c. 2

Phytoplankton Assemblages from 95 Lakes in Labrador: an Assessment of Environmental and Morphometric Influences on Species Distributions and Associations

D.A. Scruton, J.C. Earle, and H.C. Duthie

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

December 1987

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1586

Fisheries and Oceans Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

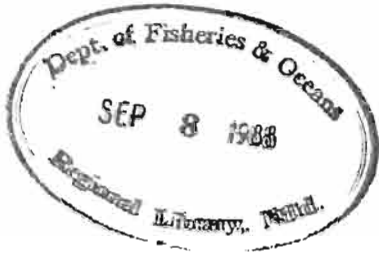
Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences 1586

December 1987



PHYTOPLANKTON ASSEMBLAGES FROM 95 LAKES IN LABRADOR: AN ASSESSMENT OF ENVIRONMENTAL AND MORPHOMETRIC INFLUENCES ON SPECIES DISTRIBUTIONS AND ASSOCIATIONS

by

D. A. Scruton[1], J. C. Earle[2], and H. C. Duthie[2]

Science Branch[1]

Department of Fisheries and Oceans

P.O. Box 5667

St. John's, Newfoundland A1C 5X1

Department of Biology[2]

University of Waterloo

Waterloo, Ontario

N2L 3G1

Cat. No. Fs 97-6/1586E ISSN 0706-6457

Correct citation for this publication:

Scruton, D. A., J. C. Earle, and H. C. Duthie. 1987. Phytoplankton assemblages from 95 lakes in Labrador: an assessment of environmental and morphometric influences on species distributions and associations. Can. Tech. Rep. Fish. Aquat. Sci. 1586: v + 71 p.

CONTENTS

ABSTRACT

Scruton, D. A., J. C. Earle, and H. C. Duthie. 1987. Phytoplankton assemblages from 95 lakes in Labrador: an assessment of environmental and morphometric influences on species distributions and associations. Can. Tech. Rep. Fish. Aquat. Sci. 1586: v + 71 p.

Physical, chemical, and morphometric data, as well as phytoplankton samples, were collected from 95 lakes throughout Labrador (south of 57°N latitude) during a two month period (August 16-October 20) in 1982. These data were used as the basis for an evaluation of the environmental factors influencing phytoplankton species distributions and associations. Multivariate statistics were used to determine the structure of the phytoplankton communities and to identify the environmental factors responsible for the organization observed. Factors analysis of 22 selected physical, chemical, and morphometric variables simplified the data into six derived environmental factors: alkalinity, dystrophy, lake size, salinity, oligotrophy, and seasonality. A complete-linkage cluster analysis of a selected subset of 80 taxa, based on a matrix of Spearman correlation coefficients, indicated that the Labrador phytoplankton can be partitioned into discrete species associations. Eight groups of co-occurring taxa were recognized from the data set and all but 2 exhibited relatively consistent habitat preferences. Spearman correlation coefficients between the phytoplankton abundances and the derived factors revealed that many species are regulated by environmental conditions. A comparison of the phytoplankton associations and environmental factors influencing these assemblages between Labrador and insular Newfoundland is also made.

An analysis of the low pH lakes revealed that this lake type is associated with the dystrophy factor and are likely naturally acidic. There was no evidence of anthropogenic acidification. Among the algal classes, the only significant correlations between lake pH and species numbers were with the Cyanophyceae and the Chlorophyceae, and only the Diatomaceae showed a significant correlation between pH and biomass.

Cluster analysis of the measured morphometric variables showed that the lakes may be described in terms of seven groups. The largest two groups were lakes with small, shallow basins and lakes with small, deep basins. Several lakes types that were identified as potentially influencing the distribution of phytoplankton in Labrador including: small, dystrophic lakes; clear, soft-water lakes; clear, hard-water lakes; large, hard-water lakes; and coloured, hard-water lakes.

RÉSUMÉ

Scruton, D. A., J. C. Earle, and H. C. Duthie. 1987. Phytoplankton assemblages from 95 lakes in Labrador: an assessment of environmental and morphometric influences on species distributions and associations. Can. Tech. Rep. Fish. Aquat. Sci. 1586: v + 71 p.

Du 16 août au 20 octobre 1982, on a recueilli des données physiques, chimiques et morphométriques ainsi que des échantillons de phytoplancton dans 95 lacs du Labrador (au sud de 57°N de latitude). Ces données ont servi de base à l'évaluation des facteurs environnementaux influant sur la répartition et l'association des espèces de phytoplancton. On a utilisé une analyse multivariée pour déterminer la structure des communautés phytoplanctoniques et identifier les facteurs environnementaux responsables de l'organisation observée. Une analyse factorielle de 22 variables physiques, chimiques et morphométriques a réduit les données en six facteurs environnementaux dérivés soit l'alcalinité, la dystrophie, la superficie du lac, la salinité, l'oligotrophie et le caractère saisonnier. Une analyse typologique à liaison complète d'un sous-ensemble de 80 taxons, basée sur une matrice de coefficients de corrélation de Spearman, a révélé que le phytoplancton du Labrador peut être réparti en associations d'espèces discrètes. On a identifié huit groupes de taxons co-occurrents dans la série de données et tous, sauf deux, montraient des préférences d'habitat relativement uniformes. Les coefficients de corrélation de Spearman entre l'abondance du phytoplancton et les facteurs dérivés révèlent que de nombreuses espèces sont soumises aux conditions environnementales. On fait une comparaison des associations de phytoplancton et les facteurs environnementaux qui influent sur ces assemblages au Labrador et dans l'île de Terre-Neuve.

Une analyse des lacs à faible pH a révélé que ce genre de lac est associé au facteur dystrophie et qu'ils sont probablement naturellement acides. Il n'existait aucun signe d'acidification antropogène. Parmi les classes d'algues, la seule corrélation significative entre le pH lacustre et l'abondance des espèces a été observée chez les familles Cyanophyceae et Chlorophyceae; de plus, seule la famille Diatomaceae a montré une corrélation significative entre le pH et la biomasse.

Une analyse typologique des variables morphométriques quantifiées a révélé que les lacs peuvent être classés en sept groupes. Les deux plus importants comprennent les lacs à petit bassin peu profond et les lacs à grand bassin peu profond. On a identifié plusieurs types de lacs qui peuvent potentiellement influer sur la répartition du phytoplancton au Labrador, notamment: les petits lacs dystrophes; les lacs d'eau douce et claire; les lacs d'eau dure et claire; les grands lacs d'eau dure; et les lacs d'eau dure et colorée.

INTRODUCTION

The freshwater algae of Labrador have been investigated both taxonomically and ecologically, however, a comprehensive study of the region's phytoplankton assemblages has been lacking. Early taxonomic work has been carried out by Cedercreutz (1944), Gardner (1949), and Croasdale and Gronblad (1964). Duthie et al. (1975a, b, c; 1976; 1978) have published several annotated lists of freshwater algae taxa confined to the western region of Labrador. Additionally, environmental impact assessments have generated species lists for Winokapau Lake (Beak Consultants Ltd. 1980) in central Labrador and for lakes in the Kaipikok river drainage in association with the proposed Kitts-Michelin uranium mine (Beak Consultants Ltd. and Kilborne Ltd. 1979). The first study of an ecological nature was conducted by Duthie and Ostrofsky (1974) and the first estimates of phytoplankton primary productivity in western Labrador lakes are published in Ostrofsky and Duthie (1975). Information on phytoplanktion biomass and seasonality in these same lakes is given in Ostrofsky and Duthie (1980) and limnological research on Labrador lakes and reservoirs has been summarized in Duthie (1979) and Duthie and Ostrofsky (1982).

In 1982, a comprehensive limnological and fisheries survey was conducted on 130 lakes in Labrador as part of the Department of Fisheries and Oceans' national lake survey program entitled The National Inventory Survey (or NIS). This program was undertaken to determine the status and sensitivity of freshwater fisheries and their (lacustrine) habitat to the effects of anthropogenic deposition of acids (acid rain). This data base was also to serve as a baseline against which future change in response to the LRTAP (long range transport of air pollutants) phenomenon could be evaluated. Details on the scope and approach of this survey program, from a regional and national perspective, are available in Scruton (1984) and Kelso et al. (1986), respectively. This survey program, which included comprehensive characterization of 95 of the study lakes (detailed morphometry, physical/chemical analysis of water) and phytoplankton sampling, made it possible to investigate relationships between the phytoplankton communities and their physical and chemical environments throughout Labrador (south of 57°N latitude).

Ecological studies of this nature deal with large numbers of highly correlated and interdependent variables which make the interpretation of environmental influences particularly difficult. Multivariate statistical approaches to evaluating the data can be used to synthesize the variability in ecological data and present it in a more interpretable form. Multivariate approaches have consequently become more common, particularly in the aquatic and biological sciences (e.g. Allen et al. 1977, Green and Vascotto 1979; Pinnel-Alloul et al. 1982; Earle and Duthie 1985). In this study, cluster analysis of the phytoplankton taxa is used to partion the species into discrete groups based on a measure of similarity between these species. Factor analysis is used to synthesize the lake physical, chemical, and morphometric data. Correlation analysis is subsequently employed to investigate relationships between the biotic groups (species associations) and their physical and chemical environments.

This contribution is similar in scope to a companion study recently completed for insular Newfoundland (Earle et al. 1987; Scruton et al. 1987). The major objectives of this study are to identify the structure of the freshwater photoplankton communities of Labrador and then to determine the critical environmental variables responsible for the organization observed. The chemical and biological data are further evaluated for evidence of acidification effects. Comparisons are made between the phytoplankton assemblages in Labrador lakes and those observed in insular Newfoundland lakes. This report is intended as a companion document to Earle et al. (1986) which focussed on a multivariate approach to the interpretation of the data. This report is also intended as a reference document for limnologists working in Newfoundland and Labrador and, as such, the detailed phycological data can be made available to interested researchers, upon request.

METHODS

One hundred and thirty (130) lakes throughout Labrador (south of 57°N latitude) were surveyed by float plane and helicopter from August 16 to October 20, 1982 (Fig. 1). Ninety-five lakes were studied in detail for lake morphometry, water chemistry, zoo- and phyto-plankton sampling and fish collection, while an additional 35 lakes were sampled for chemistry only. Details with respect to lake selection criteria and sampling methodologies are provided in Scruton (1984).

Lake morphometry was determined by sounding transects using a Raytheon DE-719B depth sounder with the transducer mounted on the wing support of the float plane or on the float support of the helicopter. One longitudinal transect was made followed by one or more transects across the width, depending on lake size and shape. Lake volume and mean depth were subsequently calculated from the sounded transects after Welch (1948). Maximum depth was read from the chart traces in order to establish the station for water quality sampling, temperature/dissolved oxygen profiling, and collection of plankton samples. Additional morphometric information was calculated from air photos and 1:50,000 scale topographic maps.

Water samples were collected from the sampling-station established over the deepest portion of the lake. In lakes with depths exceeding 3 m, a depth integrated water sample was obtained using a tube sampler in accordance with procedures outlined by the Ontario Ministry of Natural Resources (1980). In shallow lakes (i.e. <3 m), a surface dip was used to collected the sample. A surface dip was also used to collect the sample for aluminum analysis. The water sample was then subdivided as required for field and laboratory analyses.

Phytoplankton samples were collected over the sampling station by dipping a 500 ml wide mounted glass bottle 30 cm below the water surface. Samples were fixed immediately (on site) with Lugol's iodine solution.

WATER ANALYSIS

Water samples were analyzed for four parameters (pH, gran alkalinity, free carbon dioxide, and dissolved oxygen) at a mobile field laboratory within 24 hours of collection. An additional sixteen physical and chemical parameters (pH, alkalinity, conductivity, hardness, turbidity, major cations and anions, aluminum, iron, colour, dissolved organic carbon, TDS, and nutrients) were analyzed at a contracted analytical laboratory. Ten parameters, including non-marine ("excess") ion concentrations (after Watt et al. 1979), were subsequently calculated. Analytical procedures followed those outlined in Environment Canada (1979) and the American Public Health Association et al. (1975). A summary of the methods employed, including detection limits, are provided in Table 1.

Gran alkalinities were determined by acidimetric titration of the sample to pH 3.5 (after Ontario Ministry of Natural Resources 1980) and calculation of the inflection point by computer routine (after Kramer (1978). Dissolved oxygen was determined by standard Winkler titration (Strickland and Parsons 1972). Quality assurance was verified by cation/anion balance and by comparison of calculated and measured conductivity. Other checks included analysis of standard reference water samples, spiking of samples, provision of blind replicates, and participation in a inter-laboratory round robin check program (LRTAP intercomparison studies). No analytical problems were apparent.

PHYTOPLANKTON IDENTIFICATION AND ENUMERATION

The phytoplankton were identified and enumerated using the Utermohl method from the Lugol's fixed whole water samples (Ostrofsky and Duthie 1980). A Nikon Diaphot inverted microscope at magnifications of 100X, 300X, and 600X was used. A combined minimum of 500 cells, filaments, and colonies were counted per sample. Algal counts were expressed as the number of cells of each species per litre of lake water. Identifications were made chiefly from the works of Huber-Pestalozzi (1938-50), Skuja (1948, 1956, 1964), Willen (1963), Hilliard (1966), and Duthie et al. 1975a, b and c, 1976, 1978). Biomass (as $mg \cdot m^{-3}$) was estimated from calculations of cell volume based on seven geometric shapes selected to approximate the different shapes exhibited by freshwater algae and assuming unit specific gravity (Janus and Duthie 1979). The detailed phycological data (species lists, counts, biomass, cell size distribution, Shannon Diversity Index, etc.) for each lake is housed on computer tape at the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland and at the University of Waterloo (Department of Biology), Ontario and can be made available upon request.

DATA ANALYSIS AND STATISTICAL APPROACH

The statistical approaches used to help interpret the data involved a series of cluster, factor, and correlation analyses.

The first statistical approach involved linear correlation analysis of pH and algal group abundances and biomass. Since these analyses were performed on the untransformed data non-parametric statistical procedures were used.

Relationships between the physical, chemical, and morphometric lake data were initially explored by simple linear correlation analyses of the log transformed data (all parameters except pH) (SAS Institute 1979, see also Appendix 1). The original matrix of variables was reduced to a subset of 22 selected parameters for multivariate analyses. This subset of 22 parameters (non-transformed) were then standardized (X-X/SD) to reduce the variables to a common scale because many had either incompatible units or large numeric differences. Tests performed after the standardization showed that all the variables had been reasonably normalized (Kolmogorov-Smirnov-Lilliefors: $P < 0.10$). More importantly, Log-Anova tests indicated that their variances had been made relatively homogeneous ($P < 0.05$).

Exploratory factor analysis was used to simplify the relationships between interdependent variables by creating a smaller number of hypothetical variables or factors which account for the variance in the data. Each factor represented the portion of the original variables which relate to the same environmental parameter. As a result, factor analysis represents the covariance structure of the original variables in terms of a hypothetical causal model. Factor analysis was performed on a correlation matrix of the 22 selected morphometric, physical, and chemical variables from the 95 Labrador lakes, and the principal axes factoring solution was then rotated using an orthogonal rotation (VARIMAX) to simplify the factor structure. The correlation coefficients between the derived factors and the original variables were computed.

The 95 lakes were also partitioned into groups on the basis of cluster and ordination analyses of their morphometric properties (surface area, maximum depth, shoreline development, and drainage area). Lake volume and mean depth were excluded as variables because measurements were unavailable for a number of lakes.

The biological-data matrix was first reduced to a smaller subset of 80 species based on Orloci's (1978) sum of squares variance procedure. The algorithm calculates the individual proportion of the total variance accounted for by each of the species. To reduce the data set, species that failed to explain any independent share of the total variance were eliminated. This criterion was adopted because such species can provide no new information about the structure of the phytoplankton communities. The reduced data set was then transformed [$\ln (X + 1)$] in an effort to achieve a normal distribution of the variables. The Kolmogorov-Smirnov-Lilliefors test indicated that all but the rare species, amounting to 8% of the total taxa, were reasonably normalized by the transformation ($P > 0.10$).

Next a complete-linkage cluster procedure was used to examine the phytoplankton data for evidence of species associations or groups of co-occurring taxa. The analysis was based on a matrix of Spearman correlation coefficients calculated from the transformed abundance of the 80 selected species (Legendre and Legendre 1983). Complete-linkage clustering was selected to produce as functionally distinct groups of species as possible. The

criterion for selecting the cluster-group level to represent the phytoplankton associations, the last cluster level in which at least 90% of the species demonstrated significant differences in abundance between the groups, was made a priori to any analysis being performed. Significance tests were based on an analysis of variance (α=0.10). Iterative relocation was subsequently performed to optimize the classification of each species into cluster groups. The resulting groups may be considered distinct associations of species that occur together in the same lake types because of similar environmental requirements.

An attempt was made to correlate the algal taxa comprising the species associations with the morphometric, physical, and chemical variables (represented by the factors) thought to regulate their distributions in lakes. Correlations of species abundances with factor scores (Spearman's correlation analysis) were used to interpret the intraspecific preferences of the phytoplankton. Therefore, each factor potentially represents an environmental property controlling phytoplankton growth and distribution in the lakes. The general environmental preferences of the groups of co-occurring algae were interpreted through a comparison of results for each species association.

RESULTS

LAKE CHARACTERISTICS

Ninety-five (95) lakes were sampled on one occassion for lake basin morphometry, chemistry, fish, and plankton over a two month period from August 16 to October 20, 1982. An additional 35 lakes were sampled for chemistry only. Lakes were widely distributed throughout Labrador, south of 57°N latitude (Fig. 1). Generally, fewer lakes were sampled in western Labrador, owing to the relatively lower geological sensitivity of that region to the effects of acid precipitation. A higher proportion of the study lakes were within a 250 km radius of Goose Bay, the major operations base. By geographical region, the distribution of study lakes is as follows:

	Water samples	Biological samples
Northern	2	(2)
Central	43	(24)
Eastern	13	(9)
Southern	43	(31)
Western	29	(29)
	130	95

Fifteen major geological types were delineated for Labrador and lakes were

sampled from 7 of these geotypes. Lake distribution, by geological type, is as follows:

Geological types	n	Sensitivity
Gneisses	79	high (H)
Granites	15	high (H)
Acid volcanics	1	high (H)
Siltstones	4	high to moderate (H-M)
Anorthosites	16	moderate (M)
Basic volcanics	1	moderate (M)
Conglomerates, sandstones	6	low to moderate (L-M)
Unassigned (including 2 or more geotypes in the watershed)	8	other

Ninety-five lakes (73%) were underlain by geotypes designated highly (H) sensitive (after Schilts 1981) to acidic deposition (silicous bedrock, low in carbonates, and low weathering rates), while 4 lakes (3%) were located in geological types designated from high to moderate (H-M) sensitivity (metamorphic and sedimentary rocks, low in carbonates), seventeen lakes (13%) were located in moderately (M) sensitive geotypes and 6 lakes (5%) in low to moderate (L-M) sensitivity bedrock (easily weathered carboniferous rock and soils). Eight (6%) lakes were not classified owing to the occurrence of two or more geological types of differing sensitivity within the watersheds.

Lakes ranged in size from 5.0 to 1217.5 ha (mean of 165.0 ha). Ten lakes (8%) were less than 10 ha, 45 lakes (35%) were from 10 to 100 ha, 66 lakes (51%) in the 100-500 ha range, 5 lakes (4%) in the 500-1000 ha range, while the remaining 4 lakes (3%) exceeded 1000 ha (Fig. 2). Surface area was highly correlated with other morphometric variables including drainage area ($r = 0.83$), volume ($r = 0.74$), maximum depth ($r = 0.49$), and lake order ($r = 0.42$). A comparison of the areal distribution of the study lakes with natural lake distributions in Labrador (as determined from an extensive digitized data base for lakes of 1 ha and greater in size on the Minipi and Earle River drainages) reveals that the sample is not representative of natural distributions (Fig. 3). The sample was particularly under-represented in the 0-10 ha size range and over-represented in 100-1000 ha size class.

Lake distribution by drainage order is as follows: headwater (first order) lakes-55 (43%), second order lakes-33 (25%), third order lakes-18 (14%), fourth order lakes-11 (8%) and fifth or higher order lakes-13 (10%). A comparison of the distribution of lake orders in this study with the natural drainage order distribution is presented in Fig. 4. It is apparent that the study lake sample approximates the natural distribution with headwater lakes being slightly under sampled and second through fourth order lakes being slightly over sampled.

The ratio of drainage area to lake surface area varied from 2.7 to 49.3 ($\bar{x} = 12.9$). Seventy-nine (61%) of the study lakes had low ratios of 10:1 and less. Lake elevations ranged from 101 to 689 m ($x = 448$). Most lakes (90%)

were greater than 300 m above sea level, reflecting the abundance of lakes located on the extensive Labrador Lakes Plateau. High elevation lakes (>500 m) were restricted to the Mealy and Benedict Mountains. Lakes were located from 24 to 487 km from salt water ($\bar{x}$ = 171 km) and 90 lakes (69%) were located in excess of 100 km. Maximum lake depths ranged from 1 to 70 m ($\bar{x}$ = 11.4) while 36 lakes (38%) had maximum depths of less than 3 m and 52 lakes (55%) had maximum depths exceeding 10 m. Mean lake depth for 75 lakes varied from 1.4 to 25.1 m and 31 (33%) lakes had mean depths greater than 10 m. Surface water temperature varied from 1.3°C to 16.7°C. Temperature/oxygen profiles conducted on 95 lakes revealed clear evidence of thermal stratification in one lake only. Secchi depth ranged from 0.5 to 16.5 m ($\bar{x}$ = 3.6 m) and in 13 lakes (14%), the disc was visible on the lake bottom indicating the entire lake volume was in the euphotic zone. In the remaining 82 lakes, secchi depth varied from 0.5 to 16.5 m with a mean of 3.8 m. Secchi depth was very highly ($P < 0.001$) correlated to water colour ($r = -0.81$), dissolved organic carbon ($r = -0.81$), total dissolved solids ($r = -0.61$), and turbidity ($r = -0.58$); all water properties that influence the absorption of light in the water column. Secchi depth was also highly correlated ($P < 0.01$) with two morphometric characteristics; maximum depth ($r = 0.78$) and lake surface area ($r = 0.31$).

Lake water colour ranged from 5 to 175 TCU ($\bar{x}$ = 33.5 TCU). Fifty-four lakes (42%) were classified as clear water systems (0-15 TCU), 45 lakes (35%) as brown water systems (16-50 TCU), while the remaining 31 lakes (23%) were considered to be highly coloured (>50 TCU). Colour, which is considered a good indicator of organic content, was very highly correlated ($P < 0.001$) with dissolved organic carbon ($r = 0.90$). Water colour was also highly correlated ($P < 0.01$) with several morphometric characteristics including lake size ($r = -0.23$), drainage area to lake area ratio ($r = 0.32$), maximum depth ($r = -0.61$), and mean depth ($r = -0.47$). Turbidity ranged from 0.3 to 5.5 JTU ($\bar{x}$ = 0.8 JTU) and exceeded 1.0 in 33 lakes (26%). As in Newfoundland lakes, the high colour content and relatively high turbidity in some lakes likely restricts the trophogenic zone and consequently limits primary production (Scruton et al. 1987).

