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THE PHYTOPLANKTON COMMUNITIES
OF NINE LAKES, WAIKATO, NEW ZEALAND:
A COMPARATIVE STUDY OF FLORISTICS,
SEASONAL DYNAMICS AND THE INFLUENCE
OF HERBIVORY

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ABSTRACT

The structure and seasonal dynamics of the phytoplankton communities of nine shallow lakes located in relatively close proximity to one another within the Waikato Basin, and of similar age and origin, were studied for one year (July 1983 to July 1984); the lakes were Kainui, Mangahia, Mangakaware, Maratoto, Ngaroto, Rotokauri, Rotomanuka North and South, and Rotoroa. There was a broad range of physico-chemical regimes, a direct result of differing morphometries and quantities of allochthonous dissolved humic material from adjacent peatland and/or swamps, and varying degrees of exposure to wind.

Community structure was markedly influenced by humic content, in terms of both α diversity and distribution of species within the major classes, with total numbers of species found per lake ranging from 113 to 210.

Temporal patterns of community composition were directly related to specific mixing regimes and morphometry. Lakes which had minimal thermal stability throughout summer were dominated throughout the entire year by one or two algal classes, and it was shown statistically that the major phytoplankters were large, K- selected species (e.g., *Botryococcus braunii* and *Microcystis aeruginosa*). Unpredictable sequences of domination, one class replacing another after brief periods of importance, were recorded in lakes where ephemeral periods of summer stratification alternated with either equally short periods of holomixis or weakly developed stratification; the dominant species in these lakes were r- strategists such as *Asterionella formosa*, *Acanthoceras zachariasii* and *Tetrastrum triangulare*. Marked seasonal periodicity (including autogenic succession) occurred in Lake Rotomanuka North, the only warm monomictic lake within the series.

Total α diversity (402 species) was higher than that of any other group of intensively studied New Zealand lakes, but compositional overlap at both generic and specific levels was low, with only 24 species being found in all nine lakes. Of these, the most common and ecologically versatile phytoplankters were *Closterium acutum* var. *variabile*, *Cryptomonas marssonii* and *C. ovata*, *Cyclotella stelligera*, *Monoraphidium contortum* and *Trachelomonas volvocina*.

Mean total phytoplankton biomass and density ranged from 0.7 to 72.2 g m³ and 0.4 to 11.6 pu l⁻¹, respectively, and comparisons with other quantitative phytoplankton studies indicate that some of the study lakes (Maratoto, Ngaroto and Rotomanuka South) are the most productive recorded in New Zealand to date. Eutrophic waters and rich organic sediments, together with a combination of both stratified and frequently mixed water columns, resulted in relatively high euglenophyte species diversity. Conversely, the number of desmid species was relatively low.

Zooplankton exclusion experiments using limnocorrals were carried out in an almost clear-water lake (Rotomanuka North) and in a darkly-stained lake (Maratoto). The results suggest that a reduction in grazing pressure markedly influenced phytoplankton community structure in the former, causing shifts (in terms of biomass) from communities dominated by K- strategists (*Microcystis aeruginosa* or *Peridinium cinctum*) to smaller, fast-growing species (*Cyclotella stelligera* or *Coelastrum microporum*). Reduced herbivory also permitted increases in the number of taxa and total biomass of small edible phytoplankters (GALDs \leq 20 μ m), together with an increase in the number of euglenophyte species. Similar responses were not apparent in dystrophic Lake Maratoto, suggesting that the stressful physico-chemical regime was the major regulator of community structure, and that trophic organisation within the two systems differed markedly, with energy transfer in the latter operating largely through a heterotrophic-based food chain.

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Gomphonema acuminatus
G. truncatum
Gyrosigma acuminatum
Navicula cuspidata
N. radiosa
Pinnularia flexuosa
- Epithemiaceae
Epithemia argus
E. sorex

26. Nitzschiaceae 311
Nitzschia acicularis
N. sigmoidea
Rhopalodia sp.

CYANOPHYTA

Cyanophyceae

Chroococcaceae

Aphanocapsa elachista
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C. minor
Merismopedia elegans
M. glauca
M. minima
M. tenuissima
Microcystis aeruginosa

27. *Microcystis aeruginosa* 312
 Nostocaceae
Anabaena circinalis
A. flos-aquae

28. *A. solitaria* 313
A. spiroides var. *tumida*
Cylindrospermum minutissimum

Oscillatoriaceae

Oscillatoria curviceps
O. geminata
O. limnetica
O. limosa
O. splendida
O. subbrevis
O. tenuis
Spirulina major

EUGLENOPHYTA

Euglenophyceae

Euglenaceae

Astasia harrisii
Cyclidiopsis acus
Euglena acus
E. ehrenbergii
E. limnophila
E. oxyuris

29. *E. spirogyra* var. *suprema* 314
E. tripteris
Lepocinclis marssonii
L. ovum
Menoidium gracile
M. pellucidum
Phacus curvicauda
P. glaber
P. helicoides
P. inflexus
P. longicauda
P. pleuronectes

	<i>P. raciborski</i>	
	<i>P. rudicola</i>	
	<i>P. sesquitorus</i>	
	<i>P. suecicus</i>	
	<i>P. s. var. oidon</i>	
	<i>Trachelomonas armata var. inevoluta</i>	
30.	<i>T. a. var. longspina</i>	315
	<i>T. cylindrica</i>	
	<i>T. dybowski</i>	
	<i>T. furcata</i>	
	<i>T. globularis var. punctata</i>	
	<i>T. hexangulata</i>	
	<i>T. hispida var. coronata</i>	
	<i>T. lemmermannii</i>	
	<i>T. mirabilis var. obesa</i>	
	<i>T. planctonica</i>	
	<i>T. playfairi</i>	
	<i>T. pulcherrima var. minor</i>	
	<i>T. p. var. ovalis</i>	
	<i>T. volvocina</i>	
	<i>Strombomonas urceolata</i>	
	<i>Urceolus sp.</i>	
PYRRHOPHYTA		
	Cryptophyceae	
	Cryptomonadaceae	
	<i>Cryptomonas erosa</i>	
	Dinophyceae	
	Peridiniaceae	
	<i>Peridinium aciculiferum</i>	
	<i>P. cinctum</i>	
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	<i>P. pusillum tab. conjunctum</i>	
	<i>P. umbonatum tab. conjunctum</i>	
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	<i>C. h. var. furcoides</i>	
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LIST OF ABBREVIATIONS

AODC	acridine orange direct count
C.V.	coefficient of variation
DHM	dissolved humic material
GALD	greatest axial linear dimension
I.D.	internal diameter
ISI	important species index
LC	limnocorral
n	sample size
ns	not significant
pu	plankton unit
r	value of the correlation coefficient
SD	standard deviation
SE	standard error
SGALD	second greatest axial linear dimension
SK	skewness statistic
yr BP	years before present
#	tentative identification due to lack of electron microscopical observations

VOLUME I

CHAPTER ONE

INTRODUCTION

1.1 GENERAL INTRODUCTION

There is remarkably little information about the structure and functioning of Southern Hemisphere phytoplankton communities (Ashton, 1985). In New Zealand, a detailed understanding of the ecological processes which regulate phytoplankton associations and seasonal dynamics has been slow to develop, despite the presence of a wide variety of lake types (Irwin, 1975a; Lowe & Green, 1987) to engage the interest of phycologists. The first algal samples were collected during the latter half of the last century (e.g., Lindsay 1867a, b; Norstedt 1887, 1888), but few intensive quantitative studies have followed.

Many factors are responsible for the slow pace of phytoplankton research in New Zealand. First, despite a spate of publications by both resident and European biologists between c. 1850 and 1900, there is little evidence of interest during the next 50 years. Consequently, many areas of New Zealand phycology are still in the inventory stage (Parsons, 1985).

Secondly, although all species lists compiled from New Zealand freshwater studies (published and unpublished) have been referenced by Cassie (1980a, 1981, 1983), and several checklists prepared and revised (e.g., Chapman *et al.*, 1957; Flint, 1966; Sarma & Chapman, 1975; Cassie 1980b, 1984a, b, c), until phycologists have access to keys specific to New Zealand algae, doubts will continue to be cast on many identifications. Keys designed for foreign floras may be appropriate for truly cosmopolitan species, but the identical nature of many taxa from widely separated regions is questionable (Parsons, 1985). However, the recent taxonomic keys and descriptions for desmids and planktonic cyanophytes found in New Zealand (Croasdale & Flint [1986] and Etheredge & Pridmore [in press] [Appendix I], respectively), will partially alleviate this problem.

Thirdly, a lack of methodological standardisation has made accurate comparative analyses of New Zealand phytoplankton communities difficult. Many species lists are of limited value because they are based on either single (e.g., Thomasson 1974, 1980; Paerl *et al.*, 1979) or occasional (e.g., Flint, 1979) sampling visits, and

consequently species numbers are usually underestimates. Certain sampling techniques such as net tows (e.g., Jolly, 1977; Flint, 1979) and vertical net hauls (e.g., Thomasson, 1974a; Flint 1977, 1979; Cassie 1975, 1978) also result in underestimations of species diversity (such nets do not retain nanno- and ultraplanktonic species), as does restricted sampling (e.g., surface layer only [Jolly, 1977], or surface and bottom layers [Cassie & Freeman, 1980]). Different methods of phytoplankton concentration prior to counting have also been employed. The Utermöhl technique (Chapter 2.3.2 and 2.5.1) has been used by most recent workers (e.g., Kloos, 1976; Chapman & Boubée, 1977; Paerl *et al.*, 1979; Chapman, 1980; Etheredge, 1983; Forsyth *et al.*, 1983; Lineham, 1983; Viner & Kemp, 1983; Duthie & Stout, 1986, Howard-Williams *et al.*, 1986), but centrifugation (e.g., Flint 1975, 1977, 1979) and membrane filtration (e.g., Burns & Mitchell, 1974; Green, 1976a; Vincent *et al.*, 1984; Dryden & Vincent, 1986), the disadvantages of which are discussed by Etheredge (1985) (Appendix II), have also been used. Semi-quantitative abundance scales (e.g., Cassie 1974, 1978, 1980; Flint 1975, 1977, 1979), and the reluctance of some phycologists to convert cell counts to biomass, have also hindered accurate inter-community analyses.

