	5(3)	3(2)	3(2)	3
Frustulia	-	-	-	1	2	1	-	-
Gomphonema	1	-	1	2	5	3	-	2
Gyrosigma	-	-	-	-	-	-	-	1
Hantzschia	-	-	1	-	2	-	-	-
Navicula	2	5	9	3	3	3	5	6
Neidium	-	-	-	1	1	-	-	1
Nitzschia	2	9	14	7	4	3	6	10
Surirella	-	1	-	-	-	-	-	1
Synedra	2	11	35	16	102	159	112 (102)	92(90)
Unidentified Pennales	6(5)	7	8	4(2)	12(9)	10(8)	6	11

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FOOTNOTES

1. Present address: Department of Botany, University of Malaya, Kuala Lumpur, Malaysia.

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TABLE LEGENDS

TABLE I. Identified species of phytoplankton from raw, cultured, and preserved samples. N = phytoplankton from raw or preserved samples, C = from cultures, B = Benthic samples, P = periphyton.

TABLE II. Summary of distribution based on Table I. NB = Number of species in both plankton and benthos, B = Benthos only, NP = species in both plankton and periphyton, P = Periphyton only, N = Plankton from raw and preserved samples, C = from culture only, CC = from culture and natural collections. Species excluding varieties and forms.

TABLE III. Phytoplankton Analysis of Main Groups of Algae in Individuals per Millilter of Raw Sample.

TABLE IV. Phytoplankton Analysis of Main Genera of Algae in Individuals per Milliliter of Raw Sample.

TABLE V. Proportional Analysis of Diatom Genera in Number of Cells per Permanent Hyrax Slide Mount. Numbers of Individuals are Given in Brackets.