The sum of constituents (salinity) in the study lakes varied from 2.2 to 42.6 mg L^{-1} ($\bar{x}$ = 6.1 mg L^{-1}). This relatively low mean value places Labrador lakes among the most dilute in the world (Livingstone 1963). Cationically, all lakes were calcium dominated, in the order Ca>Mg>Na>K with one exception. Potassium, hydrogen ion (H^+), iron and aluminum were of minor importance. Calcium and magnesium were primarily of terrestrial origin while sodium was primarily derived from bedrock and soils and had additional marine contribution (~35% on the average). High calcium and magnesium concentrations were spatially correlated with geotypes with readily available carbonate supplies, particularly in the Labrador Trough and Seal Lake regions (see Scruton 1984). Low values were similiarly correlated with the occurrence of silicous bedrock. Anionically, all lakes were bicarbonate dominated in the order $HCO_3 > SO_4 > Cl$ (Scruton 1984). Bicarbonate is considered to be mostly of terrestrial origin, often in association with the dominant cations, calcium and magnesium. Chloride was a relatlively minor anion, compared to its dominance in soft water Newfoundland lakes (Scruton 1983). These comparisons highlight the relatively minor influence that the marine environment has on the freshwater chemistry of dilute Labrador lakes, in relation to the considerable influence of marine

aerosol deposition on insular Newfoundland's freshwaters. The cationic/anionic profiles for the study lakes, from each geological type, are shown in Fig. 5.

Sulphate was determined by the methyl-thymol blue (colourimetric) method after a u.v. pre-treatment to minimize potential colourimetric interferences. Sulphate values varied from 3.7 to 90.2 μeq L^{-1} ($\bar{x}$ = 27.2 μeq L^{-1}) and 94% of the lakes had values less than 50 μeq L^{-1}. These values are considerably less than those found in other regions of Eastern Canada that are experiencing considerable acidic deposition, suggesting that much of the sulphate in Labrador's lakes is of natural origin (i.e. from organic soils, bogs, and saltwater) with only a minor anthropogenic contribution (Scruton 1984). Many authors (e.g. Wright 1983; Harvey et al. 1981; Jefferies et al. 1986) have considered Labrador to represent a region with only background levels of lake sulphate, with respect to the LRTAP phenomenon.

Dissolved organic carbon (DOC) values ranged from 0.8 to 14.0 mg L^{-1} ($\bar{x}$ = 4.75 mg L^{-1}). The organic content of the lakes was estimated to range from 8 to 136 μeq L^{-1} ($\bar{x}$ = 46 μeq L^{-1}) of organic anions ($COOH^-$) as determined by the Oliver et al. (1983) method. While organics were not originally considered as a major anion in the study lakes (Scruton 1984), a re-examination of the data suggests that organics are the second most important anion, after bicarbonate. Organic anions were found to be proportionally dominant to bicarbonate ($COOH^- > HCO_3 > SO_4 > Cl$) in 23 lakes (25%). Organics are now recognized as a major contributor to the freshwaters of Atlantic Canada and are now routinely incorporated into water quality assessments and ion balances (Scruton 1985; Howell 1986; Scruton and Taylor 1987).

The pH of the study lakes varied from 4.80 to 7.84 ($\bar{x}$ = 6.40). Few lakes had a pH of less than 5.50 (3 lakes, 2%) or alkaline pH's (> 7.00, 6 lakes, 4%) and the majority of the values fell in the range of 6.00 to 7.00 (106 lakes, 82%). The pH distribution was unimodal, and values were spatially correlated with distribution of bedrock types (Scruton 1984). Lake pH was highly correlated ($P < 0.01$) with water colour ($r = -0.35$) and dissolved organic carbon ($r = -0.30$) suggesting considerable organic contribution to the low pH waters.

Lake alkalinities (Gran measured values) varied from -17.4 to 831.0 μeq L^{-1} ($\bar{x}$ = 72.3 μeq L^{-1}). Fourty-one lakes (32%) were categorized as extremely sensitive to the effects of acid rain (0-40 μeq L^{-1} alkalinity), while 84 lakes (65%) were classified as moderately sensitive (40-200 μeq L^{-1}) (Ontario Ministry of the Environment 1981). A small alkalinity deficit (in the order of 25 μeq L^{-1} or less) was apparent in many study lakes, suggesting possibly a response to natural and anthropogenic acid loadings.

The foregoing presents a brief synoposis of the morphometric, physical, and chemical characteristics of the study lakes, as they pertain to an evaluation of the phytoplankton associations in those systems. A detailed evaluation of lake characteristics, with a particular focus on sensitivity to and effects from acid rain, is available in Kendaris (1982), Scruton (1984, 1985), and Kelso et al. (1986). Physical, chemical, and morphometric data for the 95 lakes (with phytoplankton collections) are listed in Tables 2 and 3

while a statistical summary of data for all lakes (n = 130) is provided in Table 4.

A matrix of the correlation coefficients for linear regressions of lake parameters measured in this study is presented in Appendix 1. This matrix was used to select the subset of 22 key morphometric, physical, and chemical parameters used in the statistical analysis. Several parameters were omitted owing to redundancy (laboratory measured pH and alkalinity, non-marine ion concentrations), the fact that parameters were calculated from other variables (cation and anion sum, sum of constituents, bicarbonate, hardness), and the fact that several parameters were not available for all 95 lakes (mean depth, volume).

FACTOR ANALYSIS

The correlation coefficients between the seven derived factors and the original 22 physical and chemical variables subjected to factor analysis are shown in Table 5. Factor 1, which explains 27% of the total variance, is highly correlated with alkalinity, calcium, magnesium, potassium, and pH. It may be considered a hardness factor. Factor 2, which explains 25% of the variance, is highly correlated with colour, dissolved organic carbon, total dissolved solids, turbidity, and sulfate, and can be considered a dystrophy factor. Factor 3 is correlated with two variables reflecting lake size (lake surface area and drainage area) and explains 10.3% of the total variance in the data set. High loading by sodium and chloride on Factor 4 indicates that it is a salinity factor. This factor explains 9.8% of the variance. Factor 5, highly correlated (positively) with secchi depth and maximum depth and negatively with dissolved organic carbon, represents clear water, oligotrophic conditions and explains 9.5% of the variance. Factor 6, which is associated with water temperature, free carbon dioxide, and dissolved oxygen, is considered to express seasonal differences between the study lakes. This factor explains 8.3% of the variance.

PHYTOPLANKTON ASSOCIATIONS

The phytoplankton identified from the 95 study lakes consisted of 386 taxa. A species list with nomenclatural references is provided in Appendix 2. It was not possible to speciate several of the smaller flagellates, in particular those belonging to the genera Chromulina and Ochromonas. The group enumerations and biomasses are summarized in Table 6. The mean number of taxa per lake was 61 ranging between 29 and 106. Total

freshweight biomass per lake ranged between 59 and 1362 mg • m^{-3} with an average of 336 mg • m^{-3}. By algal group the distribution of taxa is as follows:

Cyanophyceae	18 genera	50 taxa
Chlorophyceae	47 genera	139 taxa
Euglenophyceae	3 genera	4 taxa
Chrysophyceae	23 genera	103 taxa
Bacillariophyceae	15 genera	52 taxa
Cryptophyceae	6 genera	19 taxa
Dinophyceae	2 genera	11 taxa

In terms of species numbers, the chrysophytes were dominant in 95 lakes (97%) while the chlorophytes and diatoms were numerically dominant in one lake each, while the chlorophytes and chrysophytes were equally dominant in one lake. In terms of biomass, the chrysophytes dominated in 41 lakes (43%), the diatoms in 39 lakes (41%), the chlorophytes in 8 lakes (8%), the cyanophytes in 4 lakes (4%) and the cryptophytes in one lake (1%). The chrysophytes and diatoms contributed equally (to the total phytoplankton biomass) of two lakes (2%).

The results from the complete-linkage cluster analysis, based on a matrix of Spearman correlation coefficients (Fig. 6), indicated that the Labrador phytoplankton can be justifiably partitioned into eight discrete species associations. There were two reasons for selecting this level. First, the eight groups represent the last level with a statistically reasonable number of species (>90%) that exhibit significant differences between the cluster groups; significance ($P < 0.10$) having been determined by analysis of variance. Second, the eight group solution roughly corresponds to the structure of the physical and chemical environment of the lakes described in the factor analysis. The dominant association (Group 3) comprises 37 members (47% of the total) of which the most prevalent and strongly fused members are Aphanocapsa elachista var. planktonicus, A. elachista var conferta, Crucigenia rectangularis, Dinobryon divergens, and Cosmarium bioculatium. The remaining associations were considerably smaller, each containing from 3 to 9 members.

LAKE MORPHOMETRY

The dendrogram from the Ward's cluster analysis of a matrix of four key morphometric variables (surface area, drainage area, maximum depth, shoreline development) is shown in Fig. 7. Principal components analysis produced similar results but failed to provide as much separation of the lakes. A cluster diagram, with each lake classified according to the cluster group to which it belongs and superimposed on the reduced axes of the first two principal components, is shown in Fig. 8. Seven clusters appear to adequately describe the structure inherent in the data set. A one-way analysis of variance (Table 7) indicated that the means of each variable were significantly different at the seven-cluster-group level. A relatively large increase in the distance coefficient necessary for fusion to the next level (six clusters) is an indication that the last cluster fused at this level is probably too heterogeneous. Table 7 also shows the group means for the four morphometric

variables. There are two predominant groups: Group 1 comprising 36 lakes characterized by moderately small, deep basins, and Group 2 consisting of 38 lakes characterized by small, shallow basins. The remaining five groups with two to seven lakes each, represents a range of morphometric types from extremely small, shallow lakes with extensive shorelines (Group 5), to deep, moderate sized lakes with little shoreline development (Group 6).

PLANKTONIC ASSEMBLAGES IN RELATION TO ACIDITY

Scatter-diagrams of pH plotted against the algal group abundances and biomasses, with the accompanying statistical parameters from the Spearman's correlation analysis, are shown in Figs. 9 to 12. Significant correlations ($P < 0.01$) between the number of taxa and pH were evident with the Cyanophyceae and Chlorophyceae only. Only the diatoms showed a significant correlation between pH and algal biomass. There was only a weak correlation between the total number of taxa per lake and pH; the correlation coefficient ($r = 0.188$) having a probability of 0.069 ($n=95$). No correlation was apparent between pH and total algal biomass.

The mean number of species (total planktonic assemblage and algal classes) for lakes grouped by pH interval is shown in Fig. 13 and listed in Table 8. There was no clear decline in species diversity across the pH range. Small sample sizes in the acid range (pH 5.5 and less) and the alkaline range (pH >7.0) make it difficult to demonstrate a biological response to increasing acidity. The chrysophytes were numerically dominant, with respect to species numbers, in all pH classes while the chlorophytes were subdominant in four pH classes and the diatoms in three classes. Mean algal biomass (both total and by algal class) for lakes grouped by pH class is shown in Fig. 14 and listed in Table 8. Again, there was no apparent trend in biomass in relation to lake acidity. In relation to the algal groups, the diatoms were dominant in 5 pH classes, including the acidic pH range (pH 4.5 to 5.5) and the circumneutral to alkaline pH range (pH 6.5 to 8.0). The pH class 5.5 to 6.0 was dominated by the chlorophytes and the pH class 6.0 to 6.5 by the chrysophytes. The cryptopytes, cyanophytes, and dinoflagellates were of minor importance, contributing from 8 to 23% of the total biomass in the pH classes.

The failure of univariate analyses to demonstrate clear relationships between lakewater pH and either algal biomass or diversity suggests the biotic assemblages may be regulated by many, often interdependent, environmental variables. For this reason, multivariate analyses were used to elucidate the effects of highly correlated variables, which by themselves, reveal little about the occurrence and structure of algal communities.

RELATIONSHIPS BETWEEN LAKE FACTORS AND PHYTOPLANKTON ASSOCIATIONS

Spearman correlation coefficients have been used to interpret the relationships between the six environmental factors and the phytoplankton species abundances (Table 9). The species have been grouped according to their associations to facilitate comparisons.

A large number of species are strongly correlated with Factor 1 (hardness) including Rhodomonas minuta, R. minuta var. nannoplanctica, Gomphosphaeria lacustris, Cryptomonas erosa, and Chrysolykos skujai. Such positively correlated species occur throughout all eight associations with the exception of Groups 1 and 2. Only three species were found to be negatively correlated with Factor 1, including Kephyrion obliquum, Gymnodinium varians, and Ankistrodesmus falcatus var. mirabilis. Two of these belong to Group 2 which has only four members.

Both species of Melosira found commonly in Labrador, M. distans and M. islandica, along with several other species including Cryptomonas pyrenoidifera, Cryptomonas ovata, and Nitzschia palea, are highly correlated with Factor 2, dystrophy. They belong exclusively to Groups 1 and 8, with the exception of C. ovata, which belongs to Group 6. A great many more species, including Cyclotella comta, C. ocellata, Selenastrum minutum, Dinobryon bavaricum, and Aphanocapsa delicatissima are negatively associated with the dystrophy factor. They occur in Groups 2 through 7 but are most prevalent in Group 3 where they comprise about 60% of the association.

Many species are associated with lake size (Factor 3), including Anabaena flos-aquae, Tabellaria fenestrata, Chrysamoeba mikrokonta, and Chrysochromulina parva. Only four species are negatively correlated with this factor; Cryptomonas pyrenoidifera, Chroococcus limneticus var. distans, Frustulia rhomboides and a unidentified species of Ochromonas (species J.). These four negatively correlated species occur in Group 1.

Species positively associated with sodium chloride salinity (Factor 4) include Synedra acus var. radians, Gomphosphaeria lacustris, Chrysolykos planctonicus, and Rhodomonas minuta. Negative correlations are observed for Oocystis pusilla, Merismopedia tenuissima, and Cryptomonas phaseolus. The only apparent trend is that Group 8 contains three negatively correlated taxa while no taxa were positively correlated.

The oligotrophy factor (Factor 5) shows significant correlation with Kephyrion obliguum, Ankistrodesmus falcatus var. mirabilis, Cosmarium ornata, Cyclotella comta, C. ocellata, and Selenastrum minutum. Only three species demonstrated a negative correlation with oligotrophy including Mallomonas akrokomonas, Scenedesmus quadricauda var. parvus, and Nitzschia palea. With the exception of Group 2, none of the other associations showed any consistent positive or negative pattern with this factor.

A large number of species are negatively correlated with Factor 6 which has a strong loading on water temperature, carbon dioxide and dissolved oxygen. Group 3 was the only association that had more than a single member correlated with this factor. In Group 3, three species were positively correlated with Factor 6 and one species, Cosmarium bioculatum, was negatively correlated. Few positive correlations were evident in the other groups.

DISCUSSION

LAKE BASIN MORPHOMETRY

The results of the lake morphometric analyses suggest that the 95 lakes can be divided into seven categories. The most common lake type is small and shallow with a small drainage area and a regular shoreline. Nearly as common are larger and deeper lakes with more extensive shoreline development and drainage area. Fewer in number are extremely small and shallow lakes with dendritic shorelines, and also very deep lakes with little shoreline development. This latter type are probably kettle lakes. The exclusion of lake volume and mean depth from the morphometric analysis had little consequence on the categorization of representative lake types. Very highly significant ($P < 0.001$) correlations between mean and maximum depth ($r = 0.906$) and lake volume and lake surface area ($r = 0.773$) suggest that the information lost by excluding these variables is relatively insignificant. Furthermore, when cluster and principal components analyses were performed on a subset of 75 lakes, with mean depth and volume measurements included, the results were highly similar. A comparison of the lake type distributions with geographic region and bedrock geology (maps presented in Scruton 1984) revealed no obvious connection between regional lithology and lake morphometry, suggesting that lake basin morphometry is largely controlled by localized factors. This statement must be qualified where the less representative groups are concerned, as sample size in these groups is too small to make any definitive statements. Indeed, the two Group 5 lakes (small and shallow), although situated in different regions, both occur in the same gneiss and schist formation. However, some of the deepest lakes in Labrador also occur in this lithology.

Lake morphometry has been described in terms of distinct groups or clusters. It is probably more realistic to suggest the data demonstrate gradients in morphometric characteristics. The clusters then would represent only the nodal points along a continuum of lake types. A more intensive sampling effort would probably reveal intermediates or possibly a different clustering pattern. As previously demonstrated, the distribution of study lakes by size is not representative of the natural distribution, while lake drainage order more closely approximates the natural distribution (Figs. 3 and 4). Since the sample is biased to smaller, mostly lower order lakes, the seven groups cannot be regarded as representing the full range of morphometric lake types in Labrador. Although a gradient of morphometric types appears to occur in Labrador, two or three groups stand out as being quite morphologically distinct. The two kettle lakes are an obvious example of distinct lake types that were formed by a unique glacial process.

LAKE CHEMISTRY AND PHYTOPLANKTON ECOLOGY

The Spearman correlation analysis of pH with algal group abundance showed that lakes of low pH have fewer total phytoplankton species but not lower biomass. This simplification of the community structure without a corresponding decline in standing crop was also demonstrated in insular Newfoundland (Scruton et al. 1987). The lower species number and biomass of the green and blue-green algae in relatively acidic lakes is as characteristic of

Labrador as it is of Newfoundland. The remaining groups; chrysophytes, diatoms, cryptophytes, and dinoflagellates, show no significant changes with increasing lake acidity. However, negative correlations between pH and the biomass of chrysophytes, and dinoglagellates do suggest that these groups increase as the green and blue-green algae decline. This decrease in species diversity with increasing lake acidity has been apparent in both total species numbers and in most major algal groups (Harvey et al. 1979; Kwiatowski and Roff 1974; Yan 1979; Hendrey 1981; EPA 1983). Biomass and lake acidity relationships have been much more inconclusive (EPA 1983). Interpretation of acidity effects on algal production is often more difficult owing to the association of low nutrient and inorganic carbon levels with low pH, and consequently a cause-effect relationship cannot be substantiated.

An interpretation of any relationship between lake pH and the algal groups is undoubtedly obscured by a high degree of temporal variability. Seasonality of phytoplankton species composition may be so pronounced that similar lakes sampled only weeks apart may have markedly different communities. Consequeltly, a substantial amount of the scatter observed in Figs. 9 to 12 may be a result of seasonality. Alternatively, the high degree of scatter may indicate a heterogeneous response to pH by individual species within the algal groups. If this is the case, then strong relationships between pH and entire algal groups should not be expected. Evidence of species-specific responses to environmental variables does exist. As an example, the widely varying response of diatom species to pH has been used successfully as a basis for inferring pH from sedimentary diatom assemblages (Davis and Anderson 1985).

The pH of water per se may not be directly controlling growth or competition at any level of algal community organization since pH is a consequence of a great many ionic and chemical interactions. Instead of responding to the hydrogen ion concentration of water, it is reasonable to suspect that algae respond to specific compounds. The highly different species composition evident between anthropogenic and naturally acidic waters support this view (Yan 1979). The former contribution to acidity is related primarily to sulfuric acid while the latter is associated with organic compounds. Raddum et al. (1980), for example, found acidic clearwater lakes in Norway to have lower species diversity than humic lakes with similar pH's levels. The higher species diversity in humic lakes suggests long-term functional adaptation to naturally acidic circumstances while the depoverished planktonic assemblages in clearwater acidic lakes were evidence of a response to recent anthropogenic acidification.

The nature of the Labrador study lakes has been characterized by six derived environmental factors: hardness, dystrophy, lake size, salinity, oligotrophy, and seasonality. These factors were demonstrated to have an influence on the distribution of phytoplankton associations in the lakes. A possible seventh factor "nitrate" (or nitrification), emerged from the analysis but was subsequently discarded due to a suspected anomaly in the data from one study lake. The first five factors were considered to represent environmental determinants characteristic of the study lakes that are likely to influence the distribution of phytoplankton taxa. However, the six factor, "seasonality", is not considered to influence phytoplankton distributions but rather indicates a time frame when certain taxa may predominate.

A large number of Labrador phytoplankton were highly correlated with one or more of the derived environmental factors. The relative importance of these factors in controlling phytoplankton distributions can be evaluated by the number of species that correlate with each factor. For example 23 species were significantly correlated with dystrophy, 21 species with hardness, 19 with lake size, 10 with salinity, and 9 each with the oligotrophy and seasonality factors. Consequently the physical/chemical factors influence relatively more species (54 vs 28) than do the factors representing lake morphometry (size, oligotrophy).

The term "association" in this study is used in the context of a group of co-occurring species having similar reactions to properties of the environment. Clustering and ordination analysis suggest that the Labrador phytoplankton may consist naturally of eight distinct associations. The size of these associations appear to vary greatly and not all members of an association are strongly similar to one another. Many species joining a cluster at very low similarity levels appear to be cosmopolitan in their distribution, possibly as a result of adaptation to a wide range of environmental conditions. Those species that are not correlated with any of the factors, that is the 27 species excluded from Table 9, are obvious examples.

Correlations between individual species and the seven hypothetical factors should be interpreted with care. In all cases reference should be made to any known species ecology in the literature to ensure that the interpretation is realistic. The two species of Melosira in the Labrador lakes, M. distans and M. islandica, correlated very highly with dystrophy. While the former is common in acidic and dystrophic lakes (Hudon et al. 1986) the latter species is usually considered to favor circumneutral oligotrophic waters (Davis and Anderson 1985). Two other planktonic diatoms, Cyclotella comta and C. ocellata, are often considered to be oligotrophic taxa and this agrees with their distribution in Labrador.

Many of the planktonic diatoms are significantly correlated with Factor 3, lake size, possibly as a consequence of wind-driven recirculation which tends to keep these "heavy" algae from sinking out. The strong negative correlation with Frustulia rhomboides is reasonable since it is a benthic diatom favouring dystrophic lakes. It is more difficult to explain the positive correlation of lake size with several other taxa; Anabaena flos-aquae, Chrysochromulina parva, and Chrysamoeba mikrokonta for example, although all three are common in the Laurentian Great Lakes (Munawar and Munawar 1981).

The sodium chloride content of lakes (Factor 4) appears to correlate highly with the abundances of a number of species which suggests that it may control their distributions. However, these species are not halophiles since the concentrations of dissolved salts are always very low in these typically oligotrophic lakes. It is more likely that the concentrations of sodium and chloride are more likely a reflection of general ionic strength. Species associated with salinity appear to be most abundant in lakes closest to the sea (within 25 to 30 km) where spray can contribute substantially to the ionic composition of the lakewater (Scruton 1984). A discussion of the influence of ionic balance on the phytoplankton of Labrador lakes may be found in Duthie and Ostrofsky (1974). Only a few species (e.g. Mallomonas akrokomonas and

Scenedesmus quadricauda v. parvus) show a strong negative correlation with oligotrophy (Factor 5) suggesting that most species respond to the increased nutrients found in the more productive lakes.

A great number of species are negatively associated with the seasonality factor (Factor 6) while only a few are positively associated. Initially this observation might suggest that many species prefer cool water. Since deep lakes are usually colder than shallow lakes it seems reasonable to expect depth to contribute to this factor as well. This was not observed. Alternatively, this observation probably reflects the periodicity in phytoplankton seasonality. Therefore, species sampled in mid to late summer tend to demonstrate a positive correlation with temperature when the cool water spring and fall forms are less abundant. This interpretation reveals a problem inherent in the data from this study and indeed of synoptic surveys in general. Different sampling periods introduce seasonal variability which can mask relationships between the biological and the physical and chemical variables. The more conservative variables, such as sodium and chloride, and the broadly based hypothetical factors, such as dystrophy or hardness, may be more valuable in this sort of analysis and will tend to overwhelm the seasonal bias.

In addition, many of the physical and chemical properties of the lakes can themselves undergo wide seasonal fluctuations, and the dynamics of phytoplankton species succession may be regulated by the seasonal variability in key environmental factors. An examination of the hydrological records for gauged rivers in the study area revealed that the first six weeks of the two month study program were characterized by low water flows, followed by increasing flows over the last two weeks of the survey (Environment Canada 1983; Scruton 1984). Due to the well established interrelationships of seasonal variability in physical/chemical water properties and the hydrological cycle (Gower 1970; Hem 1970; Scruton 1986) it is likely variables such as pH, alkalinity, and major cations may be close to annual maximums while peak concentrations in other variables (such sulphate, water colour, and turbidity) are often associated with the peaks in the hydrological cycle. However, the hydrological conditions were similar for much of the study and consequently the physical/chemical based factors (hardness, salinity, dystrophy) probably do represent between lake (spatial) differences. The morphology based factors (lake size, and to a large degree oligotrophy) are not affected by seasonal influences.