Fourthly, there have been few publications of intensive long-term studies; and finally, sudden interest during the 1970s in eutrophication, and its associated research fields, resulted in stronger emphasis being given to investigations in this area (e.g., Mitchell, 1971a, b; White & Payne 1977, 1978; Hoare, 1980; Mitchell & Burns, 1981; Vincent, 1981a, b; White, 1983; White *et al.*, 1985; White *et al.*, 1986) than to either general ecology or taxonomy of New Zealand phytoplankton.

In the South Island, the first study estimated the abundance of ten species over a two year period in Lake Sarah, an oligotrophic lake in Canterbury (Flint, 1938). Forty years later, the seasonality and vertical distribution of phytoplankton in Lakes Hayes and Johnson, two eutrophic, Central Otago lakes were investigated (Burns & Mitchell, 1974). More recently, the seasonal dynamics of the phytoplankton community of Lake Ellesmere, a brackish barrier-bar lake, have been described from 25 samples collected between January 1978 and July 1980 (Lineham, 1983). Also, the seasonality of phytoplankton populations in four Waitaki lakes (Tekapo, Pukaki, Ohau and Benmore) has been

detailed, following a long-term project (December 1975 to January 1980) (Duthie & Stout, 1986).

Although more seasonal analyses of phytoplankton community structure have been undertaken in the North than the South Island, many are less detailed. They include studies on northern, oligotrophic sand-dune lakes (Green, 1976a; Cassie & Freeman, 1980), man-made lakes of the Waikato River (Magadza, 1978), eutrophic Waikato lakes (Etheredge, 1983; Greenwood, 1987) and lakes from the central North Island region (Cassie 1969, 1974, 1978; Forsyth & McColl, 1975; Kloos, 1976; Flint, 1977; Jolly, 1977; Viner & Kemp, 1983; Vincent *et al.*, 1984; Dryden & Vincent, 1986).

Most of these studies have focused on relationships between periodicity of major species and physico-chemical regimes in clear water lakes. The importance of loss factors (e.g., sedimentation, flushing and parasitism) in regulating phytoplankton community dynamics has been ignored or addressed superficially (Viner & White, 1987), and investigations of allelopathy have been restricted to experimental studies (e.g., Lam, 1979; Vincent & Silvester, 1979a, b). Similarly, little is known about the impact of zooplankton grazing on the structure and periodicity of phytoplankton communities in New Zealand lakes (Chapman & Green, 1987).

Numerous brown-stained lakes occur throughout New Zealand, but few have received detailed, long-term attention. Lake Ngahewa was sampled on three occasions throughout 1973 by Forsyth & McColl (1975); the phytoplankton communities of three lakes in Westland National Park (Mapourika, Matheson and Wombat), were analysed by Flint (1979) from occasional samples taken in 1933, and during the period 1965 to 1975; and nine other Westland lakes (Ahaura, Brunner, Haupiri, Hochstetter, Kangaroo, Kaniere, Lady, Mudgie and Poerua) have been sampled once (March 1976), as a baseline study before the commencement of commercial logging projects in the area (Paerl *et al.*, 1979). In the North Island, stained lakes are found mainly within the Hamilton or Middle Waikato Basin, but apart from a preliminary summer survey of twenty-four of these lakes (Chapman & Boubée, 1977), an investigation into the structure, seasonal dynamics and vertical distribution of the phytoplankton communities of Lakes Maratoto and Rotomanuka North (Etheredge, 1983), and an analysis of the dominant phytoplankters in Lake Mangakaware (Greenwood, 1987), few details of their algal composition or biomass are known.

1.2 AIMS OF THE PRESENT STUDY

Nine small Waikato lakes, stained to varying degrees with allochthonous humic materials, were selected for detailed phytoplankton community analyses over a one year period. Because of the direct relationship between pH and DHM (dissolved humic material), the study lakes were chosen to represent the widest range of pH present in the Hamilton area; those selected were Lakes Kainui, Mangahia, Mangakaware, Maratoto, Ngaroto, Rotokauri, Rotomanuka North and South, and Rotoroa (Fig. 1/0). The meanings of the names of the study lakes are given in Appendix III.

The primary aims were to investigate:

- (1) the structure of their phytoplankton communities in terms of both composition and biomass;
- (2) the seasonal dynamics of their phytoplankton communities;
- (3) the influence of zooplankton grazing on the phytoplankton structure of both a darkly-stained and an almost clear-water lake.

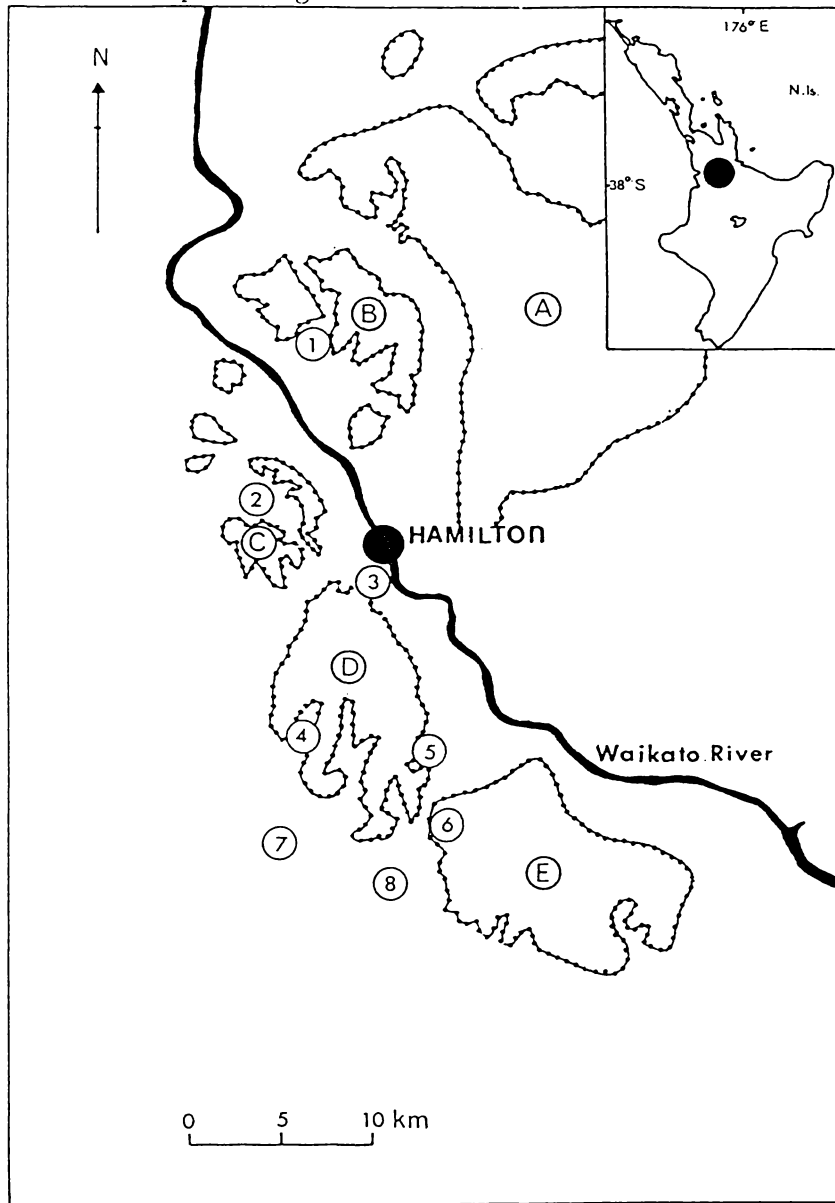
1.3 STUDY AREA

The Hamilton or Waikato Basin (2040 km²) is an oval-shaped depression running c. 80 km in a north to south direction, and more than 40 km wide (Fig. 1/0). It is surrounded almost entirely by low ranges (rising to c. 1000 m), but in the south, the boundary is less well defined as the floor rises gradually to merge with more steeply dissected country.

The main topographic features result from aggradation by the Waikato River (McCraw, 1967). During the latter part of the Otira Glaciation, it abandoned its previous course through the Hinuera Valley and Hauraki Depression, broke into the Hamilton Basin at Karapiro, and began depositing the alluvium which is now known as the Hinuera Formation (McGlone *et al.*, 1978). The first phase of active aggradation (Hinuera - 1) commenced between 65,000 and 40,000 yr BP, and declined by 20,000 yr BP. This was followed by a further period of active aggradation (Hinuera - 2), and deposition finally ceased between 14,000 and 12,000 yr BP (Schofield, 1965; Hume *et al.*, 1975; McGlone *et al.*, 1978).

Throughout this deposition period the river migrated across its aggrading plain (as evidenced by well preserved river courses); its levées dammed embayments and stream valleys forming a large number of

Fig. 1/0 The Hamilton Basin showing the locations of the nine study lakes and associated peat bogs



Key:

Lakes

1. Kainui
2. Rotokauri
3. Rotoroa
4. Mangahia
5. Maratoto
6. Rotomanuka
North and South
7. Mangakaware
8. Ngaroto

Peat bogs

- A. Komakorau
- B. Kainui
- C. Ohote
- D. Rukuhia
- E. Moanatuatua

small lakes (McCraw, 1967), including the nine study lakes, most of which were formed between c. 17,000 and 15,000 yr BP (Table 1/0).

Extensive ombrogenous peatlands (Fig. 1/0) began forming on the Hinuera surface c. 12,000 to 11,000 yr BP (McGlone *et al.*, 1978), subsequent to the final entrenchment of the river. In relation to the present study, the most important of these peatlands are Kainui (area 14.2 km²; volume 18.8 x 10⁶ m³), Moanatuatua (area 84.7 km²; volume 346.8 x 10⁶ m³), Ohote (area 6.4 km²; volume 344.9 x 10⁶ m³) and Rukuhia (area 64.2 km²; volume 344.9 x 10⁶ m³) (Davoren, 1978). Their development resulted in allochthonous humic material entering the lakes and, in some instances, quantities were sufficient to initiate dystrophic phases. Details of the developmental history of Lake Maratoto, and by implication other lakes in the area, are given by Green & Lowe (1985).