Care must be taken interpreting the relative importance of the six hypothetical factors since the major factors controlling phytoplankton distributions are not necessarily those which explain the greatest proportion of the variance. Consequently, interpretations should not be based indiscriminately on variance measures. The variance explained by each factor (see Table 5) is influenced by the number of variables which measure the same environmental property. As an example, alkalinity and bicarbonate are redundant since bicarbonate is the only component of alkalinity in these lakes and in fact is calculated from the alkalinity measure. Hence completely redundant variables should never be included simultaneously in multivariate analysis.

Comparisons of the Spearman correlation coefficients for relationships between the eight phytoplankton associations and the six factors (Table 9) suggest that the environmental conditions substantially influence species distribution. Each association of co-occurring taxa appears to require a distinct set of environmental conditions for optimal growth. For example, Group 1 appears to prefer small dystrophic lakes, while Group 3 probably requires clear, hard waters. Group 4 favours larger lakes with a high degree of mineralization, and Group 5 may also require either hard water or extremely clearwater conditions. This is also evidence that groups of algae do tend to co-occur because of similar requirements for specific environmental conditions. Such a phenomenon, although expected on theoretical grounds, has never been adequately demonstrated for the freshwater phytoplankton of Labrador. A major reason for this has been that, until now, comprehensive data sets for specific geographical regions have been scarce.

Despite the demonstrated affiliations with measured environmental conditions, many of the species associations display a considerably amount of environmental heterogeneity. The eight associations each contain at least one species with environmental preferences different from those of the majority of species forming the association. This would suggest that the seven hypothetical factors do not fully account for the observed species distributions. It is proable that additional factors, not revealed in this study, are responsible for this heterogeneity. Indeed, an entire realm of biological factors, such as competition, parasitism or selective grazing, were not considered at all. As an example, a multivariate analyses of zooplankton associations in Newfoundland lakes revealed a clear separation of species on the basis of size. This was interpreted as possible evidence of extensive feeding by resident fish on large zooplankters in some lakes (Carter et al. 1986).

ASSESSMENT OF ACIDIFICATION EFFECTS

The susceptibility and damage from the deposition of strong acids in precipitation on Eastern Canadian lakes is a problem of national concern, and provided the impetus for this comprehensive lake inventory program (The NIS). It is of interest therefore, to evaluate the possible effects that anthropogenic acidification may have had on the Labrador study lakes and the usefulness of the preceding multivariate analyses in detecting it. Lake pH, as a variable in the factor analysis, had significant negative loading on only one of the six derived factors (Factor 2). Low pH is therefore associated (naturally) with highly coloured, dystrophic waters. The factor analysis suggests that atmospheric deposition of acids has not resulted in a substantial reduction of the pH of Labrador lakes. There are a sufficient number of clear water, poorly buffered lakes, which, if they had received significant anthropogenic acid input, would likely have diverged from the non-affected lakes in the factor analysis. In this circumstance, one would expect to find a factor with a significant inverse loading on pH as well as on other variables that represent susceptibility (i.e. alkalinity and calcium content) and acidic deposition (predominately sulphate). The data show no evidence of a negative loading on pH other than in association with natural conditions (acidic, dystrophic water). Indeed, Factor 5, which represents the clear-water, poorly

buffered lakes of Labrador, had negligible loading on pH (r=0.004). We conclude that the factor analysis provides no evidence for anthropogenic acidification. However, the physical/chemical data and phytoplankton assemblages information, with the analyses contained in this report, represent baseline information against which further change in response to anthropogenic pollution and other environmental perturbations can be evaluated.

This result supports similar conclusions drawn from this study (Scruton 1984; Kelso et al. 1986) and others (Clair et al. 1981; Howell and Brooksbank 1987); that is that acid rain has not significantly affected the freshwaters and biota of Labrador. Indeed, other authors have considered Labrador (as well as northern Ontario and Quebec) to represent relatively pristine regions, largely isolated from anthropogenic acidification by virtue of latitude and geographical position in relation to prevailing winds and sources of the precursers of acid rain (Harvey et al. 1981; Wright 1983 for e.g.). However, Labrador's freshwaters are among the most dilute in the world, and therefore are extremely susceptible to potential detrimental effects from acidic deposition. Alkalinity deficits were apparent in many lakes possibly suggesting some response to the low levels of atmospheric deposition, or conversely to natural organic inputs. The location of Labrador relative to emission sources and in relation to meteorlogical patterns does not suggest any immediate threat to Labrador's freshwaters, over the forseeable future (to the year 2000) and under current or projected depositional regimes (Martin and Brydges 1986).

COMPARISON OF NEWFOUNDLAND AND LABRADOR PHYTOPLANKTON AND ENVIRONMENTAL INFLUENCES

The phytoplankton and associated environmental data sets of insular Newfoundland (Earle et al. 1987; Scruton et al. 1987) and Labrador (this report and Earle et al. 1986) were analyzed in a similar manner to facilitate comparison between the two regions. It is our intention not to attempt a detailed discussion of the species composition, but rather to focus on the environmental properties which appear to be controlling the distributions of the species in the two regions.

Factor analysis indicates Newfoundland and Labrador have similar lacustrine environmental properties. Dystrophy, hardness, differences in lake size, and salinity are identified as important lake properties in both regions. Not unexpectedly, seasonal differences in water temperature, carbon dioxide, and dissolved oxygen were also identifiable in both data sets due to the extended period of sampling. In Labrador, an oligotrophy factor was distinguished on the basis of maximum depth and secchi depth. The Newfoundland data did not include complete morphometric characterization (including lake depth) and consequently a comparable factor did not emerge (Scruton 1983; Earle et al. 1987). Lake status in Newfoundland may possibly be represented by Factor 7, phosphorus enrichment.

A large proportion of the Newfoundland and Labrador flora were correlated with one or more of the derived environmental factors. The relative importance of the various environmental factors in controlling the distribution of the

phytoplankton can be evaluated (in a qualitative sense) by the number of species correlated with each factor. In Newfoundland, 18 species were significantly correlated with salinity, 17 species with hardness, 13 species with seasonality and 12 species with dystrophy. In contrast, very few species were correlated at any level with lake size or watershed influence (drainage area vs. lake surface area). In Labrador the factors with the largest number of significantly correlated species were dystrophy (24), hardness (21), lake size (19), and salinity (10). The other factors had considerably fewer correlated species. These comparisons suggest that there are differences in the relative importance of the various environmental factors controlling phytoplankton distributions. In Newfoundland, salinity may be a more influential factor than in Labrador. This is attributable to the greater coastline, closer proximity of lakes to salt water, and insular nature of Newfoundland which provide a larger number of marine aerosol influenced lakes. In Labrador, drainage area and lake surface area (lake size) appear to influence the distribution and abundance of more species than in Newfoundland. There are also considerably more "dystrophic" species in Labrador than in Newfoundland. It is possible these differences are attributable to sampling effort or to chance, but the large size of the data sets and the similar criteria used for selecting lakes in both regions tend to discount such an explanation. Lake selection criteria for the Labrador survey was somewhat different than for insular Newfoundland, in that the sample was selected to include 0 to 10 ha size lakes, a size class unstudied in insular Newfoundland.

The phytoplankton associations of Newfoundland and Labrador correspond reasonably well with the environmental structure described by the factor analysis. Hardwater and dystrophic associations are clearly discerned in both regions while saline and lake size associations are identifiable in insular Newfoundland and Labrador, respectively. However, the species comprising the hardwater and dystrophic associations differ considerably between regions. This is in part due to fundamental differences in species composition between the two regions. The species that do co-occur exhibit significant correlations with the same environmental factors. For example, such widely distributed species as Rhodomonas minuta and Gomphosphaeria lacustris are highly correlated with hardness while Chroococcus limneticus, Selenastrum minutum, and Dinobryon divergens are negatively correlated with dystrophy in both regions.

ACKNOWLEDGEMENTS

Dobrocky Seatech (Nfld.) Ltd. completed the lake sampling program under contract to Fisheries and Oceans (DFO). The identification of an enumeration of phytoplankton was completed by N. MacNeil and J. C. Earle of the University of Waterloo (under contract to DFO). N. MacNeil also assisted in the preparation of the manuscript. The statistical analysis and data interpretation were also completed under contract to DFO and through an NSERC Operating Grant to H. C. Duthie. The graphics were completed by Mr. Neil Hefford and Mr. Herb Mullett (DFO) and Ms. N. MacNeill (University of Waterloo). Ms. Janice Lannon and Ms. Karen Scott typed the report. Mr. P. Ryan reviewed the manuscript.

REFERENCES

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1975. Standard methods for the examination of water and wastewater. American Public Health Association, Washington, D. C., 14th Edition, 874 p.

Allen, T.F.H., S. M. Bartell, and J. F. Koonee. 1977. Multiple stable configuration in ordination of phytoplankton community change rate. Ecology 58: 1076-1084.

Beak Consultants Ltd. 1980. Fisheries resources of tributaries of the Lower Churchill River. Prepared for the Lower Churchill Development Corporation, St. John's, Nfld. iii + 107 p., 3 Appendices.

Beak Consultants Ltd., and Kilborne Ltd. 1979. Environmental impact statement: Kitts-Michelin Project. Prepared for BRINEX Ltd., Mississauga, Ontario. Vol. 1. 379 p.

Carter, J.H.C., W. D. Taylor, R. Chengalath, and D. A. Scruton. 1986. Limnetic zooplankton assemblages in Atlantic Canada with special reference to acidification. Can. J. Fish. Aquat. Sci. 43: 444-456.

Cedercreutz, C. 1944. Freshwater algae from Labrador. Mem. Soc. Fauna Flora Fenn. 19: 216-222.

Clair, T. A., D. R. Engstrom, and W. Whitman. 1982. Data report. Sensitivity of surface waters in Newfoundland and Labrador to acidic precipitation. Environment Canada, Inland Waters Directorate, Water Quality Branch, Moncton, N.B. Report IWD-AR-WQB-82-32. 36 p.

Croasdale, H., and R. Grönblad. 1964. Desmids of Labrador. 1. Desmids of the southeastern coastal area. Trans. Amer. Micr. Soc. 83: 142-212.

Davis, R. B., and D. S. Anderson. 1985. Methods of pH calibration of sedimentary diatom remains for reconstructing history of pH in lakes. Hydrobiologia 120: 69-87.

Drablos, D., and A. Tollan [eds.]. 1980. Ecological impact of acid precipitation. Proceedings of an International Conference, Sandefjord, Norway, March 11-14, 1980. 383 p.

Duthie, H. C. 1979. Limnology of subarctic Canadian lakes and some effects of impoundment. Arctic Alpine Res. 11: 145-158.

Duthie, H. C., and M. L. Ostrofsky. 1974. Plankton, chemistry and physics of lakes in the Churchill Falls region of Labrador. J. Fish. Res. Board Can. 32: 1105-1117.

1982. Use of phosphorus budget models in reservoir management. Can. Water Res. J. 7: 337-348.

Duthie, H. C., M. L. Ostrofsky, M. R. Sreenivasa, and D. J. Brown. 1975. Freshwater algae from western Labrador. Nova Hedw. 26: 17-31, 253-268, 555-560.

Duthie, H. C., M. L. Ostrofsky, M. R. Sreenivasa, and D. J. Brown. 1976. Freshwater algae from western Labrador. Nova Hedw. 27: 909-917.

Duthie, H. C., M. L. Ostrofsky, M. R. Sreenivasa and D. J. Brown. 1978. Freshwater algae from western Labrador. Nova Hedw. 29: 237-242.

Earle, J. C., and H. C. Duthie. 1985. A multivariate statistical approach for interpreting marshland diatom succession. Proc. Eighth Internat. Diatom Symp., Paris, 441-458.

Earle, J. C., H. C. Duthie, and D. A. Scruton. 1986. Analysis of the phytoplankton composition of 95 Labrador lakes, with special reference to natural and anthropogenic acidification. Can. J. Fish. Aquat. Sci. 43: 1800-1811.

1987. Factoars influencing the distribution of phytoplankton in 97 headwater lakes in insular Newfoundland. Can. J. Fish. Aquat. Sci. 44: 639-649.

Environment Canada. 1979. Analytical Methods Manual, Inland Waters Directorate. Water Quality Branch, Ottawa, Canada.

1983. Surface Water Data, Atlantic Provinces. Inland Waters Directorate, Ottawa, Canada. xii + 115 p.

Environmental Protection Agency. 1983. The acid deposition phenomemon and its effects. Critical assessment review papers. Vol. II. Effects Sciences. U.S. EPA, Office of Research and Development, Washington, D. C. EPA-600/8-83-016B. xxvi + 655 p.

Gardner, G. 1949. Algues, lichens, mousses, hepatiques recolteés au Labrador à la Baie d'Hudson. Mem. Soc. Bot. France 32: 74-94.

Gower, A. M. 1980. Water quality in catchment ecosystems. J. Wiley and Sons, New York, N.Y. 535 p.

Green, R. H., and G. L. Vascotto. 1978. A method for the analysis of environmental factors controlling patterns of species composition in aquatic communities. Water Res. 12: 583-590.

Harvey, H. H., R. C. Pierce, P. J. Dillon, J. P. Kramer and D. M. Whelpdale. 1981. Acidification in the Canadian Environment. NRCC Report No. 18475. 369 p.

Hem, J. D. 1970. Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water Supply Paper No. 1473, Washington, D. C. 363 p.

Hendrey, G. R. 1981. Effects of acidification on aquatic primary producers and decomposers, p. 125-136. In: R. E. Johnson [ed.] Acid Rain/Fisheries: Proceedings of an International Symposium on acidic precipitation and fishery impacts in northeastern North America. Am. Fish. Soc., Bethsada, Maryland. vii + 357 p.

Hilliard, D. K. 1966. Studies on Chrysophyceae from some ponds and lakes in Alaska. Hydrobiologia 28: 553-576.

Howell, G. D. 1986. Water quality characterization of 78 acid precipitation monitoring lakes in Atlantic Canada. Environment Canada, Inland Water Directorate, Water Quality Branch, Moncton, N. B. Report IWD-AB-WQB-86-109. iii + 119 p.

Howell, G. D., and P. Brooksbank. 1987. An assessment of LRTAP acidification of surface waters in Atlantic Canada. Environment Canada, Conservation and Protection Service, Water Quality Branch, Moncton, N.B. Report No. 1W/L-AR-WQB-87-121. x + 292 p.

Huber-Pestalozzi, G. 1938-1950. Binnengewässer, Bd. 16. Das Phytoplankton des Süsswassers. E. Schweizerbart'sche Verlag. Stuttgart.

Hudon, C., H. C. Duthie, S. M. Smith, and S.A. Ditner. 1986. Relationships between lakewater pH and sedimentary diatoms in the Matamek watershed, northeastern Quebec, Canada. Hydrobiologia 140: 49-65.

Janus, L. L., and H. C. Duthie. 1979. Phytoplankton composition and periodicity in a northeastern Quebec lake. Hydrobiologia 63: 129-134.

Jefferies, D. S., D. L. Wales, J.R.M. Kelso, and R. A. Linkhurst. 1986. Regional chemical characteristics of lakes in North America: Part 1-Eastern Canada. Water Air Soil Pollut. 31: 551-569.

Kelso, J.R.M., C. K. Minns, J. E. Gray, and M. L. Jones. 1986. Acidification of surface waters in eastern Canada and its relationship to aquatic biota. Can. Spec. Publ. Fish. Aquat. Sci. 87. 42 p.

Kendaris, T. A. 1982. An acid rain inventory survey of selected Labrador lakes. Technical Report, Submitted to Fisheries and Oceans Canada, DSS File No. 07SC.FP001-2-1168. 52 p.

Kramer, J. R. 1978. Precise determination of low alkalinities using the modified gran analysis, an inexpensive field procedure. Dept. of Geology, McMaster University, Hamilton, Ontario. 11 p.

Kwiatowski, R. E., and J. C. Roff. 1976. Effects of acidity on the phytoplankton and primary productivity of selected northern Ontario lakes. Can. J. Bot. 54: 2546-2561.

Legendre, L., and P. Legendre. 1983. Numerical ecology. Development in environmental modelling 3. Elsevier, New York, N.Y. 419 p.

Livingstone, D. A. 1963. Chemical composition of rivers and lakes. Data of Geochemistry. 6th Edition, Chapter G. U.S. Geological Survey Professional Paper No. 400-G, Washington, D.C. 61 p.

Martin, H. C., and T. G. Brydges. 1986. Stress factors: Trends and recovery. The International Conference on Acidification and its Polcy Implications. Amsterdam, The Netherlands, May 2-5, 1986. 17 p.

Munawar, M., and I. F. Munawar. 1981. A general comparison of the taxonomic composition and size analyses of the phytoplankton of the North American Great Lakes. Verh. Internat. Verein. Limnol. 21: 1695-1716.

Oliver, B. G., E. M. Thurman, and R. L. Malcolm. 1983. The contribution of humic substances to the acidity of coloured natural waters. Geochim. Cosmochim. Acta 47: 2031-2035.

Ontario Ministry of Natural Resources. 1980. Determination of total inflection point alkalinity. Instruction manual for sampling and field titration. Ontario Ministery of Natural Resources, Fisheries Branch, Environmental Dynamics Division, Toronto, Ontario. 35 p.

Ontario Ministry of the Environment. 1981. Acid sensitivity survey of lakes in Ontario. APIOS Report No. 002/81, iv + Appendix.

Orloci, L. 1978. Multivariate analysis in vegetation research. 2nd. Ed., Dr. W. Junk Publ., Boston, Mass. 451 p.

Ostrofsky, M. L., and H. C. Duthie. 1975. Primary productivity and phytoplankton of lakes on the eastern Canadian Shield. Verh. Internat. Verien. Limnol. 19: 732-738.

1980. Trophic upsurge and the relationship between phytoplankton biomass and productivity in Smallwood Reservoir, Canada. Can. J. Bot. 58: 1174-1180.

Pinel-Alloul, B., E. Magnin, and G. Codin-Blumer. 1982. Effects de la mise en eau du reservoir Desaulniers sur la zooplancton d'une riviere et d'une tourbiere reticulee. Hydrobiologia 86: 271-296.

Raddum, G., A. Hobaek, E. Lomsland, and T. Johnsen. 1980. Phytoplankton and zooplankton in acidified lakes in southern Norway, p. 332-333. In: D. Drablos and A. Tollan [ed.] Proceedings of an International Conference on the Ecological Impact of Acid Precipitation, SNSF-Project, Sandefjord, Norway. 383 p.

SAS Institute. 1979. SAS Users guide, 1979 Edition. SAS Institute Inc., North Carolina, USA. 494 p.

Schilts, W. W. 1981. Sensitivity of bedrock to acid precipitation: modification by glacial process. Geological Survey of Canada, Paper 81-14, 7 p.

Scruton, D. A. 1983. A survey of headwater lakes in insular Newfoundland, with special reference to acid precipitation. Can. Tech. Rep. Fish. Aquat. Sci. 1195: v + 110 p.

1984. A survey of selected lakes in Labrador, with an assessment of lake status and sensitivity in relation to acid precipitation. Can. Tech. Rep. Fish. Aquat. Sci. 1296: v + 115 p.

1985. Acid rain studies and limnological characterization of lakes in Newfoundland. Can. Soc. Environ. Biol. Newsletter 42: 21-38.

1986. Spatial and temporal variability in the water chemistry of Atlantic salmon rivers in insular Newfoundland: an assessment of sensitivity to and effects from acidification and implications for resident fish. Can. Tech. Rep. Fish. Aquat. Sci. 1451: v + 143 p.

Scruton, D. A., and D. H. Taylor. 1987. A survey of dilute lakes on the south coast of insular Newfoundland in relation to natural and anthropogenic acidication. Can. Tech. Rep. Fish. Aquat. Sci. (in press).

Scruton, D. A., J. C. Earle, and H. C. Duthie. 1987. Phytoplankton assemblages from 95 headwater lakes in insular Newfoundland: An assessment of environmental and morphometric influences on species distributions and associations. Can. Tech. Rep. Fish. Aquat. Sci. (in press).

Skuja, H. L. 1948. Taxonomie des phytoplanktons einiger Seen in Uppland, Schweden. Symb. Bot. Upsal. 9. 399 p.

1956. Taxonomische und biologische studien uPH"ber das phytoplankton schwedischer Binnengewässer. Nova Acta Reg. Soc. Sci. Upsal. Ser. IV, 6, 404 p.

1964. Grundzüge der Algenflora und Algenvegetation des Fjeldgegenden um Abisko. Nova. Acta Reg. Soc. Sci. Upsal. Ser. IV, 18, 465 p.

Strickland, J. D., and T. R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Fish. Res. Board of Can. Bull. No. 167. 311 p.

Watt, W. D., D. Scott, and S. Ray. 1979. Acidification and other chemical changes in Halifax County lakes after 21 years. Limnol. Oceanogr. 24: 1154-1161.

Welch, P. S. 1948. Limnological methods. Blakiston Co., Philadelphia, Pennsyvania. 381 p.

Willen, T. 1963. Notes on Swedish plankton algae Nova Hedw. 6: 39-56 + 5 pl.

Wright, R. F. 1983. Predicting acidification of North American lakes. Norwegian Institute for Water Research (NIVA). Report 4/83. 165 p.

Yan, N. D. 1979. Phytoplankton community of an acidified, heavy metal contaminated lake near Sudbury, Ontario. 1973-1977. Water Air Soil Pollut. 11: 43-55.

Table 1. Water quality parameters measured, analytical methods employed, and limits of detection for 20 physical and chemical water properties determined for the study lakes (from Scruton 1984).

Parameter	Analytical Procedure	Required Vol. (ml)	Limit of Detection (mgL^{-1})
Conductivity	Hach Conductivity Meter Model 2511	20	0.5 ($\mu S\ cm^{-1}$)
Color	Visual Comparison using Platinum Color Plasma	10	5 (TCU)
pH	Combination Glass & Reference Electrode Radiometer Model 26 pH Meter	8	0.01 (pH units)
TDS	Evaporation of filtrate	100	0.01
Turbidity	Nephelometric Method - Hach 2424 Turbidmeter	10	-
Sodium	Atomic Absorption on Perkin Elmer AA	2	0.1
Potassium	Atomic Absorption on Perkin Elmer AA	2	0.02
Calcium	Atomic Absorption (ICP) on Jarrel Ash AA	2	0.01
Magnesium	Atomic Absorption (ICP) on Jarrel Ash AA	2	0.02
Hardness	Calculated from calcium and magnesium	-	0.02
Alkalinity	Auto Analyzer II Colormetric Bromophenol Blue	8	0.1
Bicarbonate	Calculated from field alkalinity	-	0.01
Sulphate	a) Auto Analyzer II Colormetric Methylthymol Blue b) Hydrogen-peroxide uv pre-treatment	8	0.3
Chloride	Auto Analyzer II Colormetric Mercuric Thiocyanate	8	0.1
Phosphate total as P	Auto Analyzer II Colormetric U.V. Digestion & Molybate Ascorbic Acid	8	0.001
Nitrogen total as N	Auto Analyzer II Colormetric U.V. Digestion & Diazotization	8	0.02
Aluminum	Atomic Absorption - (ICP) on Jarrel Ash AA	50	0.010 ($\mu g\ L^{-1}$)
Dissolved Organic Carbon (DOC)	Oxidation to CO_2 and Colorimetric determination	50	0.1

Table 2. Morphometric data for the 95 Labrador lakes. (See Appendix 1 for description of units.)

LAKE	LSA	MAX DEPTH	SLO	DRAINAGE AREA	WATER TEMP	SECCHI DEPTH	TURBIDITY	COLOR
301	88.3	9	2.70	750.0	8.4	8.2	0.50	5
302	92.5	9	1.17	405.0	9.5	7.6	0.54	5
354	145.8	62	2.22	878.3	10.2	9.1	0.40	5
355	387.5	70	2.51	2502.5	8.8	10.1	0.46	5
357	57.5	3	1.86	628.3	16.3	2.7	0.70	10
358	69.0	7	1.78	407.5	13.9	5.8	0.54	10
359	103.3	15	2.78	644.0	15.5	5.8	0.41	5
360	367.5	6	4.19	4397.5	16.7	2.9	0.50	10
361	65.0	39	1.75	600.0	11.0	16.5	0.48	5
362	75.0	11	1.87	2850.0	15.6	4.6	0.39	10
363	135.3	18	2.30	855.8	15.4	4.3	0.45	20
364	74.0	14	1.39	1442.5	10.7	7.6	0.35	5
365	106.5	7	1.64	476.5	15.2	1.5	0.50	10
366	175.0	35	2.56	1861.5	16.3	8.5	0.49	15
367	85.8	8	1.45	506.5	9.8	3.8	0.73	5
368	45.8	8	1.25	122.5	10.6	8.0	0.52	5
369	18.3	1	1.48	203.3	9.0	0.5	1.30	100
370	86.5	12	2.05	405.0	8.4	5.0	1.10	15
371	24.0	1	1.44	142.5	7.5	1.0	3.00	100
372	5.0	5	1.89	246.5	8.3	3.0	0.60	50
373	93.3	11	1.90	1035.0	9.7	4.0	0.60	15
374	106.5	3	2.41	433.3	8.0	2.5	0.85	20
375	10.0	5	2.90	89.0	10.4	3.0	0.95	55
376	7.5	6	1.03	70.0	9.4	3.5	0.48	20
377	109.0	16	2.19	826.5	10.4	3.0	0.64	25
378	7.5	2	6.70	170.0	10.0	1.0	0.89	65
401	171.5	18	1.78	1635.0	10.3	5.0	0.66	10
402	135.0	2	3.28	2570.0	9.9	1.0	0.93	65
403	15.0	1	1.02	194.0	8.0	0.5	5.50	175
404	87.5	4	1.28	1017.5	9.5	2.0	0.65	65
406	80.0	3	1.81	6150.8	10.0	0.7	1.70	70
407	108.3	24	1.90	787.5	9.9	9.0	0.63	5
408	7.5	2	1.29	139.0	9.5	2.0	0.56	65
409	12.5	8	1.80	62.5	8.3	8.0	0.45	5
410	1217.5	13	2.55	8891.5	2.5	4.5	0.63	15
451	7.5	9	1.44	62.5	9.9	6.0	0.48	10
453	242.5	10	4.08	1260.0	10.3	1.5	0.63	55
455	102.5	2	1.18	658.3	9.4	1.5	0.70	75
456	36.5	1	1.24	520.0	8.2	1.0	1.40	65
457	50.0	3	1.80	255.0	8.7	1.5	0.56	45
458	135.0	27	2.67	1590.8	10.1	3.5	2.40	20
459	205.0	2	2.17	6444.0	3.2	2.0	2.10	125
462	285.8	15	2.59	3045.8	5.4	3.0	0.60	30
463	148.3	2	1.51	570.0	11.0	1.5	1.30	55
464	7.5	6	1.03	35.0	10.5	2.5	1.10	55
465	5.0	3	1.26	22.5	9.1	1.5	1.10	65
466	5.0	1	1.14	217.5	9.4	1.0	0.60	50
467	7.5	1	1.03	492.5	9.2	1.5	0.53	100
468	592.5	3	1.68	2925.8	9.9	2.0	0.80	25
469	35.0	19	1.79	345.0	4.5	2.0	1.00	65
472	90.0	9	1.19	4131.5	4.1	3.0	1.80	55
473	7.5	1	2.06	47.5	7.6	1.0	1.20	25
474	7.5	1	1.03	32.5	9.4	1.0	1.20	100

Table 2 (Cont'd.)

LAKE	LSA	MAX DEPTH	SLD	DRAINAGE AREA	WATER TEMP.	SECCHI DEPTH	TURBIDITY	COLOR
475	193.3	8	2.23	665.0	10.6	3.0	1.00	50
476	121.5	2	1.28	450.8	9.2	1.3	1.30	55
477	12.5	1	1.20	232.5	8.9	1.0	0.60	45
478	152.5	5	1.48	985.0	4.8	1.5	0.72	25
479	61.3	13	1.26	439.0	4.9	7.0	0.77	20
480	104.0	12	2.77	1181.5	6.0	2.5	0.64	30
481	138.3	2	2.52	767.5	10.6	2.0	1.30	75
482	10.0	1	1.12	37.5	9.6	1.0	0.58	15
484	332.5	10	1.78	2575.0	11.0	2.5	0.67	30
485	224.0	2	2.64	1142.5	10.3	2.5	0.55	30
486	77.5	10	1.44	1180.0	10.5	1.2	1.10	100
487	182.5	19	2.48	1469.1	6.3	2.5	1.00	50
488	162.5	12	1.77	3157.5	1.3	2.0	1.90	55
501	70.0	12	1.43	2042.5	8.6	5.5	0.47	10
502	217.5	20	2.49	1000.0	8.3	4.5	0.52	10
503	50.0	17	1.99	413.3	8.6	4.5	0.50	15
504	100.0	3	1.41	1130.0	9.0	2.5	0.93	25
505	51.5	7	2.16	570.0	9.1	4.0	0.45	15
506	75.0	6	3.26	605.0	10.3	3.5	0.57	25
507	80.0	24	2.65	1356.9	9.3	3.5	0.50	25
508	52.5	11	1.36	229.0	8.6	4.5	0.48	15
509	12.5	5	7.98	62.5	7.4	3.0	0.63	25
510	408.3	23	4.89	1132.9	9.0	4.0	0.47	20
511	67.5	16	2.40	762.5	10.1	4.0	0.55	15
512	197.5	19	1.96	2515.0	7.8	4.0	1.20	15
513	157.5	8	2.92	1035.0	6.9	2.5	0.51	25
514	76.5	27	1.61	262.5	7.4	5.0	0.40	15
515	182.5	4	2.35	632.6	5.5	3.0	0.64	20
516	60.0	5	1.82	1500.8	3.7	2.5	0.89	65
517	1055.5	16	2.71	8138.3	5.2	2.0	0.93	20
518	296.5	50	1.23	858.3	8.9	8.0	1.10	5
519	95.0	9	1.04	1009.0	8.8	4.6	0.53	15
520	125.0	5	1.14	580.0	5.0	2.5	0.80	15
521	103.3	41	1.32	437.5	5.7	5.0	0.38	10
522	350.0	5	1.77	1410.8	6.6	3.0	0.64	15
523	155.0	14	1.70	922.5	6.7	3.0	0.69	30
524	286.5	14	1.67	5109.0	7.4	2.5	0.74	50
525	45.0	14	1.79	2755.0	6.7	3.0	0.73	35
526	195.0	5	3.74	1289.0	7.4	4.1	0.75	15
527	75.0	17	1.79	1585.0	7.4	4.0	0.63	10
528	212.5	13	2.71	850.0	9.9	4.5	0.78	10
529	101.5	7	2.52	1827.5	7.6	2.3	0.76	15

LSA = LAKE SURFACE AREA SLD = SHORELINE DEVELOPMENT

Table 3. Physical and chemical data for the 95 Labrador lakes. (See Table 1 for units and limits of detection.)

LAKE	DISSOLVED OXYGEN	CARBON DIOXIDE	PH	ALK	TDS	CA	MG	NA	K	CL	SULPHATE	ORTHO-PHOSPHATE	NITRATE	DOC
301	10.9	2.3	6.46	42.4	6	20.5	10.8	17.4	2.1	2.8	6.3	0.06	0.71	1.6
302	10.7	1.8	6.52	50.4	5	28.5	15.0	13.0	3.9	4.2	6.3	0.03	0.71	1.6
354	11.2	2.1	6.29	31.5	5	27.5	7.5	17.4	0.5	10.4	10.4	0.03	0.71	1.6
355	11.8	2.2	6.20	23.7	10	22.5	7.5	13.0	1.3	7.0	10.4	0.03	0.71	1.2
357	9.4	1.3	6.54	101.0	18	85.0	21.7	26.1	7.7	5.6	10.4	0.03	0.71	3.0
358	10.4	1.4	6.66	93.2	17	80.0	19.2	26.1	1.3	12.7	16.7	0.03	0.71	2.3
359	10.2	1.1	6.22	24.2	11	34.0	8.3	17.4	1.3	4.2	4.2	0.03	0.71	0.8
360	9.4	1.1	6.86	66.0	14	48.0	30.0	21.7	7.7	2.8	16.7	0.03	0.71	2.4
361	11.8	1.7	6.56	98.1	16	65.0	25.0	21.7	1.3	2.8	6.3	0.03	3.57	1.0
362	9.2	1.2	6.87	91.0	8	75.0	25.0	30.4	1.3	7.0	16.7	0.03	0.71	2.6
363	11.2	1.3	7.16	162.4	18	145.0	54.2	30.4	1.3	2.8	27.1	0.03	0.71	3.9
364	10.8	1.3	6.71	124.8	9	85.0	24.2	26.1	1.3	19.7	16.7	0.03	0.71	1.6
365	11.2	1.4	6.80	152.5	12	85.0	47.5	39.1	1.3	4.2	16.7	0.03	0.71	2.8
366	10.2	1.5	6.86	109.3	15	80.0	29.2	17.4	1.3	1.4	27.1	0.03	5.00	3.0
367	10.4	2.0	6.84	101.9	9	80.0	16.7	26.1	5.9	2.8	16.7	0.03	0.71	2.6
368	10.5	1.0	6.02	19.7	4	21.5	8.3	8.7	1.3	2.8	16.7	0.03	2.86	1.6
369	11.6	2.7	5.66	35.1	26	55.0	23.3	34.8	3.3	7.9	52.1	0.03	0.71	9.5
370	11.6	1.0	5.74	14.0	4	26.0	8.3	13.0	2.1	23.4	16.7	0.03	1.43	3.3
371	11.8	2.6	5.66	31.9	26	48.0	20.8	30.4	3.9	5.6	47.9	0.03	0.71	9.6
372	9.6	1.9	6.22	41.2	16	42.0	15.0	21.7	2.1	19.7	27.1	0.03	0.71	5.0
373	10.2	2.2	6.68	79.3	8	75.0	20.0	21.7	5.9	4.2	22.9	0.03	0.71	3.8
374	11.1	1.0	6.42	22.5	11	29.5	18.3	13.0	2.1	7.0	16.7	0.03	0.71	3.6
375	10.7	1.8	6.02	29.2	15	38.0	14.2	17.4	3.3	4.2	22.9	0.03	0.71	6.0
376	9.9	1.2	6.52	66.8	11	43.0	40.0	13.0	2.1	7.9	27.1	0.03	0.71	3.3
377	10.7	1.1	6.40	28.9	11	37.0	16.7	17.4	1.3	5.6	16.7	0.03	0.71	4.9
378	9.5	2.1	5.74	24.8	20	27.5	21.7	13.0	2.1	8.5	29.2	0.03	0.71	8.5
401	11.0	1.2	4.80	-17.4	23	42.5	15.0	30.4	4.6	33.0	16.7	0.03	52.86	3.8
402	11.0	1.6	6.30	39.3	27	39.0	23.3	47.8	3.3	36.6	31.3	0.03	0.71	7.0
403	11.2	3.5	5.25	24.0	51	43.0	26.7	26.1	1.3	33.8	62.5	0.03	0.71	14.0
404	11.1	1.4	6.44	55.5	32	44.5	34.2	30.4	4.6	19.2	37.5	0.03	0.71	8.5
406	10.7	0.4	6.64	79.8	36	65.0	43.3	47.8	2.1	27.3	43.8	0.03	0.71	8.8
407	10.3	1.2	5.92	16.2	18	21.0	13.3	17.4	1.3	8.2	18.8	0.03	6.43	3.8
408	10.4	1.8	6.52	92.0	35	70.0	46.7	47.8	2.6	33.0	35.4	0.03	0.71	9.1
409	11.2	0.9	6.50	31.6	17	24.5	23.3	8.7	0.5	2.8	8.3	0.03	0.71	2.8
410	12.5	1.8	6.71	92.2	15	70.0	36.7	43.5	0.5	31.0	18.8	0.03	0.71	2.8
451	10.4	1.2	6.48	52.2	21	39.5	23.3	17.4	0.5	6.8	18.8	0.03	0.71	4.2
453	9.6	1.4	6.22	27.2	27	41.0	20.8	13.0	3.9	6.8	29.2	0.03	0.71	6.8
455	10.6	0.7	6.28	50.7	32	55.0	29.2	17.4	2.1	10.4	31.3	0.03	0.71	9.8
456	10.2	1.8	6.48	86.7	32	65.0	51.7	34.8	0.5	12.1	27.1	0.03	0.71	8.8
457	10.6	1.1	6.56	69.4	26	45.0	35.0	26.1	3.9	7.9	25.0	0.03	0.71	6.1
458	9.9	1.2	5.84	35.4	21	34.0	21.7	13.0	2.1	5.6	20.8	0.03	0.71	4.5
459	12.0	3.4	6.42	91.0	31	80.0	45.0	69.6	3.6	45.1	47.9	0.03	0.71	9.6
462	11.1	0.7	6.60	56.0	19	60.0	33.3	17.4	3.6	5.6	29.2	0.03	0.71	3.8
463	10.0	1.3	5.81	124.7	22	24.0	12.5	8.7	2.1	4.2	25.0	0.03	0.71	6.0
464	10.1	2.3	6.16	44.8	23	43.5	18.3	26.1	0.5	9.9	27.1	0.03	0.71	6.8
465	10.3	1.5	6.34	58.8	24	44.0	38.3	13.0	3.9	7.0	31.3	0.03	0.71	6.9
466	10.6	2.0	6.52	72.7	30	65.0	32.5	34.8	3.9	9.3	37.5	0.03	0.71	7.0
467	10.6	2.0	6.30	56.5	26	65.0	29.2	21.7	2.1	12.7	43.8	0.03	0.71	9.6
468	10.4	1.0	6.52	49.1	21	48.0	29.2	17.4	3.9	9.3	29.2	0.03	0.71	5.6
469	10.5	1.9	6.00	34.3	20	35.0	19.2	17.4	2.8	7.0	27.1	0.03	0.71	5.6
472	12.0	2.1	6.44	63.0	22	60.0	28.3	39.1	3.6	26.8	33.3	0.03	0.71	6.0
473	10.8	1.5	5.88	18.5	22	24.5	15.8	8.7	0.5	6.2	25.0	0.03	0.71	6.0
474	10.3	2.4	5.66	32.4	33	60.0	24.2	17.4	3.3	10.7	54.2	0.03	0.71	11.0

Table 3 (Cont'd.)

LAKE	DISSOLVED OXYGEN	CARBON DIOXIDE	PH	ALK	TDS	CA	MG	NA	K	CL	SULPHATE	ORTHO-PHOSPHATE	NITRATE	DOC
475	11.2	1.4	6.05	32.3	20	46.0	18.3	13.0	3.3	5.6	43.8	0.03	0.71	6.2
476	11.1	1.8	6.16	35.9	22	35.5	20.0	13.0	3.3	7.9	29.2	0.03	0.71	6.0
477	.	1.2	7.00	139.2	28	100.0	47.5	43.5	7.7	12.1	35.4	0.03	0.71	5.0
478	10.8	1.7	6.16	41.0	15	39.5	17.5	13.0	1.8	5.6	25.0	0.03	0.71	4.5
479	12.0	2.1	6.22	39.6	11	33.5	20.8	39.1	1.8	28.2	18.8	0.03	0.71	3.4
480	9.6	1.8	6.41	54.1	17	48.0	22.5	17.4	3.6	5.6	27.1	0.03	0.71	4.3
481	10.0	1.8	5.78	30.8	29	50.0	25.0	21.7	3.3	12.1	45.8	0.06	0.71	8.3
482	.	1.4	5.64	10.0	15	19.5	10.0	8.7	4.6	5.1	27.1	0.03	0.71	4.2
484	10.8	1.2	6.62	74.1	19	55.0	27.5	26.1	2.1	12.1	33.3	0.03	0.71	5.0
485	10.3	1.3	6.24	30.0	20	42.5	17.5	21.7	2.1	7.9	31.3	0.03	0.71	5.0
486	11.7	2.0	5.48	23.1	30	47.0	15.8	17.4	2.1	11.3	37.5	0.03	3.57	8.6
487	10.0	1.9	6.57	58.8	23	60.0	29.2	21.7	3.6	7.0	35.4	0.03	0.71	5.0
488	13.5	2.5	6.46	68.0	18	60.0	33.3	43.5	1.8	28.2	37.5	0.03	0.71	5.7
501	11.2	1.7	6.82	104.7	10	65.0	39.2	26.1	5.1	5.6	18.8	0.03	0.71	2.9
502	10.2	1.5	6.44	38.7	9	31.0	25.8	21.7	2.6	1.4	25.0	0.03	0.71	3.7
503	10.1	2.0	6.52	41.7	10	30.0	25.0	21.7	2.6	2.8	27.1	0.03	0.71	3.5
504	11.0	2.0	6.72	99.9	12	55.0	40.8	30.4	3.9	2.8	20.8	0.03	0.71	4.8
505	10.2	1.8	6.84	100.5	14	75.0	31.7	30.4	2.6	4.2	27.1	0.03	0.71	3.6
506	9.7	2.1	6.98	165.7	28	175.0	75.0	30.4	11.0	14.1	91.7	0.03	0.71	5.4
507	9.5	2.0	6.22	52.4	16	36.0	34.2	26.1	2.6	4.2	29.2	0.03	0.71	4.2
508	9.6	1.6	6.64	75.1	17	49.5	35.8	26.1	3.9	2.3	35.4	0.03	0.71	3.5
509	12.0	2.0	6.29	19.4	10	24.0	23.3	21.7	2.6	3.7	27.1	0.03	0.71	5.1
510	10.8	1.9	6.56	53.0	13	35.0	28.3	21.7	3.6	3.7	31.3	0.03	0.71	4.4
511	10.1	3.2	6.13	84.9	14	70.0	35.8	21.7	5.1	2.8	27.1	0.03	0.71	4.2
512	10.6	1.8	6.37	40.7	7	38.5	23.3	13.0	4.6	1.4	33.3	0.03	0.71	2.9
513	10.1	2.2	6.82	84.4	22	70.0	40.0	26.1	3.6	5.6	31.3	0.06	0.71	4.8
514	10.0	1.9	6.88	98.0	15	75.0	42.5	13.0	3.6	2.8	29.2	0.03	0.71	2.4
515	10.6	1.7	6.66	93.5	17	70.0	46.7	17.4	3.6	5.6	27.1	0.03	0.71	4.5
516	11.5	2.0	6.39	61.4	18	60.0	27.5	17.4	3.6	9.9	33.3	0.03	0.71	7.3
517	11.3	1.4	6.80	83.8	14	70.0	37.5	17.4	3.6	9.9	29.2	0.03	0.71	4.5
518	9.8	1.3	6.90	105.6	12	85.0	44.2	13.0	9.7	8.5	33.3	0.03	0.71	2.5
519	9.8	1.2	7.84	831.0	52	480.0	416.7	21.7	14.9	2.8	58.3	0.03	0.71	4.8
520	10.3	2.3	6.66	61.5	11	43.0	27.5	13.0	3.6	2.8	20.8	0.03	0.71	3.5
521	9.8	2.0	5.94	12.4	6	19.5	13.3	8.7	1.8	2.8	27.1	0.03	0.71	2.8
522	10.4	1.8	6.72	82.5	15	60.0	35.0	17.4	4.4	4.2	25.0	0.03	0.71	3.8
523	11.4	1.9	6.37	45.4	19	46.5	19.2	17.4	2.8	5.1	33.3	0.03	0.71	5.1
524	10.0	1.8	6.52	53.8	16	60.0	24.2	17.4	3.6	5.6	35.4	0.03	0.71	5.4
525	10.5	1.7	6.58	101.2	18	90.0	28.3	26.1	4.4	5.1	39.6	0.03	0.71	4.5
526	12.4	1.3	7.58	440.2	29	315.0	166.7	26.1	8.5	5.1	54.2	0.03	0.71	3.6
527	10.7	1.5	7.04	169.3	14	110.0	69.2	13.0	4.4	5.1	29.2	0.03	0.71	2.4
528	9.9	1.7	7.15	287.8	24	195.0	125.0	26.1	4.4	5.6	35.4	0.03	0.71	4.1
529	9.8	1.5	7.18	221.3	23	130.0	125.0	34.8	4.4	7.0	47.9	0.03	0.71	4.6

ALK = ALKALINITY TDS = TOTAL DISSOLVED SOLIDS CL = CHLORIDE NA = SODIUM
CA = CALCIUM DOC = DISSOLVED ORGANIC CARBON MG = MAGNESIUM K = POTASSIUM

Table 4. Statistical summary of lake morphometric characteristics and physical/chemical properties of lake water for the 130 Labrador study lakes.

Parameter	n	Minimum	Maximum	Mean	Standard error
Morphometric characteristics					
Lake area (ha)	130	5.0	1217.5	165.0	189.2
Watershed area (ha)	130	22.5	8891.5	1517.5	1666.0
Watershed area to lake area ratio	130	2.7	80.5	12.9	13.9
Elevation (m)	130	101.0	689.3	447.6	111.1
Distance from the coast (km)	130	24.0	487.0	171.0	116.4
Maximum depth (m)	95	1.0	70.0	11.4	12.3
Physical Properties					
Secchi disc depth (m)	95	0.5	16.5	3.6	2.6
Colour (TCU)	130	5.0	175.0	33.5	28.5
Turbidity (JTU)	130	0.3	5.5	0.8	0.6
Hardness (μeq L^{-1})	130	29.8	892.0	90.7	90.0
Conductivity (μScm^{-1})	130	5.7	80.7	12.7	8.3
Total dissolved solids (mg L^{-})	130	4.0	52.0	17.7	8.6
Water Chemistry					
pH	130	4.80	7.84	6.40	0.42
Alkalinity (μeq L^{-1})	130	-17.4	831.0	72.3	87.6
Calcium (μeq L^{-1})	130	19.5	480.	60.6	54.3
Magnesium (μeq L^{-1})	130	7.5	416.2	32.2	40.0
Sodium (μeq L^{-1})	130	4.4	69.6	22.1	10.2
Potassium (μeq L^{-1})	130	0.5	14.9	3.2	2.1
Bicarbonate (μeq L^{-1})	130	10.0	831.0	72.6	87.4
Chloride (μeq L^{-1})	130	1.4	45.1	9.4	8.0
Sulphate (μeq L^{-1})	130	4.2	91.7	28.1	12.5
Orthophosphate (μeq L^{-1})	130	0.030	0.190	0.032	0.015
Nitrate (μeq L^{-1})	130	0.710	52.860	1.287	4.627
Anion sum (μeq L^{-1})	130	35.5	861.2	108.2	89.7
Cation sum (μeq L^{-1})	130	39.8	933.3	118.0	96.0
Excess calcium (μeq L^{-1})	130	19.3	479.9	60.2	54.3
Excess magnesium (μeq L^{-1})	130	3.7	416.1	30.3	40.1
Excess sodium (μeq L^{-1})	130	2.2	35.5	14.3	7.3
Excess potassium (μeq L^{-1})	130	0.5	14.8	3.0	2.1
Excess sulphate (μeq L^{-1})	130	3.7	90.2	27.2	12.3
Dissolved organic carbon (mg L^{-})	130	0.8	14.0	4.8	2.3
Aluminum (μg L^{-1})	130	1.0	39.4	7.1	4.9

Table 5. Factor analysis of 22 physical, chemical, and morphometric variables. Correlation coefficients are between the six derived factors and the original 22 variables. Non-significant coefficients (i.e. P < 0.250) have been replaced by 0 (after Earle et al. 1986).