At present, however, although DHM is present in all nine study lakes, the majority cannot be classified as dystrophic. Relatively unaltered areas of marginal peatland remain on the periphery of two lakes (Mangahia and Maratoto) but, drainage for agricultural purposes of large areas of peatland and/or peripheral swamp in close proximity to the other seven, means that they now receive decreasing quantities of allochthonous humic material. As a consequence, the pH of the study lakes ranges from 5.1 (Lake Maratoto) to 9.8 (Lake Rotomanuka South).

1.4 STUDY LAKES

1.4.1 Geography, Morphometry and Environs

Geographical and morphometric details of each lake are summarised in Table 1/0, and their locations shown in Fig. 1/0.

Lake Kainui, the only lake north of Hamilton, is moderately stained with no well-defined inflow or outflow. It is surrounded by gently undulating pastureland (Plate 1) developed by drainage of the Kainui Peatland. Some clumps of willow (*Salix* spp.) and *Eucalyptus* spp. are present around the margins, but there is no distinct zone of emergent or peripheral vegetation. The greater part of the lake margin abuts directly onto pastureland and cattle have direct access to the lake edge.

Lake Mangahia (Plate 1) is a small, darkly-stained lake to the west of the Rukuhia Peatland. Its dystrophic nature is largely due to 9.2 ha of adjacent swamp and peatland, but the remainder of the

TABLE 1/0 Some morphometric and geographic parameters of the nine study lakes, Hamilton Basin. Data from: Irwin (1975b); Lowe and Green (1987); Green (pers. comm.).

Lake	Location*	Altitude (m)	Area (km ²)	Maximum Length (km)	Maximum Width (km)	Maximum Depth (m)	Mean Depth (m)	Age (yr BP)
Kainui	N56 742603 S14 073893	27	0.32	0.9	0.5	6.7	-	c. 15,000
Mangahia	N65 738359 S15 062668	0-30	0.14	0.6	0.4	2.3	1.59	>c. 15,000
Mangakaware	N65 731292 S15 054608	30	0.13	0.68	0.32	4.8	2.9	c. 16,000
Maratoto	N65 812350 S15 129660	52	0.16	0.7	0.4	7.1	3.4	15,850 ± 130
Ngaroto	N65 797267 S15 113585	38	1.3	2.0	1.2	3.5	2.0	c. 16,000
Rotokauri	N65 707499 S14 037800	24	0.55	1.2	0.7	4.0	-	>c. 13,300
Rotomanuka North	N65 822301 S15 138615	40	0.14	0.64	0.36	8.7	5.0	c. 17,000
Rotomanuka South	N65 825273 S15 141613	55	0.07	0.7	0.1	5.0	2.91	-
Rotoroa	N65 782457 S15 105758	30-61	0.54	1.3	0.5	6.0	-	c. 16,000

* Sheet number and map reference for Department of Lands and Survey NZMS1 and NZMS260 series.

Plate 1

1. Lake Kainui from the south.
2. Lake Mangahia from the southern end.

Plate 1



catchment is primarily pastoral. Unlike the majority of the study lakes, it has a broad, well-defined marginal fringe of emergent vegetation consisting largely of raupo (*Typha orientalis* C.B. Presl), rush (*Eleocharis sphacelata* R. Brown), flax (*Phormium tenax* J.R. et G. Forster), and manuka (*Leptospermum scoparium* J.R. et G. Forster). Small areas of *Sphagnum* spp., intermixed with sundew (*Drosera binata* de Labillardière), are also present. The lake, drained by the Mangahia Stream, is the shallowest of the group. Its bathymetry is given in Irwin (1982a).

Lake Mangakaware (Plates 2 and 3) is moderately stained with c. 1.5 ha of associated wetland. It is fringed largely by *Salix* spp. and *Typha orientalis*, although some cabbage trees (*Cordyline australis* [Forster f.] Endlicher) and *Phormium tenax* are also present. On the western and southern margins, dense beds of *Azolla filiculoides* Linnaeus, *Callitriche* sp., *Ludwigia peploides* (Sprengel) Raven and *Polygonum decipiens* R. Brown appear at various times of the year, depending on water levels. Large mats of water lily (*Nymphaea* spp.) are a conspicuous feature of the western margin of the lake. It is surrounded by pastoral land, and fed by numerous small drains. A small outlet drain flows from the southern end of the lake. Its bathymetry is presented in Irwin (1982b).

Lake Maratoto (Plates 3 and 4) is located on the eastern margin of the Rukuhia Peatland. It has the least modified catchment of all nine study lakes and is the most darkly-stained. In 1983 it was considered to be the most acidic lake in New Zealand, excluding those in geothermal areas (Etheredge, 1983); however, increases in pH have occurred recently (Chapters 3.4 and 5.5). Green & Lowe (1985) showed that initially (c. 17,000 yr BP) it had clear water and was about 2 m deep. Marginal peat commenced to develop c. 15,000 yr BP, but the most rapid growth of the Rukuhia Peatland occurred after c. 11,000 yr BP. At present, peat depths around the lake vary; to the west and south-west it deepens to 7 to 8 m, but it is relatively shallow (1 to 4 m) around the remainder of the lake.

Plate 2

1. Lake Mangakaware from the southern end.
2. Lake Mangakaware from the western margin looking towards the southern end.

Plate 2



Plate 3

1. Lake Mangakaware from the eastern margin.
Mt. Pirongia is in the background.
2. Aerial view looking west of Lake
Maratoto. (Photograph: D.J. Lowe).

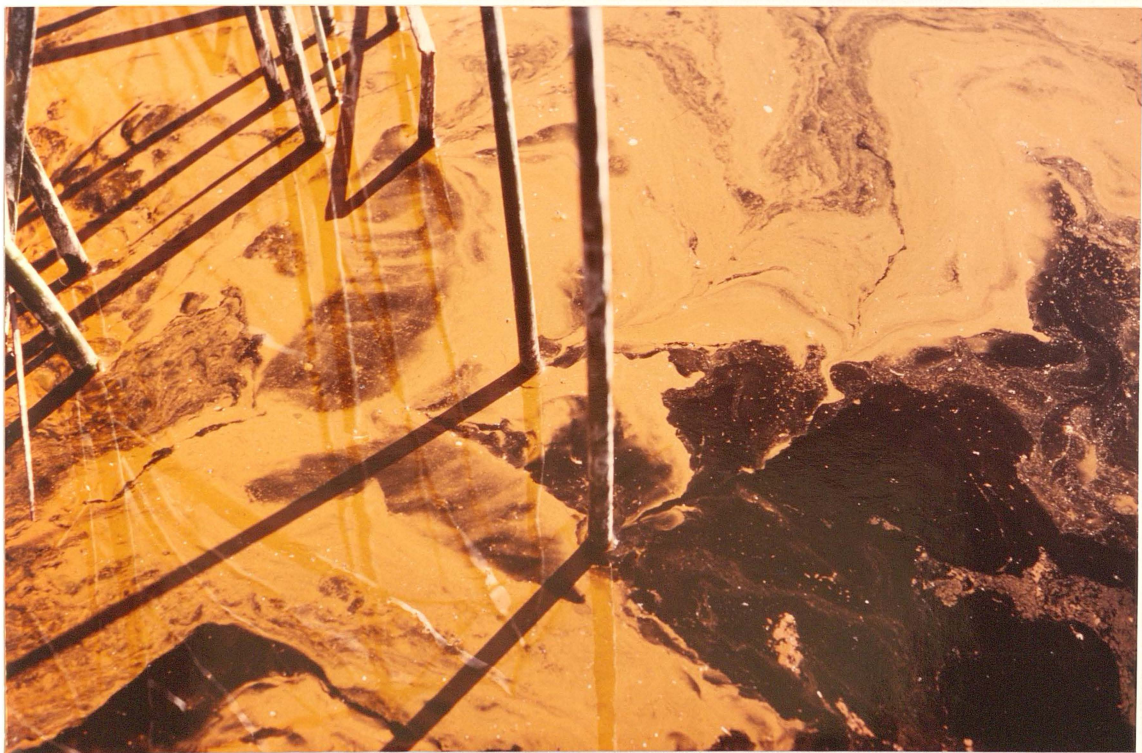
Plate 3



Plate 4

1. *Botryococcus braunii* at the margin of Lake Maratoto.
2. *Botryococcus braunii* in the surface waters of Lake Maratoto.

Plate 4



At the northern and southern ends of the lake, wave action has produced a 0.5 m bank and consequently there is minimal emergent vegetation in these areas, in contrast to the more sheltered zones where relatively dense stands of *Eleocharis sphacelata* and *Baumea articulata* (R. Brown) Blake are present. The absence of *Typha orientalis* is of interest because it is a dominant member of the emergent flora around all other study lakes.

The peripheral vegetation (43 ha) consists largely of *Leptospermum scoparium*, but gorse (*Ulex europaeus* Linnaeus) and blackberry (*Rubus fruticosus* agg.) are also present, particularly throughout the eastern and southern margins. Ferns are important subdominants within this scrub association, and include *Blechnum* spp., *Gleichenia microphylla* R. Brown, *Histiopteris incisa* (Thunberg) J. Smith and *Paesia scaberula* (A. Richard) Kuhn. Patches of *Sphagnum* spp., *Drosera binata* and *Nertera depressa* Banks et Solander ex Gaertner are also common.

No natural rivers or streams feed into Lake Maratoto but an inlet drain enters from the north-west sector of the catchment. There is also considerable sub-surface drainage and runoff from surrounding hills on the eastern side. The outlet, a drain to the north-east, is controlled by a weir, but in fact water seldom leaves the lake. The bathymetry is given in Irwin (1982b).