	FACTOR						
	1	2	3	4	5	6	7
VARIABLE	Hardness	Dystrophy	Lake Size	Salinity	Oligotrophy	Seasonality	Nitrate
Alkalinity	.961	0	0	0	0	0	0
Calcium	.972	0	0	0	0	0	0
Magnesium	.954	0	0	0	0	0	0
Potassium	.724	0	0	0	0	0	0
pH	.628	-.419	0	0	0	0	-.477
Colour	0	.902	0	0	0	0	0
DOC	0	.880	0	0	-.384	0	0
TDS	.407	.753	0	0	0	0	0
Turbidity	0	.703	0	0	0	0	0
Sulphate	.471	.633	0	0	0	0	0
LSA	0	0	.832	0	0	0	0
DA	0	0	.816	.307	0	0	0
Sodium	0	0	0	.855	0	0	.283
Chloride	0	.374	0	.645	0	0	0
Secchi Depth	0	-.464	0	0	.742	0	0
Max Depth	0	-.247	0	0	.708	0	0
Water Temp.	0	0	0	0	0	.726	0
CO2	0	.396	0	0	0	-.410	0
DO	0	0	0	.286	0	-.583	0
Nitrate	0	0	0	0	0	0	.743
SLD	0	0	0	0	0	0	0
Orthophosphate	0	0	0	0	0	0	0
% Variance Explained	27.0	25.1	10.3	9.8	9.5	8.3	5.9

DOC = Dissolved Organic Carbon DO = Dissolved Oxygen TDS = Total Dissolved Solids
LSA = Lake Surface Area DA = Drainage Area SLD = Shoreline Development

Table 6. Biomass and number of taxa by algal class for the 95 Labrador lakes.

		NO. TAXA							BIOMASS (%)						
LAKE	pH	CY	CHL	CH	DI	CR	PY	TOT	CY	CHL	CH	DI	CR	PY	TOT
301	6.46	6	14	30	6	2	5	63	4	23	52	4	1	16	160
302	6.52	2	15	28	7	5	3	57	1	10	60	18	5	7	144
354	6.29	9	10	30	8	4	2	63	6	17	49	21	4	4	100
355	6.20	5	14	25	8	1	3	56	21	19	32	21	1	6	83
357	6.54	7	11	18	9	2	2	49	11	8	49	18	3	10	398
358	6.66	7	12	26	10	4	6	60	8	7	14	33	5	32	182
359	6.22	2	4	18	5	.	.	29	.	3	90	7	.	.	88
360	6.86	9	16	30	13	2	4	73	7	12	32	35	3	10	211
361	6.56	5	11	19	6	1	.	42	9	20	63	6	2	.	59
362	6.87	7	13	23	7	1	.	51	10	8	38	38	4	.	235
363	7.16	9	10	24	6	4	1	54	15	15	29	21	17	2	135
364	6.71	6	14	22	11	5	1	59	2	4	36	48	8	1	252
365	6.80	13	15	27	10	6	1	68	10	11	24	50	5	1	282
366	6.86	6	15	29	14	11	3	68	3	22	31	21	18	5	219
367	6.84	6	19	23	6	5	1	60	5	17	9	63	6	.	895
368	6.02	5	9	17	1	1	0	33	26	8	64	1	2	.	144
369	5.66	4	9	19	16	5	1	53	77	1	6	11	4	1	1132
370	5.74	5	12	19	5	3	2	46	5	57	20	11	1	5	284
371	5.66	3	4	19	18	.	.	44	1	22	10	67	.	.	1309
372	6.22	1	12	25	12	4	2	56	.	5	78	4	10	2	72
373	6.68	9	13	28	8	3	1	52	3	9	18	64	5	.	410
374	6.42	8	22	29	13	3	3	78	5	21	30	37	4	2	398
375	6.02	4	10	33	5	6	4	62	6	18	43	13	11	6	123
376	6.52	10	19	23	12	8	1	73	7	28	38	16	9	1	235
377	6.40	10	11	23	10	3	1	58	27	10	22	20	20	.	120
378	5.74	4	8	32	13	3	6	66	1	11	37	11	4	34	258
401	4.80	6	16	28	12	5	1	68	2	11	27	49	8	1	169
402	6.30	3	13	34	10	3	5	68	2	36	21	32	1	7	402
403	5.25	2	11	19	15	3	1	61	1	36	9	53	1	.	1762
404	6.44	5	19	30	16	2	2	74	49	11	10	26	2	2	332
406	6.64	1	6	17	11	5	3	43	.	4	54	12	22	7	62
407	5.92	1	13	25	8	3	3	53	.	27	31	14	10	18	89
408	6.52	5	11	24	9	5	1	55	5	8	43	8	30	6	71
409	6.50	6	13	29	8	2	2	60	4	17	35	24	3	13	88
410	6.71	7	17	21	14	5	2	66	6	20	25	38	7	4	157
451	6.48	5	12	31	10	3	1	62	15	8	50	22	2	3	84
453	6.22	3	12	17	9	5	2	48	5	3	9	77	3	3	350
455	6.28	3	15	18	3	4	1	46	28	13	24	19	10	1	180
456	6.48	5	20	23	17	6	1	72	1	24	18	51	6	1	597
457	6.56	5	12	16	10	6	.	49	8	10	17	19	40	.	268
458	5.84	4	10	29	5	4	.	52	17	6	63	8	7	.	181
459	6.42	4	10	32	23	5	4	78	3	11	25	52	2	7	464
462	6.60	8	17	33	12	3	1	74	1	5	5	84	4	1	462
463	5.81	3	9	24	9	5	.	50	1	2	93	3	1	.	1190
464	6.16	3	10	35	4	6	1	59	4	15	50	2	26	2	202
465	6.34	3	10	22	26	7	1	69	.	3	84	4	6	2	487
466	6.52	1	11	18	8	8	2	48	.	61	14	10	11	2	189
467	6.30	5	13	24	2	6	.	50	5	8	59	2	27	.	191
468	6.52	7	14	28	9	4	.	62	2	3	67	25	2	.	619
469	6.00	4	6	22	7	6	1	46	2	13	49	18	17	.	319
472	6.44	9	10	28	12	3	1	63	5	9	28	53	2	2	265

Table 6 (Cont'd.)

		NO. TAXA							BIOMASS (%)						
LAKE	pH	CY	CHL	CH	DI	CR	PY	TOT	CY	CHL	CH	DI	CR	PY	TOT
473	5.88	6	39	33	18	8	2	106	1	80	6	5	5	3	597
474	5.66	4	15	32	16	3	3	73	4	5	16	62	1	11	400
475	6.05	6	15	19	6	5	1	52	14	34	18	22	7	2	212
476	6.16	4	13	29	15	3	1	65	16	12	47	20	2	2	273
477	7.00	4	20	29	23	3	1	80	6	19	47	25	2	2	132
478	6.16	2	11	37	10	3	1	64	6	7	46	38	3	5	147
479	6.22	3	6	22	8	4	.	44	1	8	39	48	3	.	469
480	6.41	5	14	28	11	7	1	66	3	16	20	45	13	2	151
481	5.78	3	16	30	20	5	2	76	28	12	23	32	3	1	396
482	5.64	3	9	19	7	6	2	46	8	25	31	18	3	8	60
484	6.62	6	12	38	20	5	.	81	5	3	23	65	4	.	459
485	6.24	3	18	26	7	4	.	58	2	12	61	7	10	9	97
486	5.48	1	9	22	11	9	2	54	.	2	49	33	13	1	199
487	6.57	5	15	17	8	8	1	54	1	4	4	83	8	.	423
488	6.46	5	17	24	12	3	1	62	.	9	3	86	1	.	532
501	6.82	4	15	25	6	7	1	58	5	17	2	32	11	3	164
502	6.44	8	14	27	13	4	1	67	13	11	47	18	5	6	140
503	6.52	6	17	27	9	8	.	67	3	13	48	10	21	5	124
504	6.72	7	13	24	10	4	2	60	9	6	18	63	1	2	900
505	6.84	8	15	27	12	2	1	65	6	26	40	24	1	3	141
506	6.98	5	15	26	9	9	2	66	3	10	49	16	15	6	444
507	6.22	5	9	39	14	7	1	75	2	8	48	27	6	8	110
508	6.64	11	18	33	14	5	.	81	17	21	28	31	2	1	153
509	6.29	6	15	26	1	4	.	52	3	23	61	5	6	1	186
510	6.56	6	14	33	14	6	1	74	4	9	32	41	10	2	180
511	6.13	7	12	18	12	6	1	56	4	9	9	71	4	1	529
512	6.37	6	19	19	7	6	1	58	5	48	13	14	9	4	142
513	6.82	8	11	12	6	6	1	44	4	12	13	63	7	1	124
514	6.88	3	8	32	4	5	.	52	2	16	25	31	26	.	425
515	6.66	8	12	31	12	3	.	66	3	20	26	48	3	1	476
516	6.39	3	15	33	20	6	2	79	2	18	39	26	4	10	120
517	6.80	8	16	49	20	6	.	99	1	32	7	56	3	.	865
518	6.90	6	14	20	9	7	2	58	9	15	28	27	12	8	158
519	7.84	7	20	23	13	5	1	69	3	30	10	45	11	1	600
520	6.66	5	17	28	9	5	2	66	4	26	44	17	3	5	327
521	5.94	4	14	26	10	5	1	60	2	20	9	63	4	1	200
522	6.72	11	13	42	14	2	.	82	3	7	19	70	.	.	565
523	6.37	3	11	32	7	5	.	58	1	59	16	22	3	.	576
524	6.52	6	14	24	13	8	2	67	8	42	13	18	15	3	233
525	6.58	5	15	30	14	6	.	70	2	11	34	34	18	.	164
526	7.58	1	8	24	17	5	1	56	.	19	17	52	7	5	283
527	7.04	2	6	13	6	5	.	32	.	.	6	91	2	.	495
528	7.15	6	14	37	10	5	2	74	5	4	18	68	3	2	1024
529	7.18	4	7	27	17	5	2	62	2	4	43	45	3	3	447

CY = CYANOPHYCEAE CHL = CHLOROPHYCEAE CH = CHRYSOPHYCEAE TOT = TOTAL
CR = CRYPTOPHYCEAE PY = PYRROPHYCEAE DI = DIATOMACEAE TOTAL BIOMASS IN MG.M-3

Table 7. Cluster group means of the four morphometric variables; lake surface area, maximum depth, shoreline development and drainage area. F-ratios and associated probabilities are from a one-way analysis of variance (unequal sizes) comparing means.

	Cluster Group							ANOVA	
Variable	1	2	3	4	5	6	7	F-ratio	P < F
Surface Area (ha)	129.9	53.8	195.5	318.1	10.0	165.14	1136.5	69.7	< .001
Maximum Depth (m)	13.5	4.6	49.5	9.1	3.5	7.0	14.5	47.6	< .001
Shoreline Development	2.2	1.4	1.9	3.5	7.3	1.7	2.6	57.4	< .001
Drainage Area (ha)	1228	429	1190	2374	116	5459	8515	74.6	< .001
Number of Lakes (n)	36	38	6	7	2	4	2		

Table 8. Mean number of taxa and mean proportional biomass (%) of phytoplankton (both total and by algal class) for the study lakes grouped by pH class.

pH interval	No. of lakes	CY		CHL		CH		DI		CR		PY		Totals	
		No. species	Biom. (%)	No. species	Biom. (%)	No. species	Biom. (%)	No. species	Biom. (%)	No. species	Biom. (%)	No. species	Biom. (%)	No. species	Biom.
4.51-5.00	1	6.0	2.0	16.0	11.0	28.0	27.0	12.0	49.0	5.0	8.0	1.0	1	68.0	169.0
5.01-5.50	2	1.5	0.5	10.0	19.0	20.5	29.0	13.0	43.0	6.0	7.0	1.5	0.5	52.5	980.5
5.51-6.00	13	3.7	11.6	12.6	27.1	25.3	29.6	11.7	25.4	4.3	4.7	1.7	6.5	59.3	493.5
6.01-6.50	35	4.8	8.3	12.9	15.9	26.3	38.3	10.0	27.5	4.1	6.3	1.5	3.7	60.1	246.1
6.51-7.00	38	6.6	5.3	18.1	15.4	26.3	30.3	10.8	36.3	5.1	9.3	1.3	3.4	64.7	310.7
7.01-7.50	4	5.3	5.5	9.3	5.8	25.3	24.0	9.8	56.3	4.8	6.3	1.3	2.0	55.8	523.3
7.51-8.00	2	4.0	1.5	14.0	24.5	23.5	13.5	15.0	48.5	5.0	9.0	1.0	3.0	62.5	441.5

CY = Cyanophyceae
CHL = Chlorophyceae
CH = Chrysophyceae
DI = Diatomaceae
CR = Cryptophyceae
PY = Pyrrophyceae

Table 9. Spearman correlation coefficients and associated probabilities between seven derived factors and the abundance of selected species. Non-significant correlations ($r < 0.18$; $P > 0.10$) have been omitted. Other critical values are $r = 0.20$ ($P \leq 0.05$) and $r = 0.25$ ($P < 0.01$). Species having no significant correlation with any of the six factors were eliminated from the table (after Earle et al. 1986).

	Factor					
Species	1 Hardness	2 Dystrophy	3 Lake Size	4 Salinity	5 Oligotrophy	6 Seasonality
Group 1						
Chroococcus limneticus var. *distans*			−0.21			
Cryptomonas pyrenoidifera		0.32	−0.27			
Frustulia rhomboides		0.18	−0.21			
Nitzschia palea		0.25	0.21			
Ochromonas species J			−0.30			
Scenedesmus quadricauda var. *parvus*		0.21			−0.29	
Group 2						
Ankistrodesmus falcatus var. *mirabilis*	−0.19				0.31	
Chrysolykos planctonicus				0.22		
Kephyrion obliquum	−0.23	−0.20			0.33	
Oocystis submarina var. *variabilis*		−0.18				
Group 3						
Aphanocapsa elachista var. *planctonica*	0.20	−0.25		0.18		0.24
Aphanocapsa elachista var. *conferta*		−0.23				0.17
Characium curvata		−0.20				0.20
Chroococcus limneticus		−0.20				
Cosmarium bioculatum					−0.30	−0.30
Gomphosphaeria lacustris	0.43	−0.24		0.25		
Oocystis pusilla				−0.33		
Quadrigula pfitzeri	0.25					
Rhodomonas minuta var. *nannoplanctica*	0.27					
Stichogloea doederleinii		−0.21				
Tabellaria fenestrata	0.25		0.31			
Group 4						
Anabaena flos-aquae			0.32			0.20
Chrysamoeba mikrokonta	0.18		0.27			
Chrysolykos skujai	0.27		0.21			
Gomphosphaeria lacustris var. *compacta*			0.18			
Merismopedia tenuissima				−0.24		
Monosiga varians	0.18		0.23			
Group 5						
Crucigenia rectangularis		−0.20				
Cryptaulax rhomboidea					0.18	
Cryptomonas erosa	0.33					
Dinobryon divergens	0.19	−0.20	0.21			
Elakatothrix gelatinosa		−0.19				
Planctonema lauterbornii	0.19					
Rhodomonas minuta	0.52		0.19	0.21		−0.28
Group 6						
Aphanocapsa delicatissima		−0.29				
Cryptomonas ovata		0.24				
Cyclotella comta	0.27	−0.28	0.26		0.26	
Cyclotella ocellata		−0.17			0.21	−0.20
Synedra acus var. *radians*			0.22	0.30		
Group 7						
Dinobryon bavaricum		−0.33				−0.29
Dinobryon borgei			0.18			
Gymnodinium varians	−0.22					
Salpingoeca frequentissima	0.18					
Selenastrum minutum		−0.33			0.22	
Group 8						
Chrysocapsa planctonica	0.18					
Chrysochromulina parva	0.17		0.23			
Cryptomonas marssonii				−0.18		
Cryptomonas phaseolus				−0.19		
Cryptomonas pusilla		0.19		−0.33		
Mallomonas akrokomos					−0.33	
Melosira distans		0.42	0.19			−0.26
Melosira islandica	0.18	0.35	0.18			
Oocystis borgei	0.19					

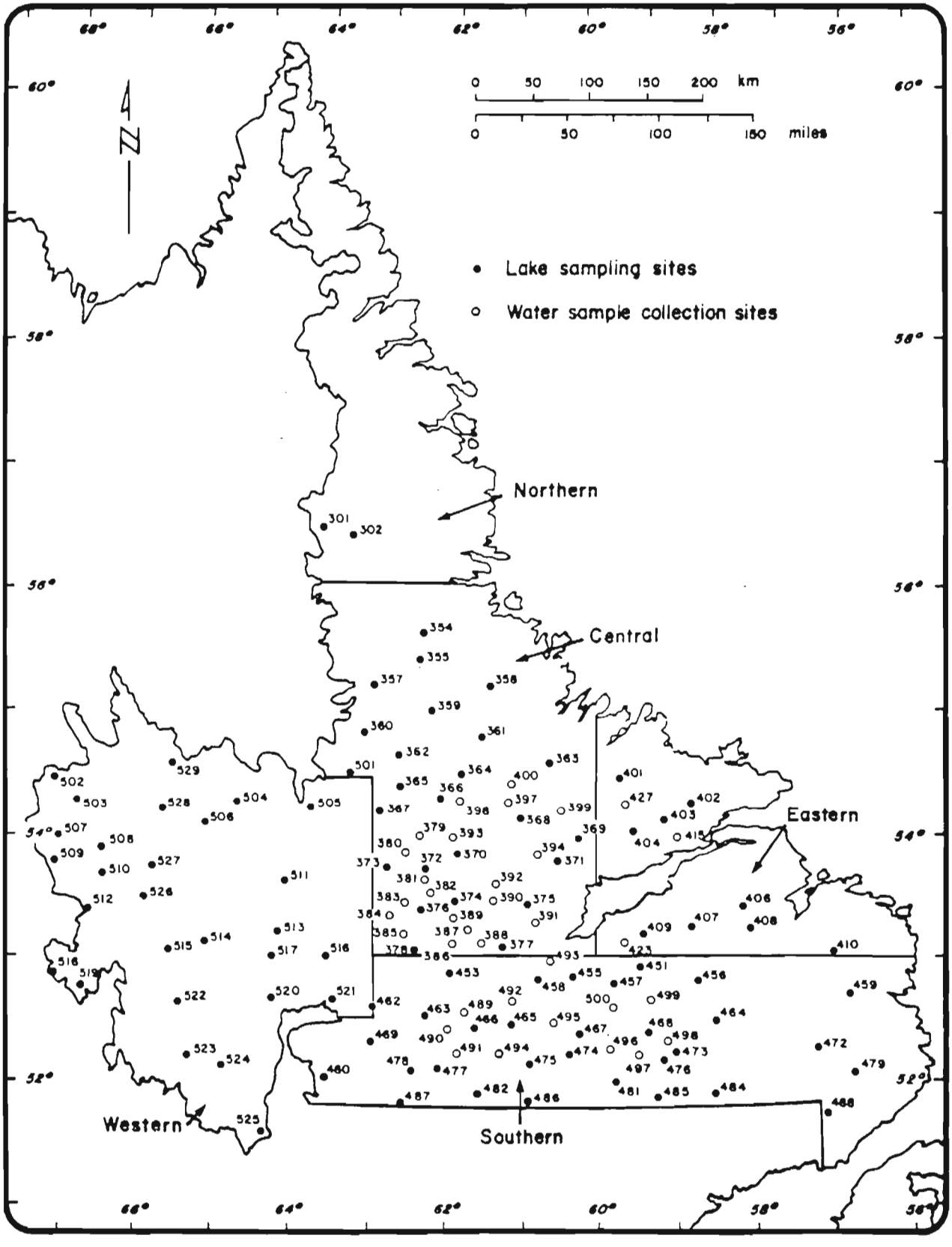


Fig. 1. Map of Labrador showing the locations of the study lakes in relation to the geographic regions (from Scruton 1984).

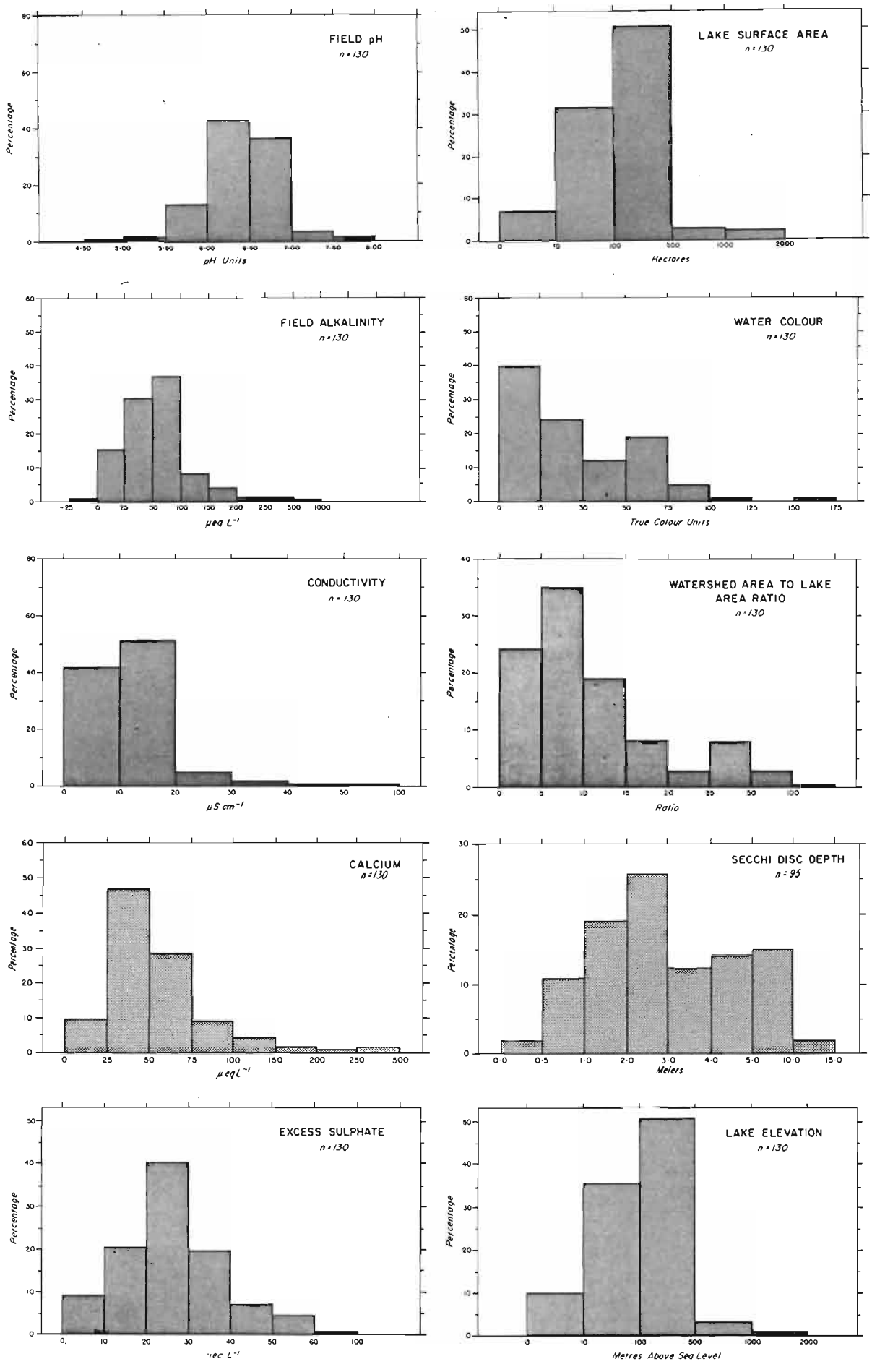


Fig. 2. Distribution of key morphometric, physical, and chemical parameters for the study lakes.

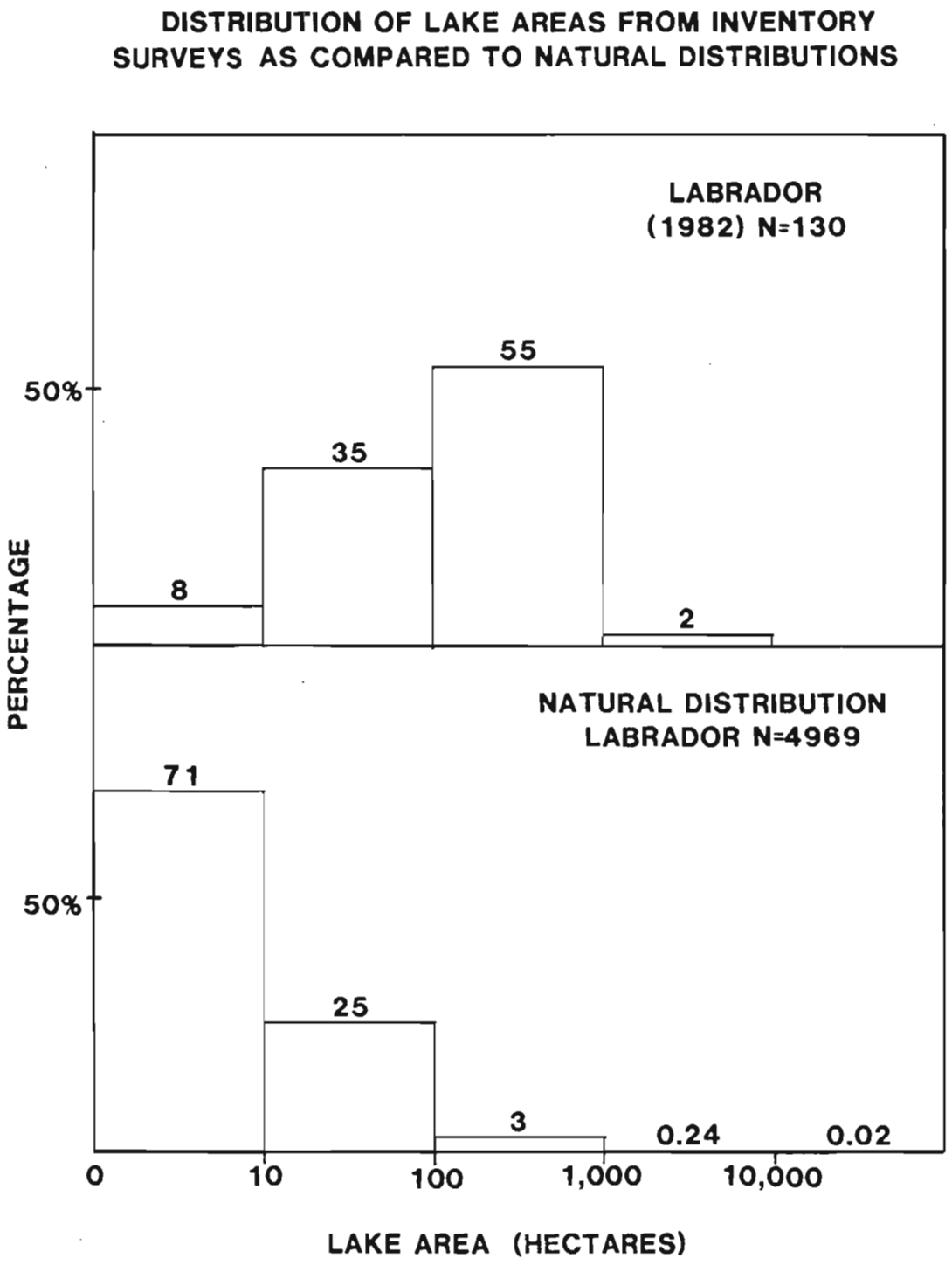


Fig. 3. Distribution of areal classes for lakes included in this survey versus natural lake distributions.

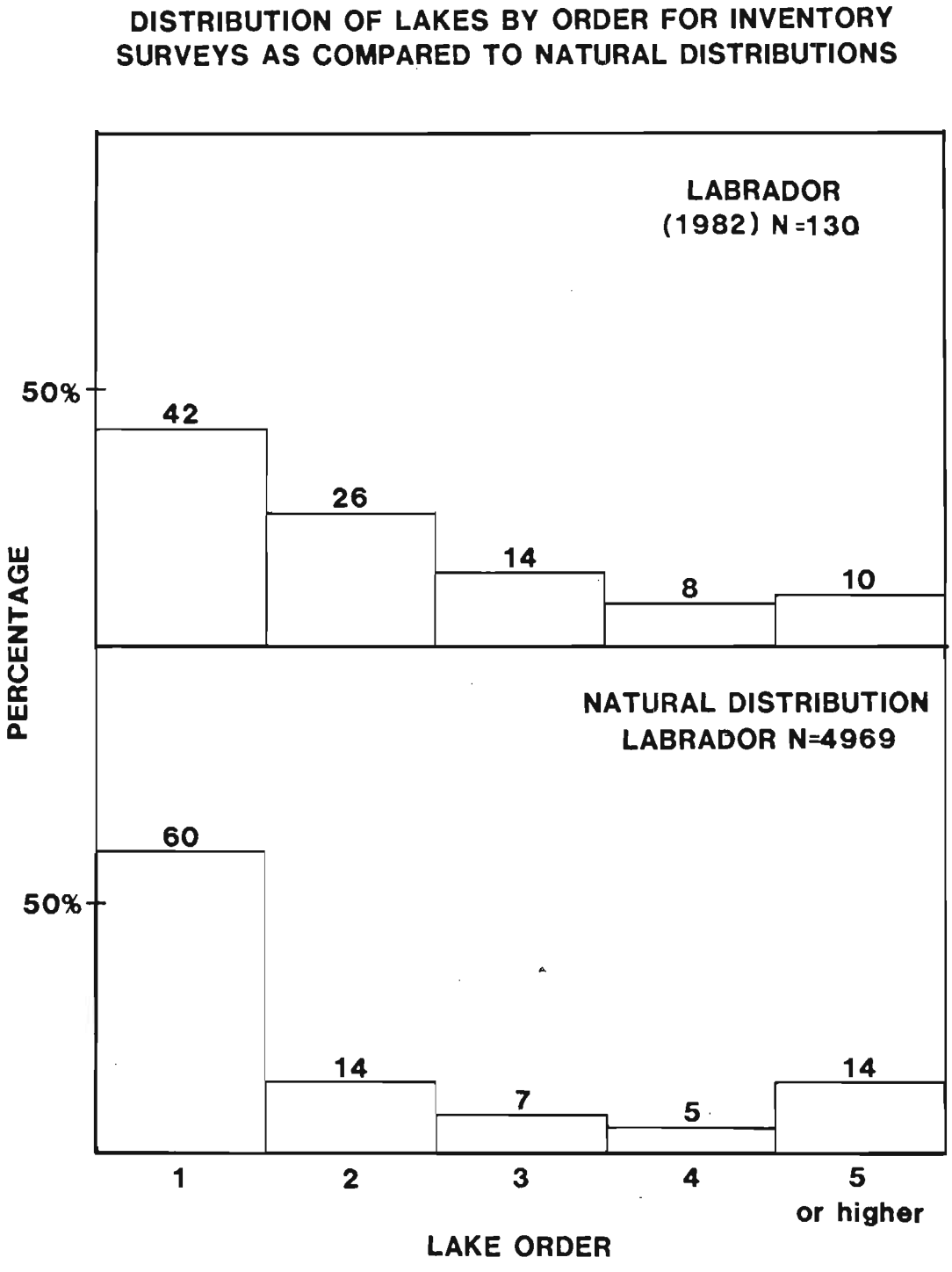


Fig. 4. Distribution of lake drainage orders for lakes included in this survey versus natural lake distributions.

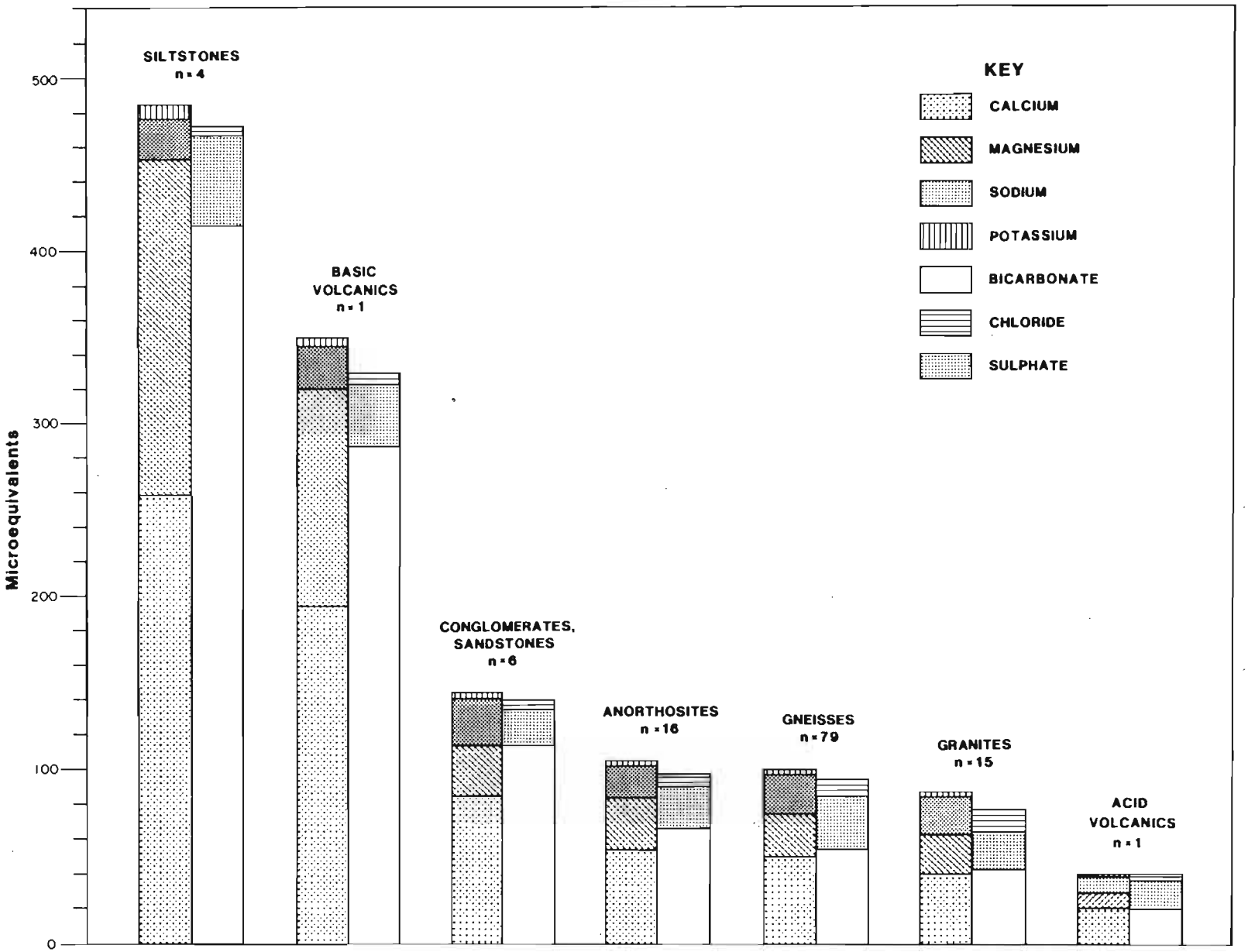


Fig. 5. Mean cationic and anionic profiles for the study lakes grouped by geological type.

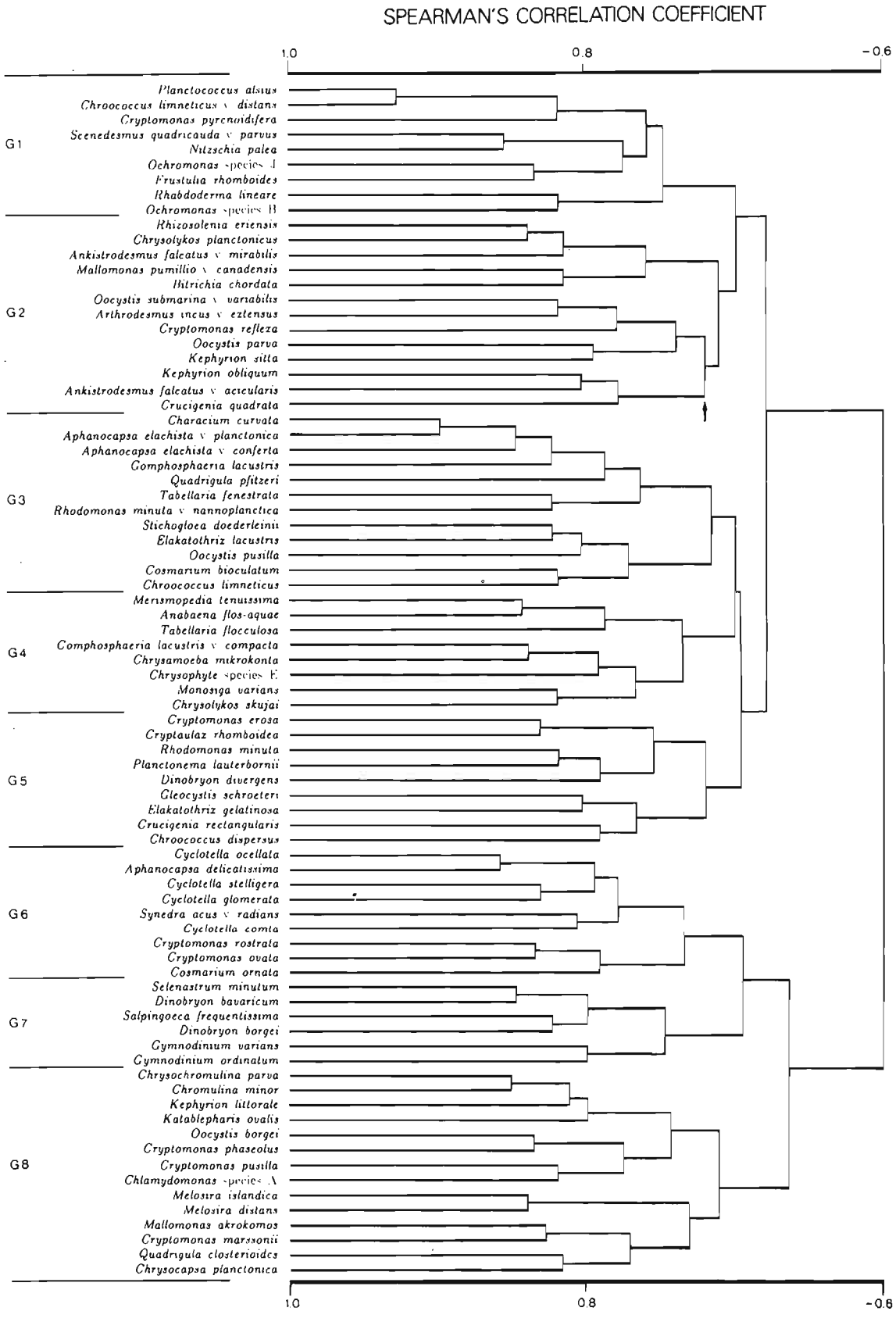


Fig. 6. Results of a complete-linkage cluster analysis of 80 selected phytoplankton taxa based on their abundances in 95 Labrador lakes. The arrow indicates the 8 cluster group level.

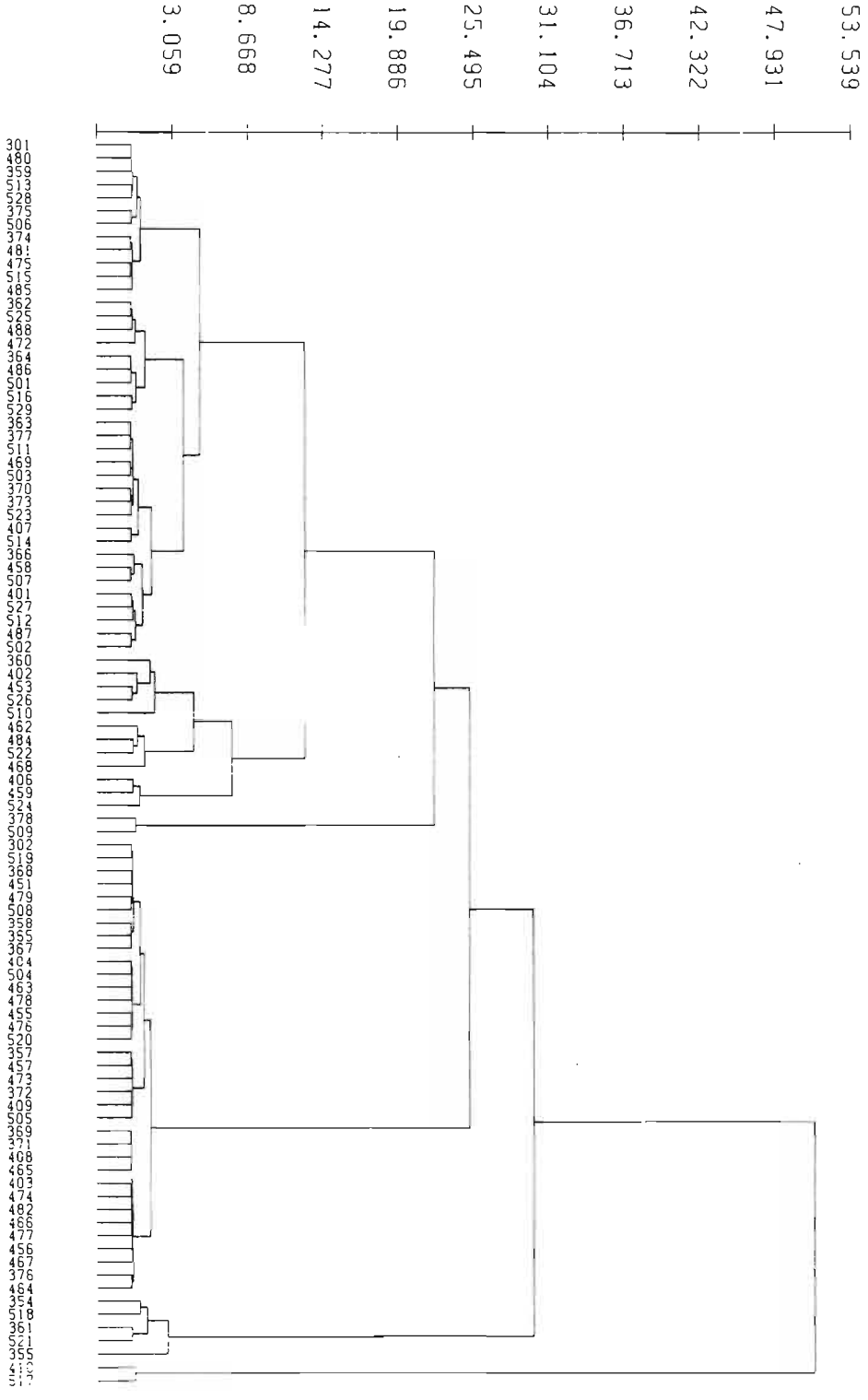


Fig. 7. Results of a Ward's cluster analysis of 95 Labrador lakes based on four morphometric variables.

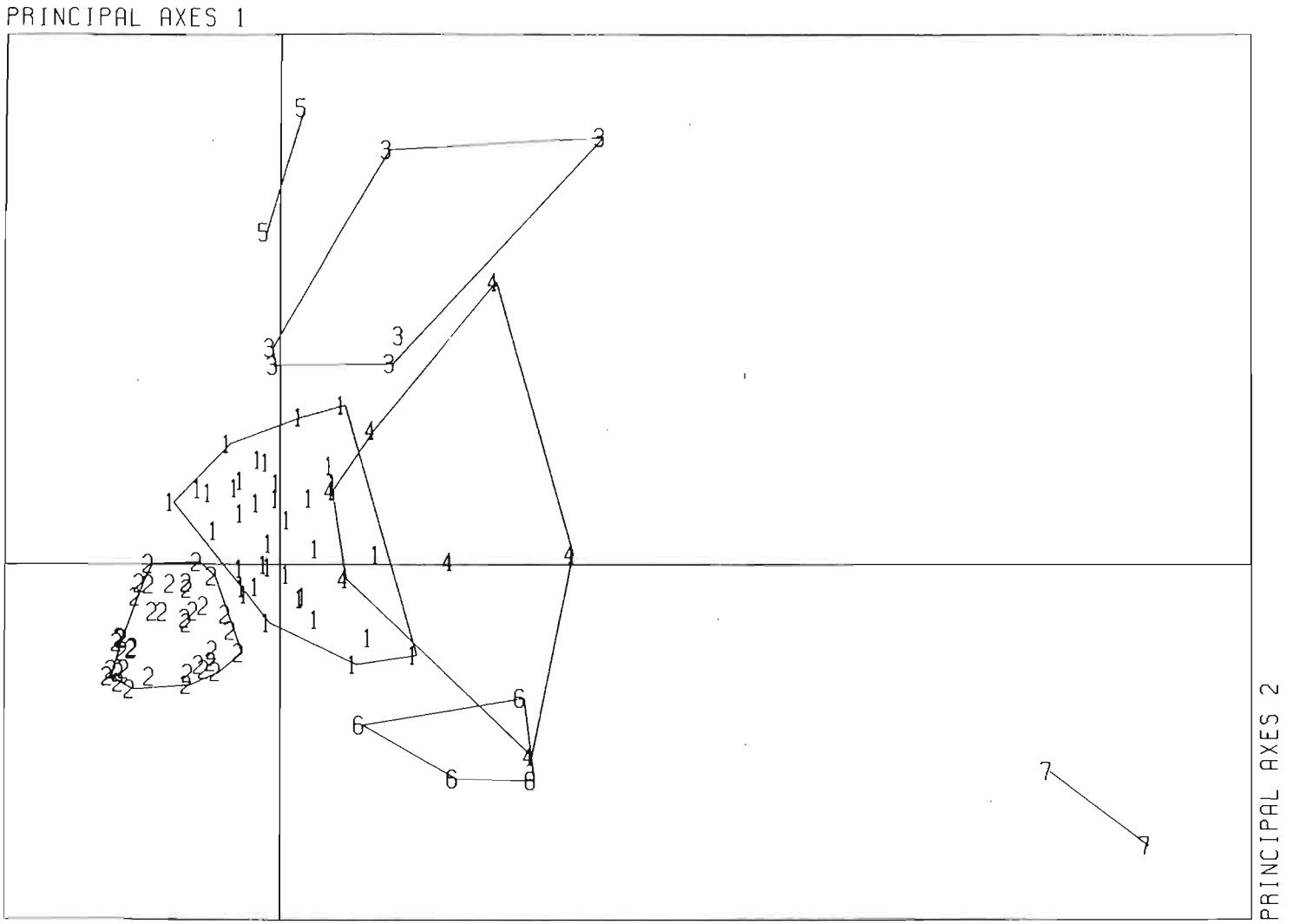


Fig. 8. Cluster diagram with the seven morphometric lake groups superimposed on the first two principal component axes.