Lake Ngaroto (Plates 5 and 6), the largest of the study lakes (Table 1/0), lies 30 km south of Hamilton and c. 6 km north-west of Te Awamutu. Less protected from wind than other study lakes, it is highly turbid and yellow-brown in colour. The catchment is largely pastoral and consists mainly of low hills, but some small pockets of wetland still exist; the largest (30 ha) lies to the south. The lake is surrounded almost entirely by a relatively narrow band of peripheral vegetation in which the dominant species are *Typha orientalis* and *Salix* spp. Numerous drains enter the lake from low-lying areas of the catchment, and surface runoff from surrounding hills is high. To prevent winter flooding, the water level is controlled by a weir on the outlet stream near the north-western end of the lake.

Lake Rotokauri lies 7 km north-west of Hamilton, and differs markedly from the other study lakes in that its catchment (c. 1300 ha)

Plate 5

1. Lake Ngaroto from the southern end.
2. Lake Rotokauri from the southern end.

Plate 5



Plate 6

1. Aerial view looking west of Lake Ngaroto (top left). The smaller lakes are Lakes Ngarotoiti (top right) and Rotopiko (foreground). (Photograph: D.J. Lowe).

2. Aerial view looking east of Lakes Rotomanuka North (right) and South (left). (Photograph: D.J. Lowe).

Plate 6



includes residential and industrial areas, together with pastoral land developed from the Ohote Peatland. It is brown-green in colour, and surrounded by low undulating hills which offer considerable protection from wind (Plate 5). The peripheral wetland is generally narrow, and does not contain a wide diversity of species; *Typha orientalis* and *Eleocharis sphacelata* are the dominant emergents. The lake drains via the Ohote Stream into the Waipa River, and its level is controlled by a weir at the outlet.

Lake Rotomanuka was once horse-shoe shaped but, as a direct result of drainage of much of the surrounding area for agricultural purposes, it is now two separate, and markedly different, water bodies (Lakes Rotomanuka North and South), divided by c. 10 ha of wetland (Plate 6). It lies adjacent to the Moanatuatua Peatland near Ohaupo, about 15 km south of Hamilton. Lake Rotomanuka North differs in a number of respects from the other study lakes. It is the deepest lake of the group (Table 1/0), and its almost clear water contrasts strongly with the yellow-brown turbid water of Lake Rotomanuka South, and also with that of the other more darkly-stained lakes. It is well sheltered from the prevailing westerly wind by low surrounding hills. This, together with its moderate depth, permits stable thermal stratification to develop throughout summer (Chapter 3.1; Fig. 3/0). Inlet drains enter both water bodies on their southern margins, but the only outlet stream flows from Lake Rotomanuka North to the north-east. Lake Rotomanuka South is smaller, shallower, and more exposed to wind. Both lakes are surrounded almost entirely by pastoral land (except for the wetland adjoining them), with narrow, peripheral buffer zones consisting largely of *Eleocharis* spp. and *Typha orientalis*. *Salix* spp. and *Leptospermum scoparium* are present in some areas (Plates 6 and 7). Their bathymetries are given in Irwin (1982a).

Lake Rotoroa, or Hamilton Lake (Plate 8), is situated at the eastern edge of the Rukuhia Peatland and within the Hamilton City boundary. It has brown-green coloured water and, unlike the other study lakes, has an urban catchment. Large sections of the shoreline are modified for recreational purposes, but along the western and south-western margins there are narrow buffer fringes consisting mainly of *Eleocharis* spp., *Iris pseudacorus* Linnaeus, *Leptospermum scoparium* and *Typha orientalis*. Large areas of *Nymphaea* spp. are also

Plate 7

1. Lake Rotomanuka North from the south-western side.
2. Lake Rotomanuka South from the southern end.

Plate 7



Plate 8

1. Lake Rotoroa from the western margin.
2. Lake Rotoroa from the north-eastern side.

Plate 8



present. Stormwater from the surrounding urban area drains into the lake, and the water level is controlled by a weir on an outlet to the west.

1.4.2 Submerged Vegetation

Submerged vegetation is absent from the most darkly-stained lakes (Maratoto and Mangahia), and varies in both composition and biomass in the remainder. In general, it is sparse in the moderately stained waters, but forms dense stands throughout large areas of the brown-green to clear-water lakes (Rotokauri, Rotoroa and Rotomanuka North). In Lake Rotokauri, *Egeria densa* Planchon is the dominant species and, despite several herbicide applications over recent years, forms an exceptionally wide littoral band. *Potamogeton ochreatus* Raoul and *Nitella hookeri* A. Brown are also present, but not common. In Lake Rotoroa, *Egeria densa* and *Lagarosiphon major* (Ridley) Moss ex Wager are the dominant vascular taxa. Charophytes (e.g., *Chara corallina* Klein ex Willdenow, em. R.D. Wood and *Nitella hookeri*) are also common (Tanner *et al.*, in press). In the past, as part of various lake management strategies, these macrophyte beds have been sprayed with herbicides and harvested mechanically. However, there have been no macrophyte eradication programmes in Lake Rotomanuka North, and *Egeria densa* forms an almost monospecific, broad, littoral band to a depth of c. 4 m.

1.4.3 Zooplankton Communities

The zooplankton communities of some of the study lakes have been analysed in terms of composition and/or seasonal dynamics (see Chapman & Boubée 1977; Greenwood, 1987; Cryer, in press). In general, the most abundant taxa are *Calamoecia* and/or *Boeckella* (which atypically coexist in some of the lakes), together with *Ceriodaphnia* and *Bosmina*. Rotifers also are quantitatively important.

1.5 CLIMATE

The topography of the Hamilton Basin, in conjunction with its position in relation to the large-scale weather systems, gives it warm

humid summers and mild winters (de Lisle, 1967). Annual rainfall varies between 1200 and 1400 mm with usually a distinct summer minimum and winter maximum. Rain occurs on between 130 to 150 days per year. The Hamilton Basin receives about 2000 h of bright sunshine per year, about 47% of the possible total. Wind is predominantly from the west, and the average daily wind run at Ruakura is 169 km (7.0 km h^{-1}) (Marshall & Petch, 1985). The Hamilton Basin is regarded as one of the least 'gusty' regions of New Zealand (de Lisle, 1967).

CHAPTER TWO

DATA COLLECTION AND ANALYSES

2.1 INTRODUCTION

A one year sampling programme (July 1983 to July 1984) was carried out in all study lakes, except Rotomanuka South, where it ran for only 9 months (October 1983 to July 1984). The lakes were sampled fortnightly, except during winter (May to September), when the interval was increased to 28 days, and were usually visited in the following sequence:

Day 1 - Lakes Maratoto, Rotomanuka North, Rotomanuka South, Ngaroto;

Day 2 - Lakes Mangahia, Mangakaware;

Day 3 - Lakes Rotoroa, Rotokauri, Kainui.

A sampling station was established in the deepest area of each study lake.

2.2 PHYSICO-CHEMICAL METHODS

Water temperatures and dissolved oxygen concentrations were measured at 0.5 m intervals from the surface to the bottom, using a YSI oxygen meter (model 54). A standard 20 cm Secchi disc was used to measure water transparency. Water samples for pH analyses were collected at 0.1 m, transported to the laboratory in an ice box and allowed to return to room temperature while remaining in the dark. Measurements were made with an Orion Research Digital Ionalyzer (model 501).

Two series of water samples (spring and summer), collected from c. 0.1 m below the lake surface, were analysed for conductivity, turbidity, absorbance (270 and 400 nm; filtered and unfiltered) and chemical composition. The analyses were performed by the Ministry of Works and Development, Water Quality Centre, Hamilton.

2.3 BIOLOGICAL METHODS

2.3.1 Sample Collection and Preservation

Water samples for phytoplankton analyses were collected with a 10 mm (I.D.), rubber, integrated tube sampler (Lund, 1949; Lund & Talling, 1957) lowered to within 5 cm of the bottom sediments. Each sample was emptied into a well-rinsed bucket and thoroughly mixed before 100 ml were removed and immediately preserved with c. 2 ml Lugol's iodine.

2.3.2 Phytoplankton Enumeration

Phytoplankton were counted using the sedimentation technique (Utermöhl, 1958). Each sample was gently but thoroughly shaken prior to the removal of an aliquot (5 to 25 ml) for sedimentation. A minimum of 24 h settling time was allowed.

Two Olympus inverted microscopes (M1 and M2) were used during the study. M1 was used to count the July to October 1983 samples, while the remainder were counted using M2.

Two counting procedures were employed: first, large and rare taxa were counted during a scan of the complete chamber using a low magnification (x240, M1; x300, M2); secondly, using a higher magnification (x480, M1; x600, M2), the remaining taxa were counted along diameter belt transects. To achieve 20% counting accuracy (an acceptable level for phytoplankton analyses [Utermöhl, 1958; Hobro & Willén, 1977]), counting continued until each major species had been recorded at least 100 times (Lund *et al.*, 1958). Empty or 'dead' cells were excluded from the counts; a cell was considered 'dead' if it contained less than one-half of the usual cellular contents for that species.

Coenobial and filamentous species were counted as independent units or plankton units (Chandler, 1940; Lewis, 1978). Irregular, colonial species were treated similarly, with the exception of *Aphanocapsa*, *Botryococcus* and *Microcystis*, which were recorded as plankton units only, because of the problem of counting individual cells.

The total number of each species per aliquot was calculated by multiplying the ratio of the chamber area to the area of the belt transect/transects by the number recorded. Data were subsequently converted to pu ml^{-1} . The results of the phytoplankton counts (Appendix IV) are held in the library, University of Waikato.

2.3.3 Identification

The general taxonomic texts consulted for identification were: Huber-Pestalozzi (1938, 1941, 1942, 1955, 1961); Prescott (1962); Bourrelly (1966, 1968, 1970); Huber-Pestalozzi & Fott (1968, 1972); Whitford & Schumacher (1973); Huber-Pestalozzi & Förster (1982); Huber-Pestalozzi *et al.*, (1983). These texts were supplemented by specialist literature (Appendix V). The taxonomic arrangement to the

familial level follows Bourrelly (1966, 1968, 1970).

Two methods were used to remove organic material from diatoms. During a mild cleaning treatment, a subsample was mixed with H₂O₂ (30% v/v) and allowed to stand at room temperature for 24 h (Barber & Haworth, 1981). However, extremely persistent organic matter was removed by heating a subsample with H₂O₂ (40% v/v) (Munawar & Munawar, 1982) for c. 30 minutes. Water mounts were subsequently prepared.

A magnification of x945 (M2) was used for critical taxonomy, and photographic records were made of the majority of taxa (Appendix VI).

2.4 METHODOLOGY FOR DATA ANALYSES

2.4.1 Mean Cell Biovolume and Biomass

The biovolumes of a minimum of ten individuals selected from throughout the entire sampling period were used to calculate a mean cell/colony/filament biovolume for each species in each lake. Linear measurements (excluding spines and gelatinous material) were made with an ocular micrometer at x480 (M1) or x600 (M2). Biovolumes were calculated using stereometric formulae which most closely approximated their shape or composite shapes, and were subsequently converted to biomass expressed as wet weight (mg or g m³), assuming that the specific gravity of phytoplankton is unity (Willén, 1959; Reuter, 1979; Holmgren, 1984).

2.4.2 Greatest Axial Linear Dimensions

The mean GALD (greatest axial linear dimension [Lewis, 1976]) was calculated for each species in each lake; wherever possible, measurements were obtained from a minimum of twenty individuals selected from throughout the entire sampling period. For a cylindrical species it was the length of the cylinder, for a spherical species the diameter, and for an ellipsoidal species the longest axis of rotation. However, for irregular colonies, the GALD was taken as the longest line connecting any two surfaces, despite the fact that this line could not pass through an axis of symmetry (Lewis & Riehl, 1982). The SGALD (second greatest axial dimension [Lewis, 1979]) was recorded for all phytoplankton species present throughout Experiments I and II (Chapter 8).

2.4.3 Size Fractions

The GALD of each species was used as a size criterion (Willén, 1959; Kalff, 1967). Taxa with GALDs $\geq 64 \mu\text{m}$ were categorised as net plankton, while those with GALDs of 6 to $63 \mu\text{m}$, and $\leq 5 \mu\text{m}$, were regarded as nanoplankton and ultraplankton, respectively (Kalff, 1972; Sheath & Munawar, 1974; Kalff & Knoechel, 1978).

2.4.4 Statistical Analyses

Statistical analyses were used to determine both distribution and association patterns. Species diversity was calculated in three ways: (1) α diversity (d) (Whittaker, 1975), where

$$d = S/\log N$$

and S = number of species per sample

N = total number of individuals per sample,
was calculated for each sample per lake;

(2) β diversity (BD) (Whittaker 1960, 1972; Wilson & Schmida, 1984), where

$$BD = S_c/\bar{S}$$

and S_c = composite number of species

\bar{S} = mean number of species per sample,
was calculated for the composite phytoplankton community from all nine study lakes;

(3) Shannon-Wiener Information Index (Atlas, 1984; Washington, 1984) where

$$H' = -\sum_{i=1}^s p_i \log_2 p_i$$

and p_i = proportion of the community belonging to the i th species,
was calculated for each sample per lake.

An Important Species Index (ISI), calculated by multiplying the percent frequency of occurrence of each species by its mean relative density (Ross & Rushforth, 1980; Grimes & Rushforth, 1983; Rushforth *et al.*, 1986), was calculated for species with mean contributions \geq

0.1% of the mean total density in each lake.

Measurements of relative similarity of the phytoplankton communities were calculated from both presence/absence data and relative density data. The two indices used were:

(1) Coefficient of Community (CC) (Jaccard's Index [Washington, 1984]), where

$$CC = 100 \{N_c / (N_i + N_j)\}$$

and N_c = number of species common to samples i and j
 N_i and N_j = number of species in samples i and j , respectively;

(2) Percentage Similarity (PSc) (Whittaker, 1952; Whittaker & Fairbanks, 1958), where

$$\begin{aligned} PSc &= 100 - 0.5\sum(a-b) \\ &= \sum \min(a,b) \end{aligned}$$

and a and b = for a given species, the percentages of samples A and B which that species represents.

Clustering of CCs as dendrograms for single linkage analyses followed Hellawell (1978) and Legendre & Legendre (1978).

The coefficient of variation (C.V.) where $C.V. = s/\bar{x}$ and a skewness statistic (SK) (Glass & Stanley, 1970), where

$$SK = \frac{\sum_{i=1}^n (x_i - \bar{x})^3 / n}{s^3}$$

were used to quantify variations in species abundance.

2.5 ASSESSMENT OF METHODOLOGY

2.5.1 Biological Methods

The frequency of sampling necessary for a particular investigation is controlled by its overall objectives. However, because phytoplankton communities are highly dynamic, most phycological research demands a relatively short sampling interval. In the present study, a 14 day sampling interval (except during the winter when it

was increased to 28 days), was considered appropriate because the investigation focused on variations in community structure and biomass, rather than detailed population dynamics within each community. A 14 day sampling interval has been recommended by Willén & Willén (1978) for studies of this type.

The number of sampling stations needed to yield data representative of the planktonic systems of relatively small lakes is uncertain. Since Hutchinson (1961) questioned the early view of a homogeneous planktonic environment at equilibrium over a large scale, horizontal heterogeneity of phytoplankton has been studied widely over a range of scales (e.g., Powell *et al.*, 1975; Richerson *et al.*, 1975; George & Edwards, 1976; Heaney, 1976; Richards & Happeywood, 1979; Abbott *et al.*, 1982; Jones & Francis, 1982; Trimbee & Harris, 1983). The importance of horizontal patchiness in marine environments is unquestionable (Riley, 1976) but, in lakes where distance scales are smaller, its significance is still unclear. Lewis (1978a), for example, considered that horizontal heterogeneity was not important in Lake Lanao, despite the fact that it was detectable statistically, and concluded that significant patchiness occurred only at scales considerably greater than 1 km.

In the present study, it was assumed that a sample taken from a single station (at the deepest area of each lake) was adequate to describe major seasonal trends. The lakes are relatively small, the majority displayed marked vertical mixing (Chapter 3), and no obstructions (such as islands) are present. Also, phytoplankton species composition tends to vary more along the vertical axis than in the horizontal plane (Richerson *et al.*, 1970, 1975). A stratified sampling programme (e.g., Irish & Clarke, 1984) or an analysis of integrated samples, as recommended by Vietinghoff *et al.*, (1984), may have produced more accurate assessments of the phytoplankton population dynamics, but such techniques were considered unnecessary in relation to the objectives of the study, and impractical because of time restrictions.

The Utermöhl technique is the preferred method for the determination of phytoplankton community structure and population dynamics (Lund *et al.*, 1958; Hasle, 1978; Wetzel & Likens, 1979; Rott, 1981). Although Willén (1962) rejected the technique as too time-consuming, there is no quicker method that could replace it and at the same time provide accurate quantitative information.

There are two major disadvantages inherent in the technique. The first, which may lead to inaccuracies in biomass estimations and thus spurious conclusions, results from difficulties in determining cell viability, particularly of armoured species. For example, Paerl (1978), compared counts of viable cells using Utermöhl and autoradiography techniques, and found significant discrepancies between the two methods, because the former presents the problem of distinguishing between functional intracellular material and decomposing cellular contents. In Lakes Mangahia and Ngaroto, where diatoms were quantitatively important (Tables 4/8 and 4/23, respectively), this problem is of particular concern. Armoured phytoplankton such as these do not decompose rapidly, their cellular contents may persist for several days after death, and they can remain in the water column for an appreciable time before sedimenting (Paerl, 1978).

The second disadvantage is the 'closed' nature of the counting chamber. Because phytoplankton cannot be manipulated for taxonomic purposes during counting, it necessitates a time-consuming relocation and repositioning of specific organisms after counting has been completed.

Accurate estimates of biomass are essential for analyses of phytoplankton community dynamics and comparative studies, but they are very difficult to obtain and reproduce (Hobro & Willén, 1975, 1977; Hallegraeff, 1977; Smayda, 1978). The sources of error in biovolume estimations based on species composition, number and estimated biovolumes are: (1) lack of accuracy in measuring and calculating the biovolumes of irregularly shaped taxa; (2) varying ratios of metabolising cytoplasm, vacuolar 'dead' volume and resistant wall materials; (3) influences of the physiological state of a cell on volumes of cytoplasmic constituents (Sicko-Goad *et al.*, 1977). Also, a transformation of numerical abundance to biomass units may exaggerate the importance of larger taxa relative to smaller ones (Lohmann, 1908).

2.5.2 Statistical Analyses of Laboratory and Field Techniques

The distribution of phytoplankton on the basal plate of the sedimentation chamber was tested using Fisher's Index of Dispersion

(Fisher, 1948), as defined by Lund *et al.*, (1958):

$$\chi^2 = \Sigma(x - \bar{x})^2/\bar{x}$$

Counts were made of the six most common taxa in each of eight chamber transects from a Lake Mangakaware sample (Table 2/0). The limiting value for χ^2 ($p = 0.05$) is 14.067, with 7 degrees of freedom, thus all taxa, except *Dinobryon cylindricum* and *Synura uvella*, were distributed randomly. The nonrandom distribution of these two species may be because while each lorica or cell represented one plankton unit, the number of colonies relative to the number of individual units which sedimented onto the chamber base was not constant.

In order to test for the existence of an 'edge effect' (Sandgren & Robinson, 1984), comparisons were made of the densities of the six most common taxa in the peripheral and central areas of the chamber. Stratified sampling was used; the phytoplankton from the two areas were counted separately, and three transects (0.25 diameter of chamber) were used per area. There was no significant difference (t test; $p \geq 0.05$) between the two regions (Table 2/1).

Fisher's Index of Dispersion was used to determine whether or not aliquots were randomly drawn from a particular sample. A 200 ml Rotomanuka North sample was gently but thoroughly shaken, and 10 x 10 ml aliquots removed by means of a quick-filling pipette. After settling, counts were made of the six most abundant taxa in each aliquot (Table 2/2). The limiting value for χ^2 ($p = 0.05$) is 16.919 with 9 degrees of freedom, hence the technique was considered to produce a random distribution.