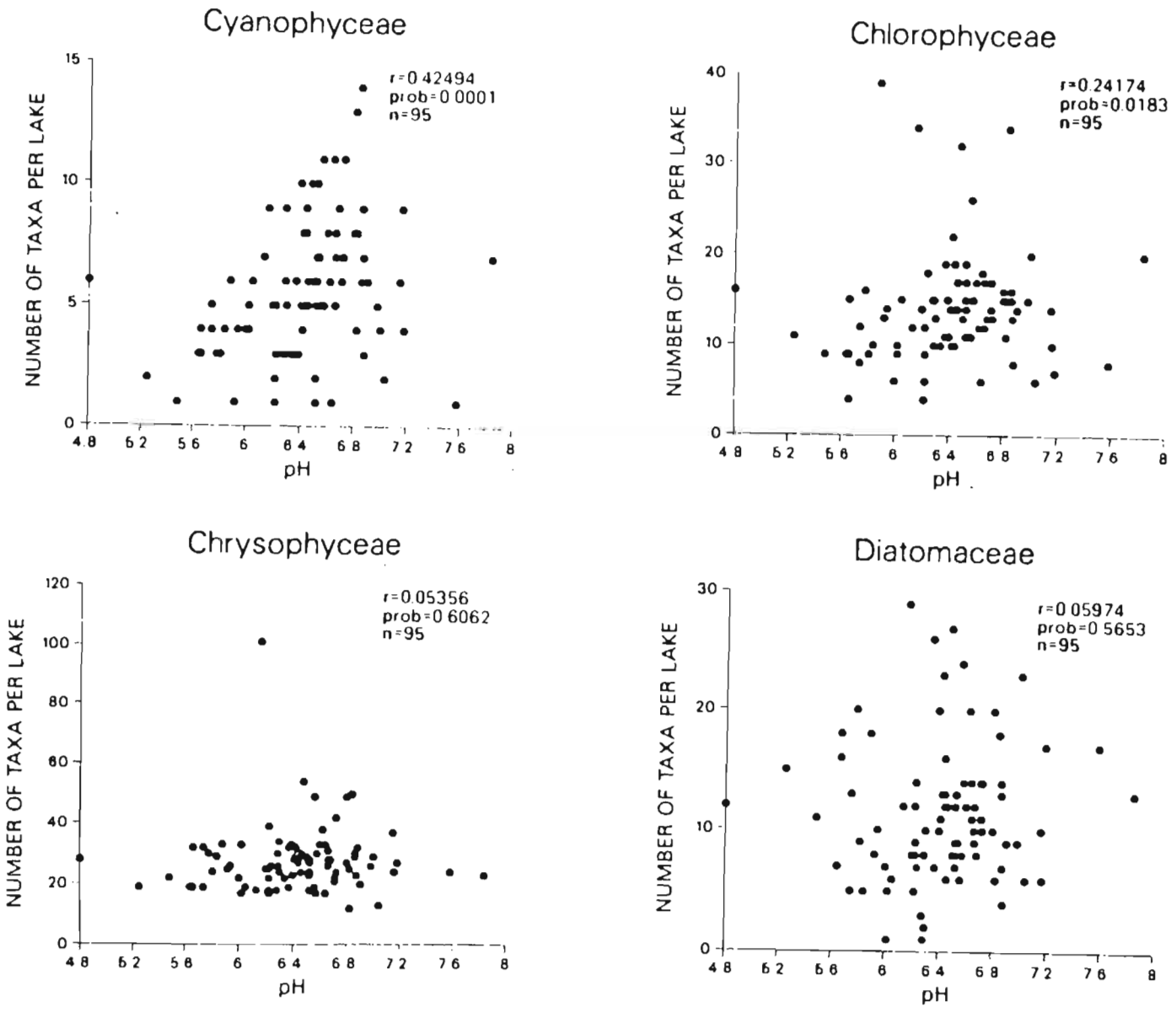


Fig. 9. Scatter-diagrams of lakewater pH plotted against the number of taxa per lake for the Cyanophyceae, Chlorophyceae, Chrysophyceae and Diatomaceae.

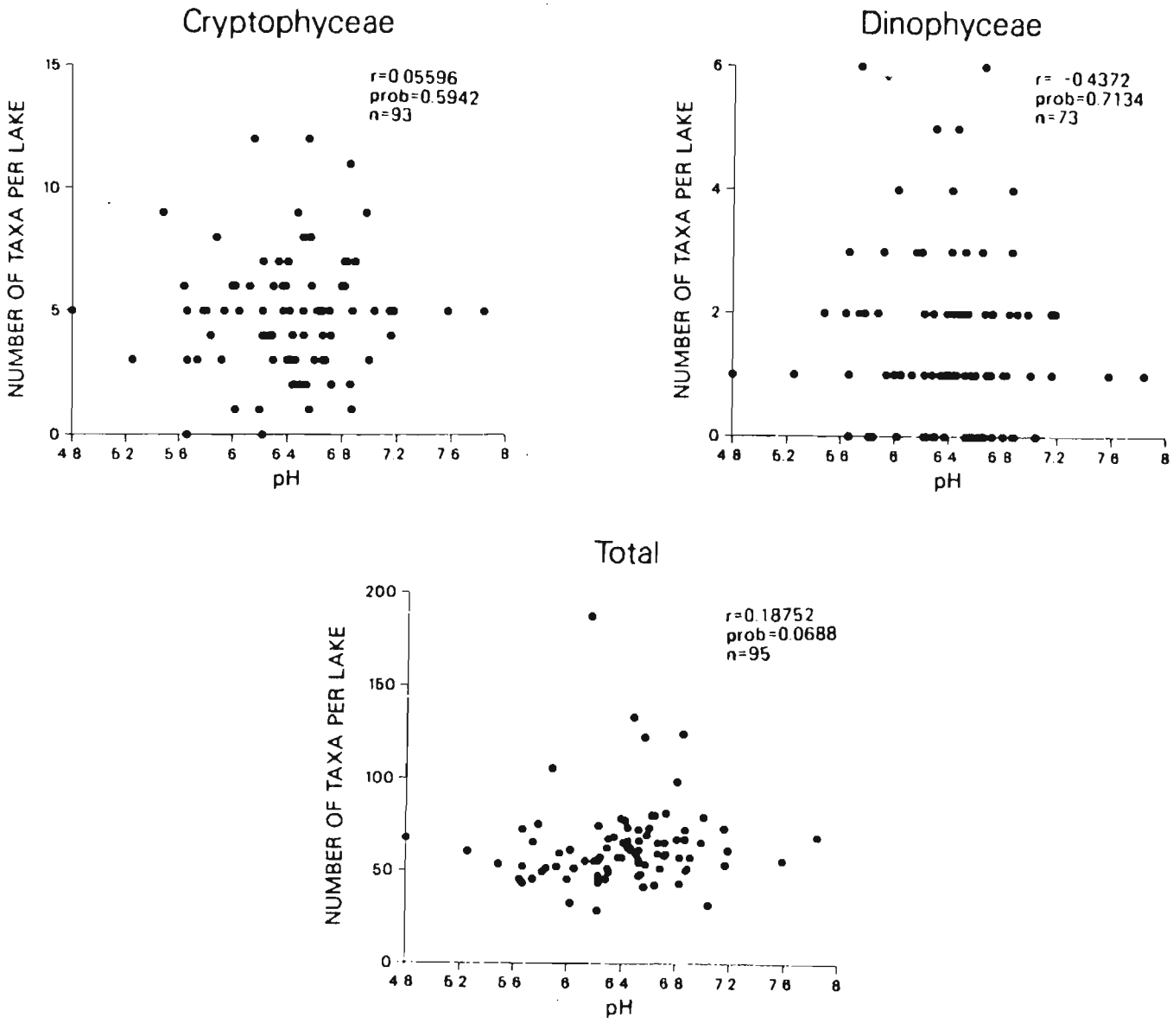


Fig. 10. Scatter-diagrams of lakewater pH plotted against the number of taxa per lake for the Cryptophyceae, Dinophyceae and total taxa.

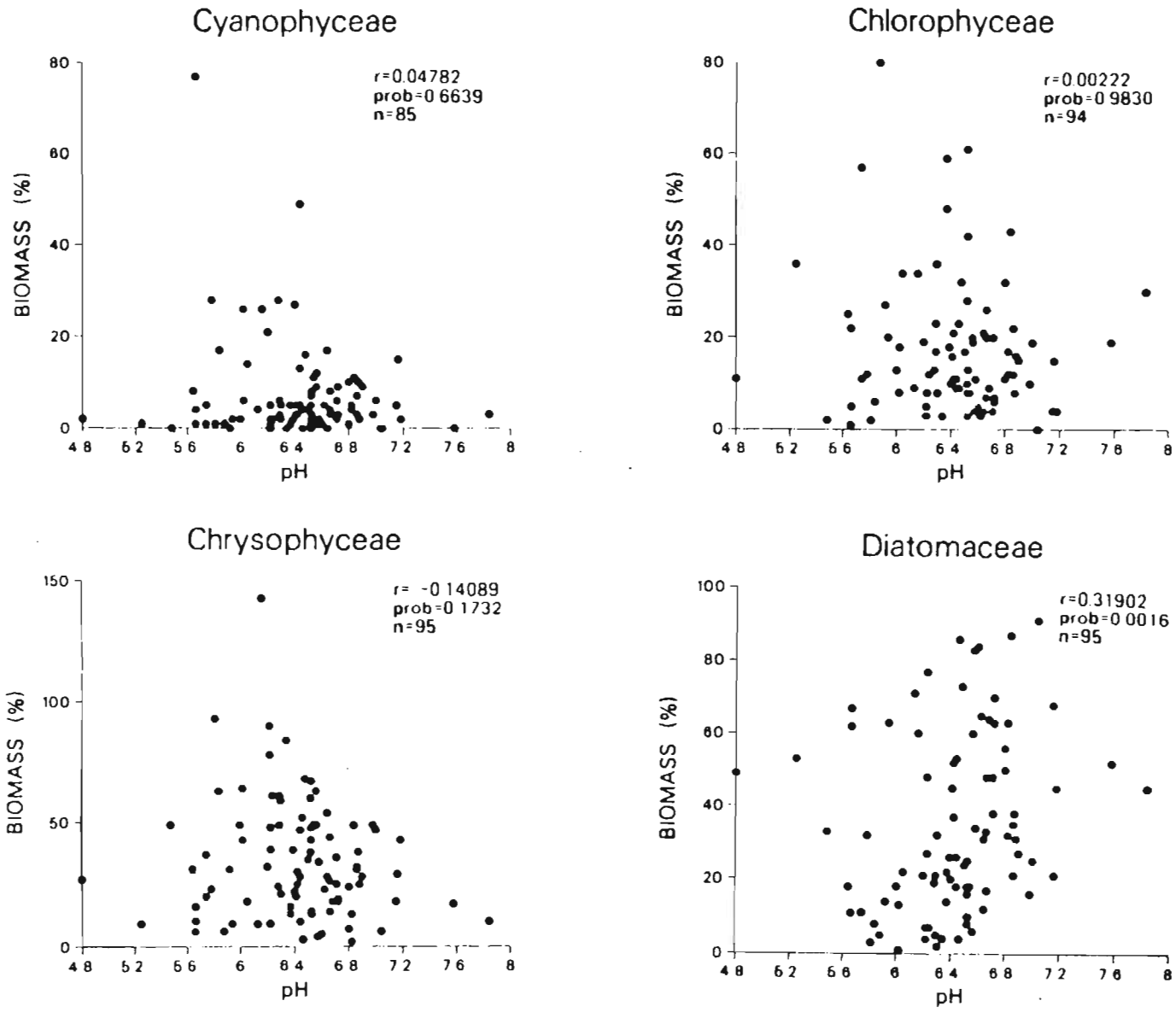


Fig. 11. Scatter-diagrams of lakewater pH plotted against percent algal biomass for the Cyanophyceae, Chlorophyceae, Chrysophyceae and Diatomaceae.

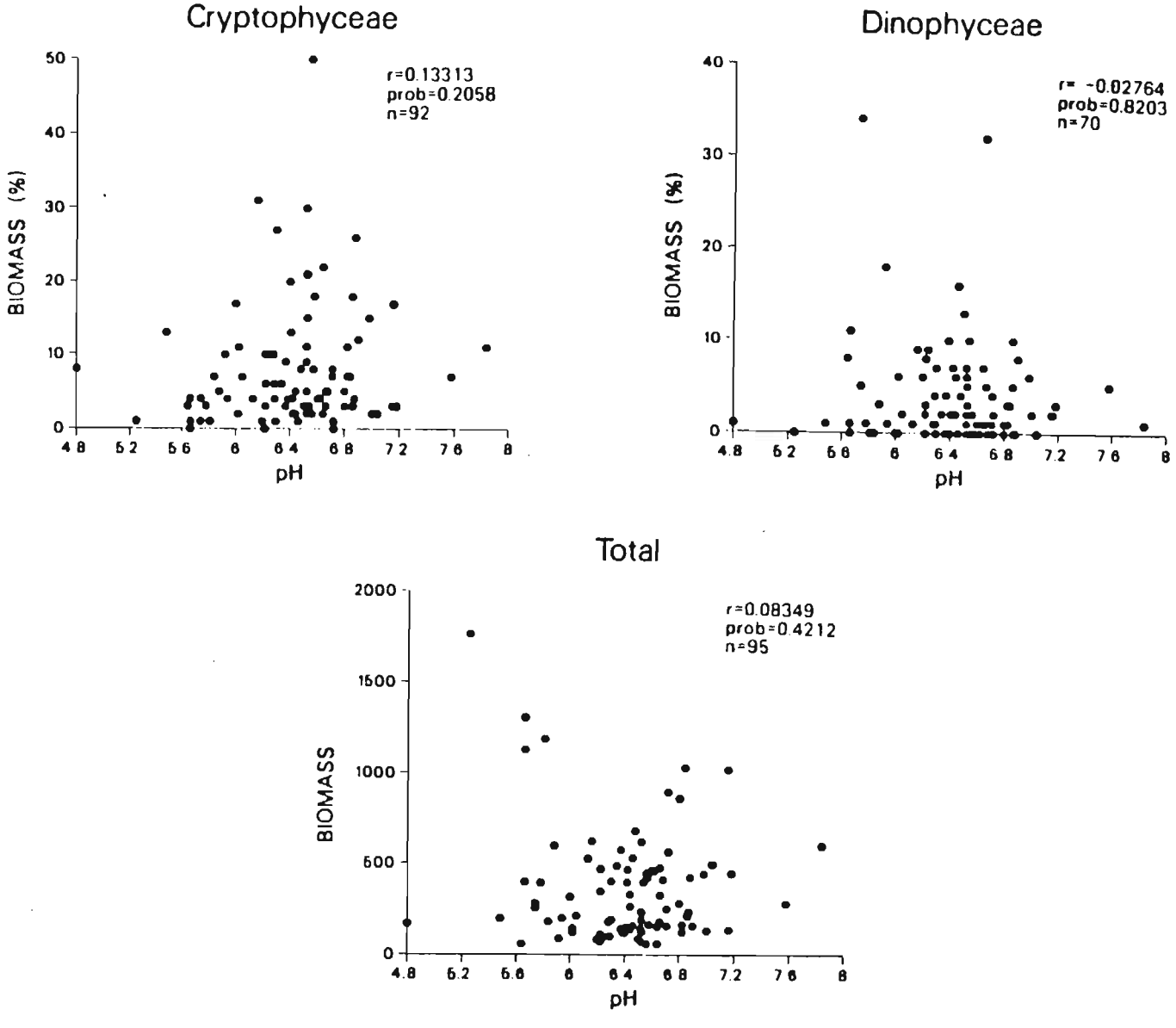


Fig. 12. Scatter-diagrams of lakewater pH plotted against the total algal biomass and percent biomass for the Cryptophyceae and Dinophyceae.

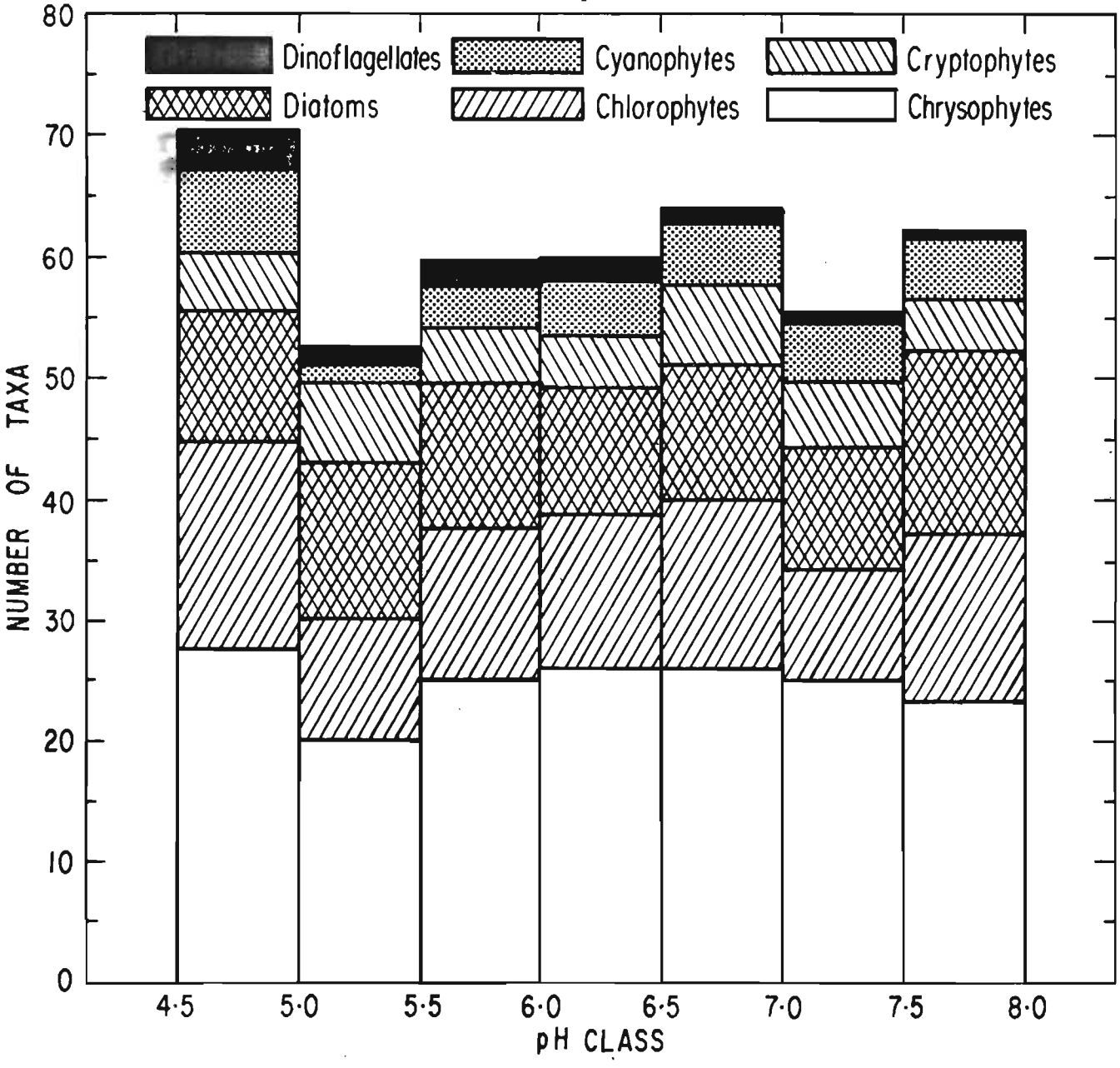


Fig. 13. Mean number of species (both total and by algal class) for the study lakes grouped by pH intervals.

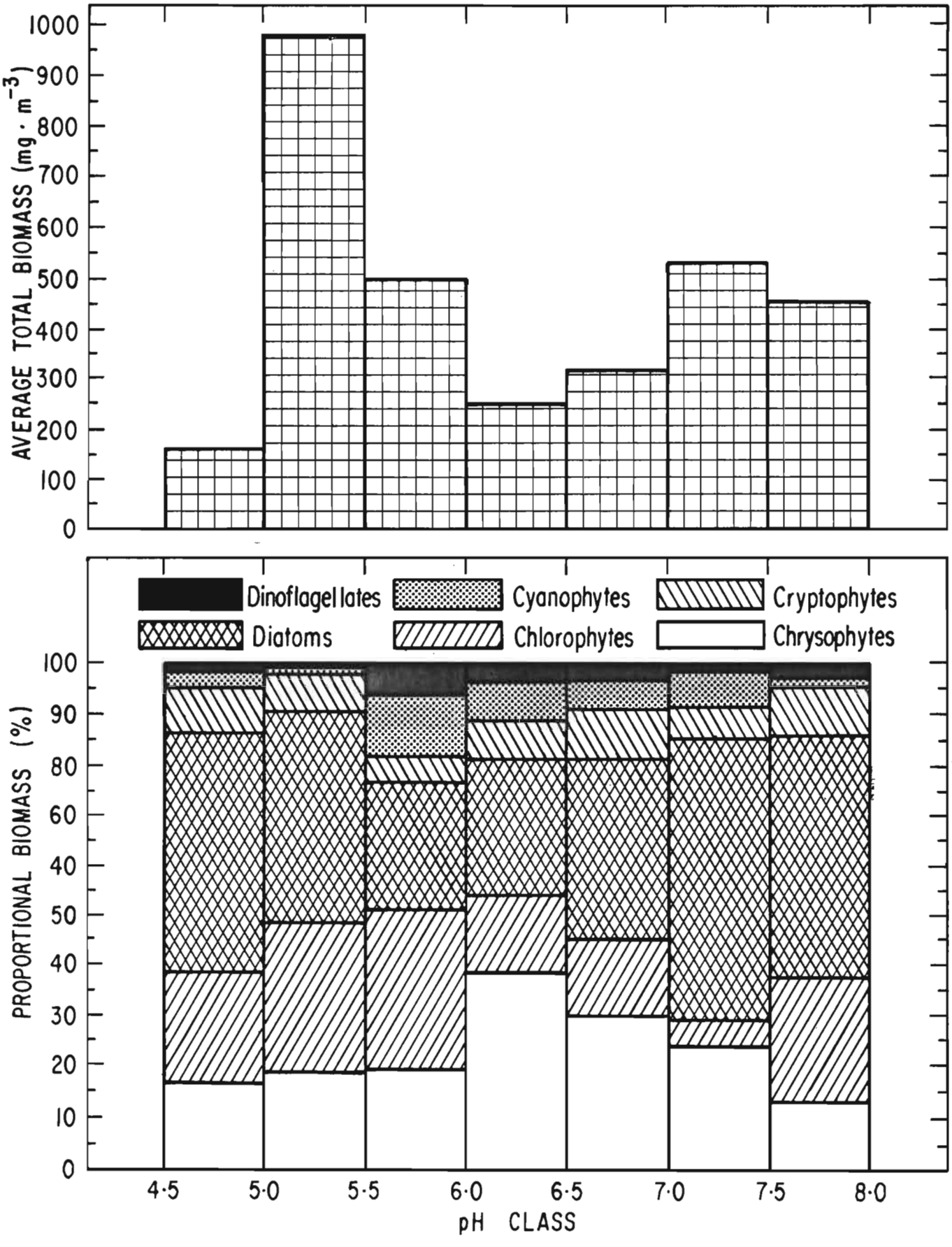


Fig. 14. Total algal biomass and proportional (%) distribution of algal classes for the study lakes grouped by pH intervals.

APPENDIX 1:

Matrix of correlation coefficients (log:log regression) for 39 physical, chemical, and morphometric parameters for 130 Labrador lakes

Only significant correlations are listed. Note: a = significant ($P < 0.05$), b = highly significant ($P < 0.01$), c = very highly significant ($P < 0.001$). Also n = 130 for all parameters except maximum depth and secchi depth (n = 95) and for mean depth and volume (n = 75).