The time required to obtain complete sedimentation of the phytoplankton was determined using a modified method of Furet & Benson-Evans (1982). Three x 25 ml aliquots from a Lake Mangahia sample were prepared in sedimentation chambers (Chapter 2.3.2). After 12 h, 15 ml of the supernatant from each chamber was siphoned off, made up to 25 ml with distilled water and resettled in three new chambers for a further 12 h. The process was repeated after a total period of 36 h. Three replicate transects were counted per chamber, and the results indicate that a minimum of 24 h was adequate for sedimentation (Table 2/3).

TABLE 2/0 Test for random distribution of phytoplankton on the basal plate of a Utermöhl counting chamber: Fisher's index of dispersion (X^2) for counts of the 6 most abundant taxa that occurred in each of 8 transects. (Aliquots drawn from a Lake Mangakaware subsample.)

Taxon	Mean No. Plankton Units. ml ⁻¹ ± 1 SD (n = 10)	X ² *
<i>Asterionella formosa</i>	4425.5 ± 50.6	4.05
<i>Closterium acutum</i> var. <i>variabile</i>	1049.5 ± 36.5	8.87
<i>Aulacosira granulata</i>	174.0 ± 17.2	11.95
<i>Trachelomonas volvocina</i>	104.13 ± 13.8	12.84
<i>Synura</i> sp.	61.25 ± 11.4	14.88
<i>Dinobryon cylindricum</i>	29.0 ± 12.5	37.8
*Critical value (p = 0.05) is 14.067 with 7 degrees of freedom		

TABLE 2/1 Test for an 'edge effect' using a stratified counting technique: mean numbers of plankton units ml⁻¹ ± 1 SD of the 6 most abundant taxa. (Aliquot drawn from a Lake Mangakaware subsample.)

Taxon	<u>Peripheral Region</u>	<u>Central Region</u>	<u>t Test</u>	
	Mean No. pu ml ⁻¹ ± 1 SD (n = 3)	Mean No. pu ml ⁻¹ ± 1 SD (n = 3)	t	p
<i>Asterionella formosa</i>	4431.3 ± 61.3	4405.3 ± 33.2	0.65	ns
<i>Closterium acutum</i> var. <i>variabile</i>	1055.3 ± 29.1	1049.3 ± 42.0	0.2	ns
<i>Dinobryon cylindricum</i>	30.0 ± 12.5	16.7 ± 10.1	1.44	ns
<i>Aulacosira granulata</i>	150.0 ± 12.0	166.7 ± 16.3	1.43	ns
<i>Synura</i> sp.	62.0 ± 12.5	64.7 ± 11.7	0.27	ns
<i>Trachelomonas volvocina</i>	111.3 ± 16.7	92.7 ± 9.9	1.67	ns

TABLE 2/2 Test for random distribution of phytoplankton in 10 aliquots drawn from a Lake Rotomanuka North subsample: Fisher's index of dispersion (X^2) for counts of the 6 most abundant taxa.

Taxon	Mean Number pu ml ⁻¹ ± 1 SD (n = 10)	X ² *
<i>Cryptomonas ovata</i>	111.52 ± 12.6	12.82
<i>Peridinium cinctum</i>	43.2 ± 8.0	13.2
<i>Monoraphidium irregulare</i>	27.12 ± 6.8	15.5
<i>Closterium acutum</i> var. <i>variabile</i>	13.0 ± 4.14	11.9
<i>Cyclotella stelligera</i>	12.8 ± 3.6	9.3
<i>Botryococcus braunii</i>	12.72 ± 4.7	15.3
*Critical value (p = 0.05) is 16.919 with 9 degrees of freedom		

TABLE 2/3 Mean numbers of plankton units ml⁻¹, mean volumes and cumulative percentages of each Class of phytoplankton sedimented successively over 12, 24 and 36 hours, from a 25 ml Lake Mangahia subsample (preserved with Lugol's iodine; n = 9).

Taxon	Mean Volume/ Plankton Unit (μm^3)	12 Hours		24 Hours		36 Hours	
		Mean No. pu ml ⁻¹	Mean Biomass (mg m ³)	Mean No. pu ml ⁻¹	Mean Biomass (mg m ³)	Mean No. pu ml ⁻¹	Mean Biomass (mg m ³)
CHLOROPHYTA							
Euchlorophyceae							
<i>Ankistrodesmus fusiformis</i>	50.0	4	0.2				
<i>Crucigeniella apiculata</i>	41.9	12	0.5				
<i>Monoraphidium contortum</i>	17.7	36	0.6				
<i>M. minutum</i>	6.2	96	0.6	4.0	0.02		
<i>M. tortile</i>	12.9	140	1.8	8.0	0.1		
<i>Raphidocelis contorta</i>	23.5	48	1.1				

TABLE 2/3 contd.

<i>Scenedesmus intermedius</i>	188.5	20	3.8		
<i>S. opoliensis</i>	502.6	280	140.7		
<i>S. quadricauda</i>	402.1	640	257.3		
<i>Tetrastrum heteracanthum</i>	81.0	32	2.6		
<i>T. staurogeniaforme</i>	64.0	32	2.0		
<i>T. triangulare</i>	125.0	236	29.5		
Percentage		99.2	99.97	0.8	0.02
Zygophyceae					
<i>Closterium acutum</i> var. <i>variabile</i>	83.8	80	6.7		
<i>C. gracile</i>	775.5	60	46.7		
<i>Staurostrum</i> sp.B	670.0	28	18.7		
		100	100		
CHROMOPHYTA					
Chrysophyceae					
<i>Chrysococcus rufescens</i>	381.7	80	30.5		
<i>Mallomonas acaroides</i>	268.1	8	2.1		

TABLE 2/3 contd.

Percentage		100	100		
Diatomophyceae					
<i>Cyclotella stelligera</i>	100.5	68	6.8	4	0.4
<i>Aulacosira distans</i>	196.3	5600	1099.3		
<i>A. granulata</i> var. <i>angustissima</i>	1005.3	2400	2452.9		
<i>Tabellaria flocculosa</i>	1600.0	96	153.6		
Percentage		99.95	99.99	0.05	0.01
Xanthophyceae					
<i>Centritractus belonophorus</i>	6900.0	8	55.2		
<i>Goniochloris smithii</i>	312.5	28	8.8		
<i>Tetraedriella jovetii</i>	134.0	20	2.7	4	0.5
Percentage		99.33	99.2	6.66	0.79

TABLE 2/3 contd.

EUGLENOPHYTA				
Euglenophyceae				
<i>Phacus pleuronectes</i>	1734.9	4	7.0	
<i>Trachelomonas volvocina</i>	2572.0	240	617.3	
Percentage		100	100	
PYRRHOPHYTA				
Cryptophyceae				
<i>Cryptomonas ovata</i>	307.9	328	101.0	
Percentage		100	100	

CHAPTER THREE

PHYSICO-CHEMICAL REGIMES

3.1 TEMPERATURE

Two types of mixing patterns were recorded during the present study: first, a pattern incorporating winter holomixis and weak vernal stratification, followed by permanent and marked summer stratification, and a gradual return to holomixis throughout autumn; and secondly, a cycle in which summer stratification was either transient or frequently interrupted by brief periods of mixing.

Lake Rotomanuka North belonged to the first category, and thus may be described as warm monomictic. In July 1983, the lake was almost homothermal, but stratification gradually developed during August and September, and was marked by the end of October. During late summer and autumn the depth of the thermocline increased, and the water column was completely mixed by 24.5.84 (Fig. 3/0). The maximum temperature at 0.5 m was 24°C (19.1.84), and the mean was 17.6°C. Further details of the thermal regime are given in Table 3/0. This pattern was remarkably similar to that recorded in 1979 (Etheredge, 1983).

Lake Rotokauri also displayed marked stability of the water column throughout summer, but clearly it was not a continuous feature, with bottom temperatures indicating that mixing occurred at least once between 24.12.83 and 7.1.84 (Fig. 3/1). The mean temperature at 0.5 m was 17.3°C, the lowest in the series (Table 3/0).

The remainder of the study lakes were discontinuous, warm polymictic (Lewis, 1983). The vertical temperature profiles of Lakes Maratoto (Fig. 3/2), Kainui (Fig. 3/3) and Ngaroto (Fig. 3/4) indicate that although their water columns stabilised at some stage during summer, such stability was short-lived. The maximum temperature difference between surface and bottom waters in these lakes, for example, was 4.5°C (Lake Ngaroto).

The mixing patterns of Lakes Mangahia (Fig. 3/5), Mangakaware (Fig. 3/6) and Rotoroa (Fig. 3/7) were more complex than those of other study lakes. In July 1983, they were all homothermal but, throughout spring and summer, periods of water column stability were frequently interrupted by brief periods of mixing. For example, in Lake Mangahia, holomixis clearly occurred between late September and

Fig. 3/0 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Rotomanuka North, July 1983 to July 1984

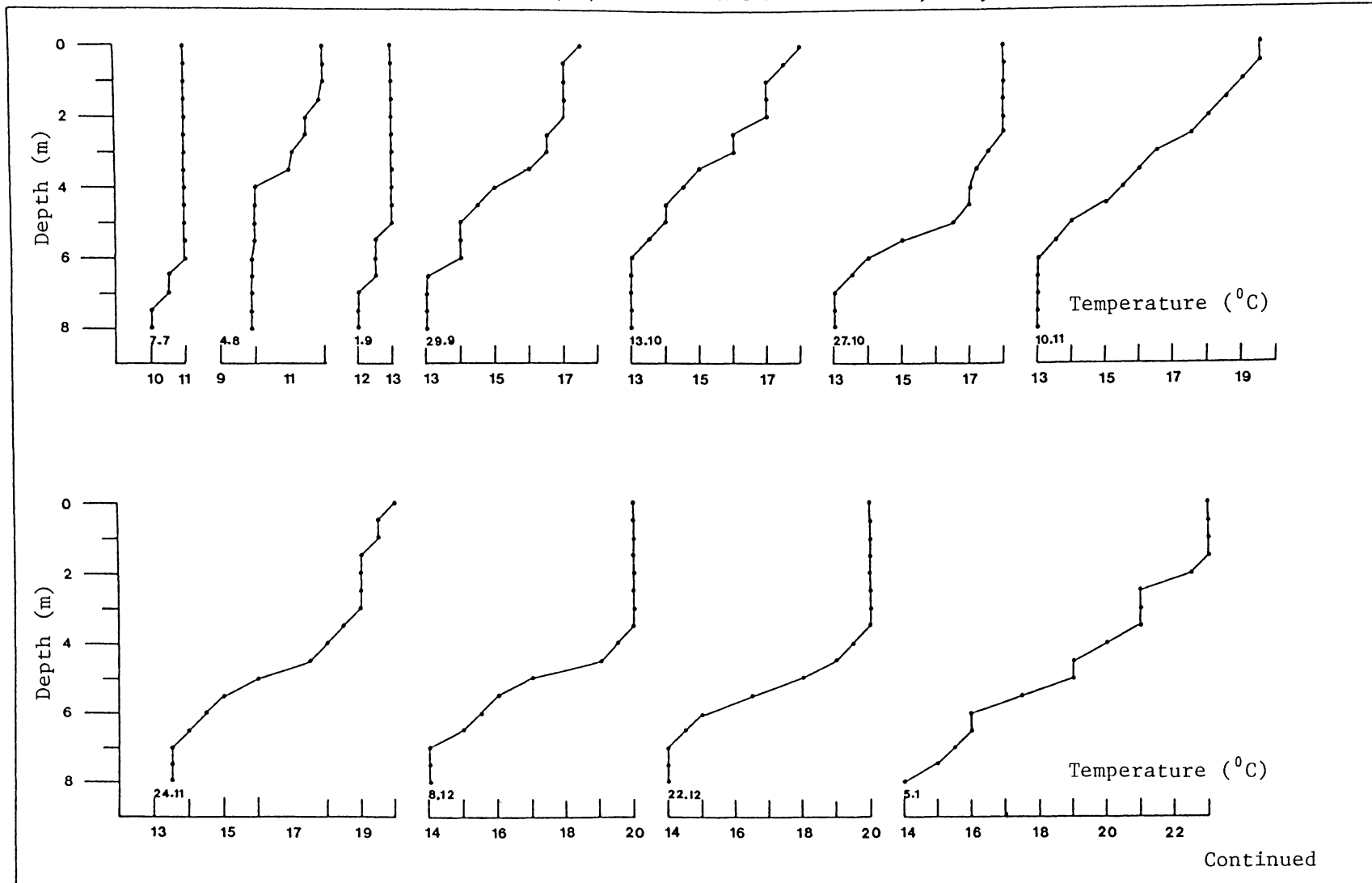


Fig. 3/0 continued

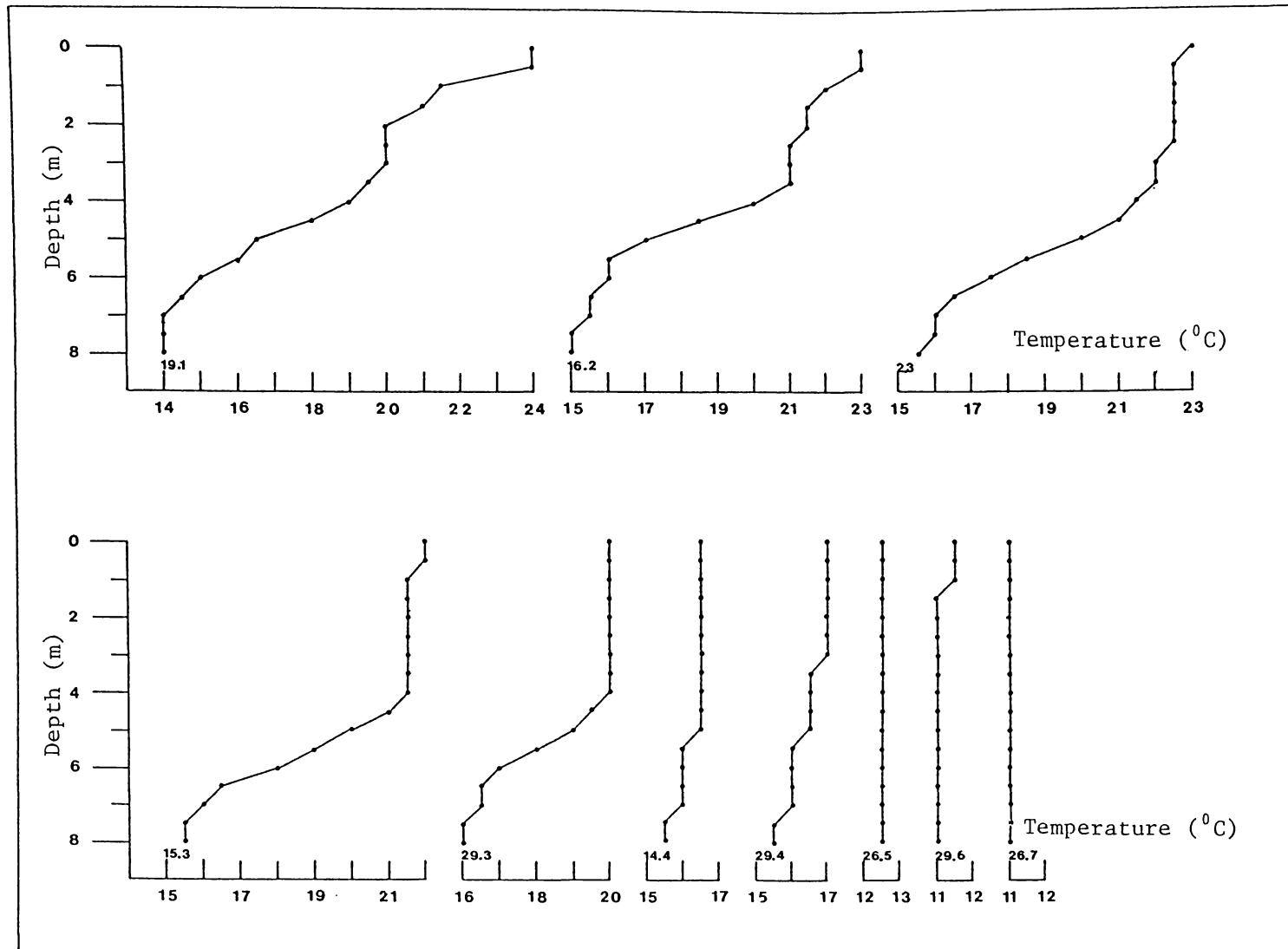


TABLE 3/0 Mean temperatures (°C) and percentage oxygen saturation at two depths (with ranges below) for the 9 study lakes, July 1983 to July 1984 (n = 22).

Lake	Mean Temperature (°C)		Mean Percentage Oxygen Saturation	
	0.5 m below surface	Bottom	0.5 m below surface	Bottom
Kainui	18.1 (11 - 24)	17.4 (11 - 22)	98.7 (81 - 115)	79.6 (2.3 - 112)
Mangahia	18.0 (11 - 25)	16.7 (11 - 21.5)	81.2 (63 - 102)	44.8 (8.3 - 85)
Mangakaware	18.3 (11 - 25)	16.5 (10.9 - 22)	93.0 (69 - 115)	42.9 (2.3 - 91)
Maratoto	17.5 (11 - 23)	16.7 (11 - 21)	88.8 (64 - 116)	46.9 (2.3 - 96)
Ngaroto	17.7 (11 - 23)	17.1 (11 - 22)	100.3 (88 - 121)	68.5 (15 - 110)
Rotokauri	17.3 (11 - 24)	15.6 (9.5 - 20.5)	83.8 (24.5 - 121)	30.0 (4 - 86)
Rotomanuka North*	17.6 (11 - 24)	13.3 (9.9 - 15.5)	93.4 (74 - 117)	24.9 (1 - 80)
Rotomanuka South**	18.8 (11 - 24)	17.1 (11 - 20.5)	98.9 (62 - 150)	34.7 (2.2 - 91)
Rotoroa	18.5 (11 - 24)	17.3 (11 - 21.5)	92.7 (79 - 108)	72.8 (44 - 104)
* n = 21				
** n = 18				

Fig. 3/1 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Rotokauri, July 1983 to July 1984