2

Key to Parameters

1. Field pH
2. Lake area
3. Mean depth
4. Maximum depth
5. Elevation
6. Distance from the coast
7. Drainage area
8. Ratio drainage area to lake area
9. Secchi disc
10. Field alkalinity
11. Conductivity
12. Total dissolved solids
13. Hardness
14. Calcium
15. Magnesium
16. Sodium
17. Potassium
18. Chloride
19. Sulphate
20. Excess sulphate
21. Orthophosphate
22. Nitrate
23. Cation sum
24. Anion sum
25. Sum of constituents
26. Turbidity
27. Colour
28. Aluminum
29. Excess sodium
30. Excess potassium
31. Excess calcium
32. Excess magnesium
33. Dissolved organic carbon
34. Lake order

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	-																
2	0.19[a]	-															
3			-														
4	0.22[a]	0.49[c]	0.93[c]	-													
5					-												
6	0.32[c]			0.28[b]	0.63[c]	-											
7	0.22[a]	0.83[c]		0.39[c]	-0.16[a]		-										
8		-0.19[a]					0.35[c]	-									
9	0.31[b]	0.31[b]	0.65[c]	0.78[c]					-								
10	0.85[c]					0.21[a]	0.18[a]	-0.21[a]		-							
11	0.66[c]				-0.21[a]			0.18[a]		0.89[c]	-						
12		-0.22[a]	0.40[c]	-0.52[c]	-0.27[b]	-0.18[a]		0.21[b]	-0.61[c]	0.34[c]	0.51[c]	-					
13	0.75[c]					0.23[b]		0.18[a]		0.88[c]	0.94[c]	0.50[c]	-				
14	0.72[c]				-0.17[a]	0.17[a]				0.90[c]	0.96[c]	0.47[c]	0.94[c]	-			
15	0.69[c]					0.26[b]				0.81[c]	0.87[c]	0.52[c]	0.51[c]	0.82[c]	-		
16	0.31[c]		-0.29[a]			-0.24[b]				0.49[c]	0.61[c]	0.41[c]	0.52[c]	0.51[c]	0.46[c]	-	
17	0.27[b]				0.19[a]	0.40				0.35[c]	0.43[c]	0.18[a]	0.42[c]	0.41[c]	0.40[c]		-
18	-0.26[b]		-0.30[b]	-0.32[b]	-0.49[c]	-0.50[c]			-0.35[c]			0.36[c]				0.46[c]	
19			-0.25[a]	-0.37[c]		0.19[a]			-0.57[c]	0.28[b]	0.51[a]	0.65[c]	0.50[c]	0.47[c]	0.55[c]	0.30[c]	0.40[c]
20			-0.24[a]	-0.36[c]		0.22[a]			-0.57[c]	0.29[b]	0.50[c]	0.64[c]	0.50[c]	0.47[c]	0.56[c]	0.26[b]	0.41[c]
21																	
22	-0.29[c]			0.23[a]		-0.19[a]			0.27[b]								
23	0.71[c]				-0.18[a]					0.90[c]	0.98[c]	0.52[c]	0.96[c]	0.96[c]	0.90[c]	0.64[c]	0.43[c]
24	0.70[c]					0.19[a]	0.20[a]			0.89[c]	0.98[c]	0.49[c]	0.95[c]	0.95[c]	0.90[c]	0.59[c]	0.43[c]
25	0.65[c]				-0.19[a]		0.18[a]			0.87[c]	0.99[c]	0.54[c]	0.94[c]	0.95[c]	0.89[c]	0.62[c]	0.46[c]
26	-0.43[c]		-0.33[b]	-0.41[c]	-0.17[a]	-0.23[b]			-0.58[c]	-0.21[b]		0.31[c]					
27	-0.35[c]	-0.23[b]	-0.47[c]	-0.61[c]	-0.22[a]			0.32[c]	-0.81[c]			0.61[c]				0.21[b]	
28	-0.38[c]	-0.21[a]		0.25[a]	-0.21[a]			0.22[a]	-0.43[c]	-0.26[c]		0.37[c]					
29	0.60[c]				-0.18[a]			0.21[a]		0.58[c]	0.53[c]	0.21[a]	0.55[c]	0.54[c]	0.51[c]	0.70[c]	0.19[a]
30	0.33[c]				0.22[a]	0.46[c]				0.39[c]	0.45[c]		0.44[c]	0.43[c]	0.43[c]		0.98[c]
31	0.72[c]					0.18[a]				0.90[c]	0.96[c]	0.46[c]	0.94[c]	1.00[c]	0.82[c]	0.51[c]	0.41[c]
32	0.72[c]					0.31[c]				0.81[c]	0.83[c]	0.50[c]	0.90[c]	0.80[c]	0.99[c]	0.40[c]	0.39[c]
33	-0.30[c]	-0.27[b]	-0.51[c]	-0.65[c]				0.23[b]	-0.81[c]			0.68[c]			0.24[a]	0.24[b]	
34		0.42[c]		0.34[c]			0.57[c]	0.38[c]				-0.46[c]					

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
-																
0.24[b]	-															
0.18[c]	0.99[c]	-														
			-													
		0.18[a]		-												
	0.51[c]	0.51[c]			-											
	0.53[c]	0.52[c]			0.98[c]	-										
0.18[a]	0.58[c]	0.57[c]			0.99[c]	0.99[c]	-									
0.40[c]	0.35[c]	0.35[c]						-								
0.44[c]	0.63[c]	0.62[c]		-0.24[b]				0.60[c]	-							
0.26	0.35[c]	0.34[c]						0.35[c]	0.61[c]	-						
	0.18[a]	0.19[a]		-0.21[a]	0.61[c]	0.53[c]	0.54[c]	-0.20[a]			-					
	0.38[c]	0.39[c]			0.45[c]	0.44[c]	0.47[c]				0.22[a]	-				
	0.47[c]	0.47[c]			0.96[c]	0.95[c]	0.95[c]				0.54[c]	0.43[c]	-			
	0.53[c]	0.55[c]		-0.21[a]	0.87[c]	0.86[c]	0.84[c]				0.52[c]	0.43[c]	0.22[a]	-		
0.40[c]	0.72[c]	0.71[c]					0.19[a]	0.56[c]	0.90[c]	0.55[c]				-0.22[a]	-	
-0.26[a]	-0.34[c]															-

APPENDIX 2:

SPECIES LIST OF THE PHYTOPLANKTON TAXA IDENTIFIED IN THE LABRADOR STUDY LAKES

Appendix 2. Species List of the Phytoplankton Taxa Identified in the Labrador Study Lakes.

Division *CYANOPHYTA*

Class *Cyanophyceae*

Anabaena catenula (Kuetzing) Bornet and Flahault

Anabaena circinalis Rabenhorst

Anabaena circinalis var. *macrospora* (Wittrock) De Toni

Anabaena flos-aquae (Lyngbye) Brébisson in Bornet and Flahault

Anabaena levanderi Lemmermann

Anabaena planctonica Brunnthaler

Anabaena variabilis Kuetzing in Born Flahault

Anabaena wisconsinense Prescott

Aphanizomenon flos-aquae Ralfs

Aphanocapsa delicatissima West and West

Aphanocapsa elachista var. *conferta* West and West

Aphanocapsa elachista var. *plnactonica* G.M. Smith

Aphanocapsa pulchra (Kuetzing) Rabenhorst

Aphanothece clathrata G.S. West in West and West

Aphanothece gelatinosa (Henn.) Lemmermann

Aphanothece nidulans P. Richter

Chroococcus dispersus (Keissl.) Lemmermann

Chrococcus dispersus var. *minor G.M. Smith*

Chrococcus limneticus Lemmerman

Chrococcus limneticus var. *distans* G.M. Smith

Chrococcus limneticus var. *subsalsus* Lemmermann

Chrococcus minutus (Kuetzing) Naegeli

Chrococcus minor (Kuetzing) Naegeli

Chrococcus Prescottii Drouet and Daily

Coelosphaerium dubium Grunow in Rabenhorst

Appendix 2 (cont'd)

Coelosphaerium Kuetzingiaum Naegeli

Coelospfhaerium Naegelianum Unger

Eucapsis alpina Clements and Schantz

Gloeothece linearis Naegeli

Gloeothece linearis var. *composita* G.M. Smith

Gloeotrichia echinulata (J.E. Smith) P. Richter

Gomphosphaeria aponica var. *delicatula* Viriewx

Gomphosphaeria lacustris Chodat

Gomphosphaeria lacustris var. *compacta* Lemmermann

Hapalosiphon hibernic West and West

Lyngbya limnetica Lemmermann

Marsoniella species A. (unidentified)

Merismopedia glauca (Ehrenberg) Naegeli

Merismopedia punctata Meyen

Merismopedia tenuissima Lemmermann

Nostoc comminutatum Kuetzing

Nostoc linckia (Roth) Bornet and Thuret

Oscillatoria limnetica Lemmermann

Oscillatoria minima Gicklhorn

Oscillatoria rubescens De Candolle

Oscillatoria tenuis C.A. Agardh.

Phormidium tenue (Meheghini) Gomont

Rhabdoderma gorskii Woloszynska

Rhabdoderma lineare Schmidle and Laterborn

Merismopedia tenuissima Lemmermann

Nostoc comminutatum Kuetzing

Nostoc linckia (Roth) Bornet and Thuret

Appendix 2 (cont'd)

Oscillatoria limnetica Lemmermann

Oscillatoria minima Gicklhorn

Oscillatoria rubescens De Candolle

Oscillatoria tenuis C.A. Agardh.

Phormidium tenue (Meneghini) Gomont

Rhabdoderma gorskii Woloszynska

Rhabdoderma lineare Schmidle and Lauterborn

Division *CHLOROPHYTA*

Class *Chlorophyceae*

Acanthosphaera Zachariasi Lemmermann

Ankistrodesmus falcatus (Croda) Ralfs

Ankistrodesmus falcatus var. *mirabilis* (West and West) G.S. West

Ankistrodesmus falcatus var. *spiralis* (Turner) Lemmermann

Ankistrodesmus setigerus Schroeder

Ankistrodesmus spiralis (Turner) Lemmermann

Arthrodesmus incus Brébisson

Arthrodesmus incus var. *extensus* Anderson

Arthrodesmus octocornis Ehrenberg

Arthrodesmus Ralfsii W. West

Arthrodesmus species A. (unidentified)

Arthrodesmus triangularis Lagerhorst

Bambusina moniliformis var. *gracilescens* Nordstedt

Botryococcus braunii Kuetzing

Characiopsis species A *(unidentified)*

Characium ambiguum Hermann

Characium curvatum G.M. Smith

Characium obtusatum A. Braun

Appendix 2 (cont'd)

Characium Pringsheimii A. Braun

Chlamydomonas frigida Skuja

Chlamydomonas gleopara Rodhe and Skuja

Chlamydomonas globosa Snow

Chlamydomonas lapponica Skuja

Chlamydomonas sagittula Skuja

Chlamydomonas species A (unidentified)

Chlamydomonas species B (unidentified)

Chlorella species A (unidentified)

Closterium acutum var. *variable* (Lemm.) Krieg.

Closterium costatum Corda in Ralfs

Closterium Dianae Ehrenberg

Closterium gracile var. *tenue* (lemmermann) West and West

Closterium kuetzingii Brébisson

Closterium Pseudodianne Roy

Closterium setaceum var. *sigmoideium* Ireene-Marie

Coccomyxa species A (unidentified)

Coelastrum cambricum Archer

Cosmarium bioculatum Brébissonin Ralfs

Cosmarium bioculatum var. *refringens* Croasdlae

Cosmarium bipunctuatum Borg

Cosmarium blytii Wille

cosmarium botrytis Meneghini

Cosmarium granatum Brébisson

Cosmarium minimum West and West

Cosmarium moniliforme (Turpin) Ralfs

Cosmarium norvegicum Strom

Appendix 2 (cont'd)

Cosmarium ornatum Ralfs

Cosmarium Protianum Archer

Cosmarium punctulatum Brébisson

Cosmarium pyramidatum Brébisson in Ralfs

Cosmarium tenue Archer

Crucigenia fenestrata Schmidle

Crucigenia irregularis Wille

Crucigenia quadrata Morren

Crucigenia rectangularis (A. Braun) Gay

Crucigenia tetrapedia (Kirchner) West and West

Desmatractum bipyramidatum (Chodat) Pascher

Dictosphaerium Ehrenbergianum Naegeli

Dictyosphaerium simplex Skuja

Elakatothrix gelatinosa Wille

Elakatothrix lacustris Holmgren

Euastrum binale (Turpin) Ralfs

Euastrum bidentatum Naegeli

Eastrum denticulatum (Kirchner) Gay

Euastrum dibium Naegeli

Gemellicystis neglecta Teiling and Skuja

Gleocystis gigas (Kuetzing) Lagerheim

Gleocystis Schroeteri Chodat

Golenkinia radiata Chodat

Gyromitis cordiformis Skuja

Gyromitis species A (unidentified)

Kirchneriella contorta (Schmidle) Bohlin

Kirchneriella lunaris (Kirchner) Moebious

Appendix 2 (cont'd)

Kirchneriella obesa (W. West) Schmidle

Kirchneriella obesa var. *major* (Bernard) G.M. Smith

Kirchneriella subsolitaria G.S. West

Microspora elegans Hansgirg

Microspora Loefgrenii (Nordstedt) Lagerheim

Microspora quadrata Hazen

Microspora tumidula Hazen

Mougeotia species A (unidentified)

Mougeotia species B (unidentified)

Mougeotia species C (unidentified)

Mougeotia species D (unidentified)

Mougeotia species E (unidentified)

Nephrocytium Agardhianum Naegeli

Oocystis Borgei Snow

Oocystis crassa Wittrock

Oocystis elliptica W. West

Oocystis lacustris Chodat

Oocystis parva West and West

Oocystis pusilla Hansgirg

Oocystis submarina Lagerheim

Oocystis submarina var. *variabilis* Skuja

Paramastix coifera Skuja

Pediastrum tetras (Ehrenberg) Ralfs

Planctococcus alsius Skuja

Planctonema Lauterbornii Schmidle

Planktosphaeria gelatinosa G.M. Smith

Quadrigula closterioides (Bohlin) Printz

Appendix 2 (cont'd)

Quadrigula pfitzeri (Schroeder) Printz

Scenedesmus abundans (Kirchner) Chodat

Scendesmus abundans var. *asymmetrica* (Schroeder) G.M. Smith

Scendesmus abundans var. brevicauda ***G.M. Smith***

Scenedsmus bijuga (Turpin) Lagerheim

Scenedesmus denticulatus Lagerheim

Scenedesmus denticulatus Lagerheim

Scenedesmus quadricauda (Turpin) Brébisson

Scenedesmus quadricauda var. *parvus* G.M. Smith

Scenedesmus quadricauda var. *quadrispina* (Chodvat) G.M. Smith

Scenedesmus quadricauda var. ***Westii*** G.M. Smith

Scenedesmus serratus (Croda) Bohlin

Schroederia setigera (Schroeder) Lemmerman

Selenastrum minutum (Naegeli) Collins

Sphaerocystis schroeteri Chodat

Spodylosium planum (Wolle) West and West

Sphaerozoma excavatum Ralfs

Staurastrum brevispinum Brébisson

Staurastrum cuspidatm Brébisson

Staurastrum Johnsonni West and West

Staurastrum megacanthum Lundell

Staurastrum paradozum Meyen

Staurastrum planctonicum Teiling

Staurastrum tetracerum vr. *trigonum* Lundell

Staurodesmus cuspidatus (Brébisson) Teiling

Tetraëdron lobulatum var. *polyfurcatum* G.M. Smith

Tetraëdron minimum (A. Braun) Hansgirg

Appendix 2 (cont'd)

Tetraëdron minimum var. tetralobulatum *Reinsch*

Tetraspora lacustris lemmermann

Ulothrix tenuissima Kuetzing

Westella botryoides (W. West) de Wildemann

Xanthidium antilopaeum (Brébisson) Kuetzing

Xanthidium antilopaeum var. *polymason* Nordstedt

Xanthidium pseudobengalicum Gronb.

Division *EUGLENOPHYTA*

Class *Euglenophyceae*

Anisonema strenum Skuja

Euglena gracilis Klebs

Euglena variabilis Klebs

Phacus agilis Skuja

Division *CHRSOPHYTA*

Class *Chrysophyceae*

Aulomonas purdyi Lackey

Bicoeca campanulata (Lackey) Bourrelly

Bicoeca cylindrica (Lackey) Bourrelly

Bicoeca mitra var. *suecica* Skuja

Bicoeca multiannulata Skuja

Bicoeca ovata Lemmermann

Bicoeca synoica Skuja

Bitrichia chodati (Reverdin) Hollande

Chromulina minor Pascher

Chromulina minuta Doflein

Chromulina species A (unidentified)

Chromulina species B (unidentified)

Appendix 2 (cont'd)

Chromulina species C (unidentified)

Chromulina specied D (unidentified)

Chromulina species E (unidentified)

Chromulina species F (unidentified)

Chromulina species G (unidentified)

Chromulina species H (unidentified)

Chromulina species I (unidentified)

Chromulina species J (unidentified)

Chromulina species K (unidentified)

Chromulina species L (unidentified)

Chromulina species M (unidentified)

Chromulina species N (unidentified)

Chromulina species O (unidentified)

Chromulina species P (unidentified)

Chromulina species Q (unidentified)

Chromuline tenera Matvienko

Chrysamoeba nobilis (Skuja) Matvienko

Chrysamoeba tetragene (Skumja) Matvienko

Chrysochromulina parva Lackey

Chrysolykos planctonicus Mach

Chrysolykos skujai (Nauwerck) Bourelly

Chrysosphaerella longispina Lauterborn

Chrysocapsa planctonica (West and West) Pascher

Chrysophyte species A (unidentified)

Chrysophyte species B (unidentified)

Chrysophyte species C (unidentified)

Chrysophyte species D (unidentified)

Appendix 2 (cont'd)

Chrysophyte species E (unidentified)

Chrysophyte speices F (unidentified)

Chrysophyte species G (unidentified)

Derepyxis dispar (Stokes) Senn

Dinobryon acuminatum Ruttner in Pascher

Dinobryon bavaricum Imhof

Dinobryon borgei Lemmermann

Dinobryon crenulatum West and West

Dinobryon cylindricum var. *alpinum* (imhof) Bachmann

Dinobryon cylindricum var. *palustre* Lemmermann

Dinobryon cylindricum Imhof

Dinobryon dilatatum Hilliard

Dinobryon divergens Imhof

Dinobryon elegantissimum Bourrely

Dinobryon elegantissimum Bourrely

Dinobryon sertularia Ehrenberg

Dinobryon sociale Ehrenberg

Dinobryon sociale var. *americanum* (Brunnthaler) Bachmann

Dinobryon species A. (unidentified)

Epipyxix borgei (Lemmermann) Hilliard and Asmund

Epipyxis borgei var. *radiosum* Brutschy

Epipyxis polymorpha (Lund) Hilliard and Asmund

Epipyxix tabellariae (Lememrmann) G.M. Smith

Helipchrysis eradians Pascher

Kephyrion boreale Skuja

Kephyrion doliolum Conrad

Kephyrion littorale Lund

Appendix 2 (cont'd)

Kephyrion obliquum Hilliard

Kephyrion sitta Pascher

Mallomonas akrokomos Ruttner in Pascher

Mallomonas elongata Reverdin

Mallomonas lilloensis Conrad

Mallomonas producta Iwanoff

Mallomonas pumillio var. *canadensis* Holngren

Mallomonas species A (unidentified)

Mallomonas species B (unidentified)

Mallomonas sepcies c (unidentified)

Mallomonas species D (unidentified)

Mallomonas species E (unidentified)

Mallomonas species F (unidentified)

Mallomonas sphaerica Prowse

Monosiga species A (unidentified)

Monosiga varians Skuja

Ochromonas species A (unidentified)

Ochromonas species B (unidentified)

Ochromonas species C (unidentified)

Ochromonas species D (unidentified)

Ochromonas species E (unidentified)

Ochromonas species F (unidentified)

Ochromonas species G (unidentified)

Ochromonas species H (unidentified)

Ochromonas species I (unidentified)

Ochromonas species J (unidentified)

Ochromonas species K (unidentified)

Appendix 2 (cont'd)

Ochromonas species L (unidentified)

Ochromonas species M (unidentified)

Ochromonas species N (unidentified)

Ochromonas species O (unidentified)

Ochromonas species P (unidentified)

Ochromonas sphaerocystis Matvienko

Ochromonas species T (unidentified)

Ochromonas species V (unidentified)

Ochromonas vallesiaca Chodat

Pseudokephyrion alaskanum Hilliard

Pseudokephyrion angulosum Hilliard

Pseudokephyrion attenuatum Hilliard

Pseudokephyrion species A (unidentified)

Pseudokephyrion tintinnabulum Conrad

Salpingoeca frequentissima (Zacharias) Lemmermann

Stichogloea doederleinii (Schmidle) Wille

Stichogloea olivacea Chodat

Uroglena americana Catkins

Division *BACILLARIOPHTA*

Class *Bacillariphyceae*

Asterionella formosa Hassall

Asterionella ralfsii W. Smith

Cyclotella comta (Ehrenberg) Kaetzing

Cyclotella glomerata Bachmann

Cyclotella ocellata Pantocsek

Cyclotella stelligera Cleve and Grunow

Cymbella lunata W. Smith

Appendix 2 (cont'd)

Diatoma elongatum var. *tenue* (Ag.) Kuetzing

Eunotia curvata (Kuetzing) Lagerstedt

Eunotia serra var. *diadema* (Ehrenberg) Patrick

Fragilaria construens (Ehrenberg) Grunow

Fragilaria crotonensis Kitton

Fragilaria constricta var. *stricta* (Cleve) Hustedt

Fragilaria construens var. *venter* May

Fragilaria pinnata Ehrenberg

Frustulia rhomboides (Ehrenberg) De Toni

Melosira Binderana Kuetzing

Melosira distans (Ehrenberg) Kuetzing

Melosira distans var. alpigena *Grunow*

Melosira distans var. *lirata* (Ehrenberg) Bethge

Melosira islandica O. Mueller

Melosira islandica sbsp. *helvetica* O. Mueller

Melosir italica (Ehrenberg) Kuetzing

Nitzschia acuminata (W. Smith) Grunow

Nitzschia fonticola Grunow

Nitzschia linearis W. Smith

Nitzschia palea (Kuetzing) *W. Smith*

Nitzschia sigmoidea (Ehrenberg) W. Smith

Pinnularia biceps var. *petersenii* Ross

Pinnularia mesolepta (Ehrenberg) W. Smith

Rhizosolenia eriensis H.L. Smith

Rhizosolenia longiseta Zacharias

Semiorbis hemicyclus (Ehrenberg) Patrick

Surirella linearis Hustedt

Appendix 2 (cont'd)

Synedra acus var. *delicatissima* (W. Smith) Grunow

Synedra rumpens Kuetzing

Synedra ulna (Nitzsch) Ehrenberg

Tabellaria fenestrata (Lyngbye) Kuetzing

Tabellaria flocculosa (Rothest) Kuetzing

Tabellaria fenestrata var. *intermedia* Grunow

Tabellaria quadriseptata Knudson

Division *CRYPTOPHYTA*

Class *Cryptophyceae*

Cryptaulax rhomboidea Skuja

Cryptophyte species A (unidentified)

Cryptomonas caudata Schiller

Cryptomonas curvata Ehrenberg

Eryptomonas erosa Ehrenberg

Cryptomonas erosa var. *reflexa* Marsson

Cryptomonas marssonii Skuja

Cryptomonas ovata Ehrenberg

Cryptomonas phaseolus Skuja

Cryptomonas pusilla Bachmann

Cryptomonas pyrenoidifera Geitler

Cryptomonas relfexa (Marsson) Skuja

Cryptomonas rostrata Skuja

Cryptomonas tenuis Pascher

Gonatozygon Kinahani (Archer) Rabenhorst

Katablepharis ovalis Skuja

Rhodomonas minuta Skuja

Rhodomonas minuta var. *nannoplanctica* Skuja

Appendix 2 (cont'd)

Rhodomonas tenuis Pascher

Division *PYRROPHYTA*

Class *Dinophyceae*

Gymnodinium eurytopum Skuja

Gymnodinium inversum Nygaard

Gymnodinium Lantzschii UtermöL

Gymnodinium ordinatum Skuja

Gymnodinium uberrimum (Allman) Kofoid and Swezy

Gymnodinium varians Maskell

Peridinium cinctum (Mueller) Ehrenberg

Peridinium inconspicum Lemmerman

Peridinium pusillum (Pernard) Lemmeramnn

Peridinium umbonatum var. *inaquaele* Lemmermann

Peridinium willei Huitfeld-Kaas