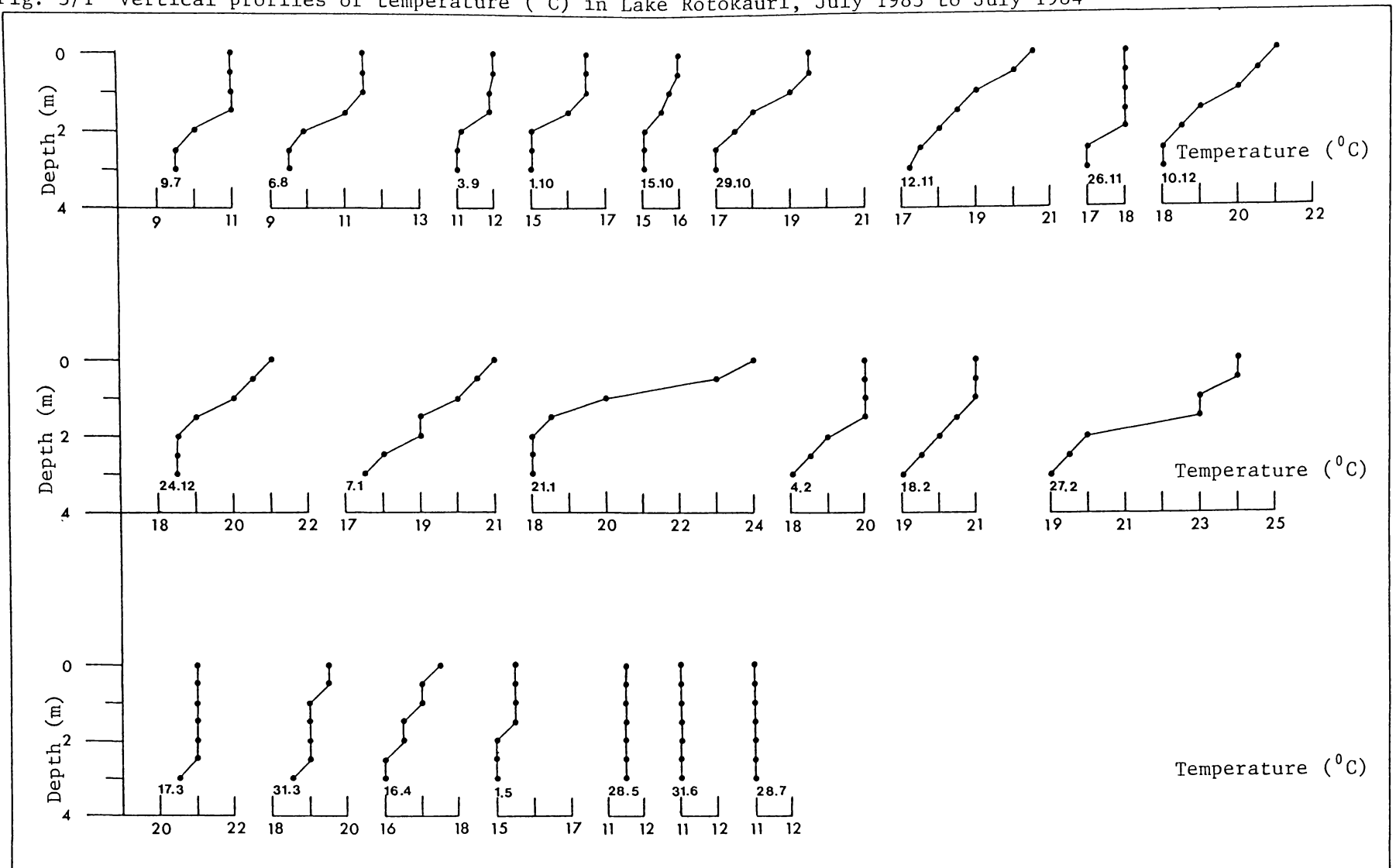


Fig. 3/2 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Maratoto, July 1983 to July 1984

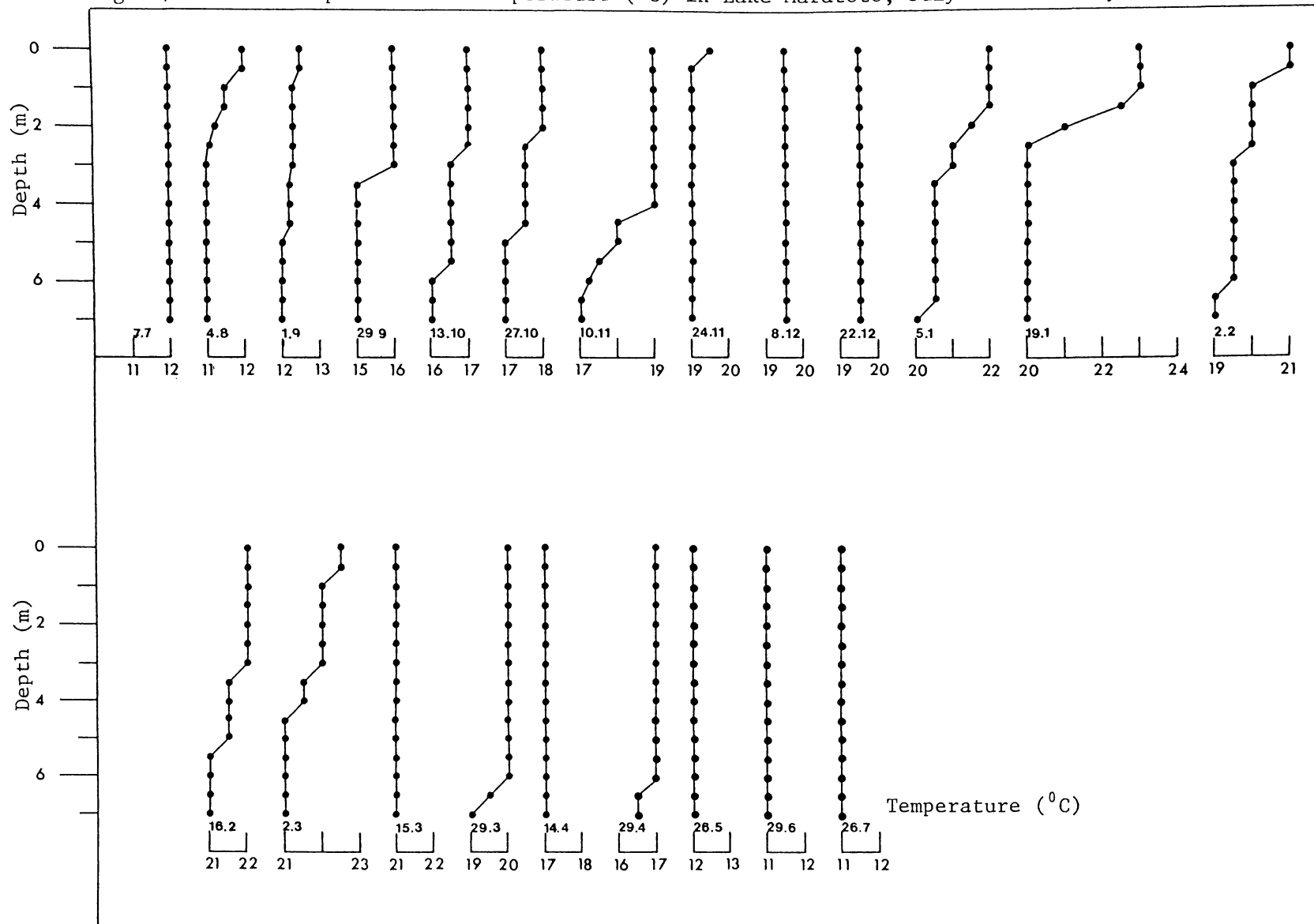


Fig. 3/3 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Kainui, July 1983 to July 1984

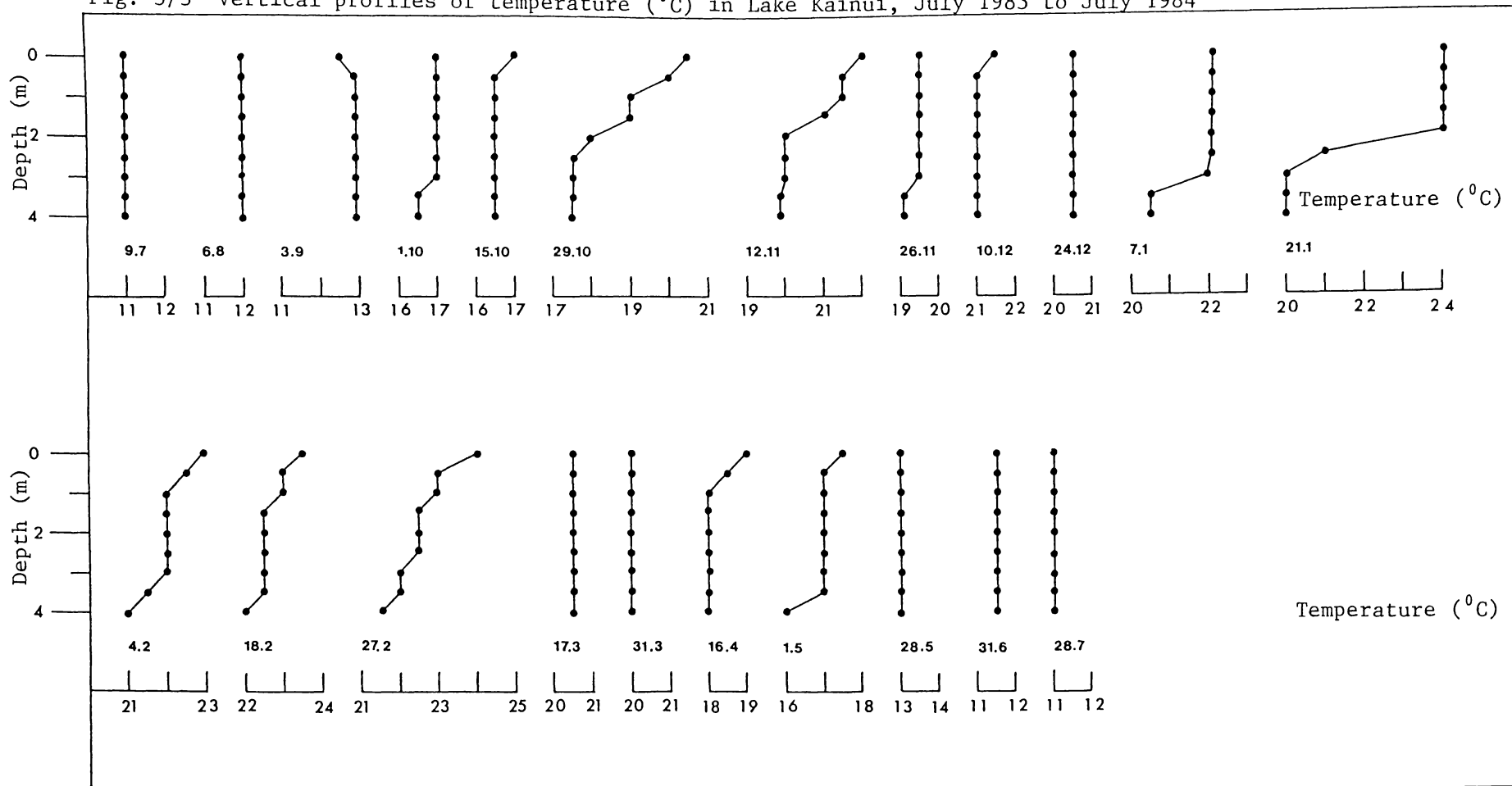


Fig. 3/4 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Ngaroto, July 1983 to July 1984.

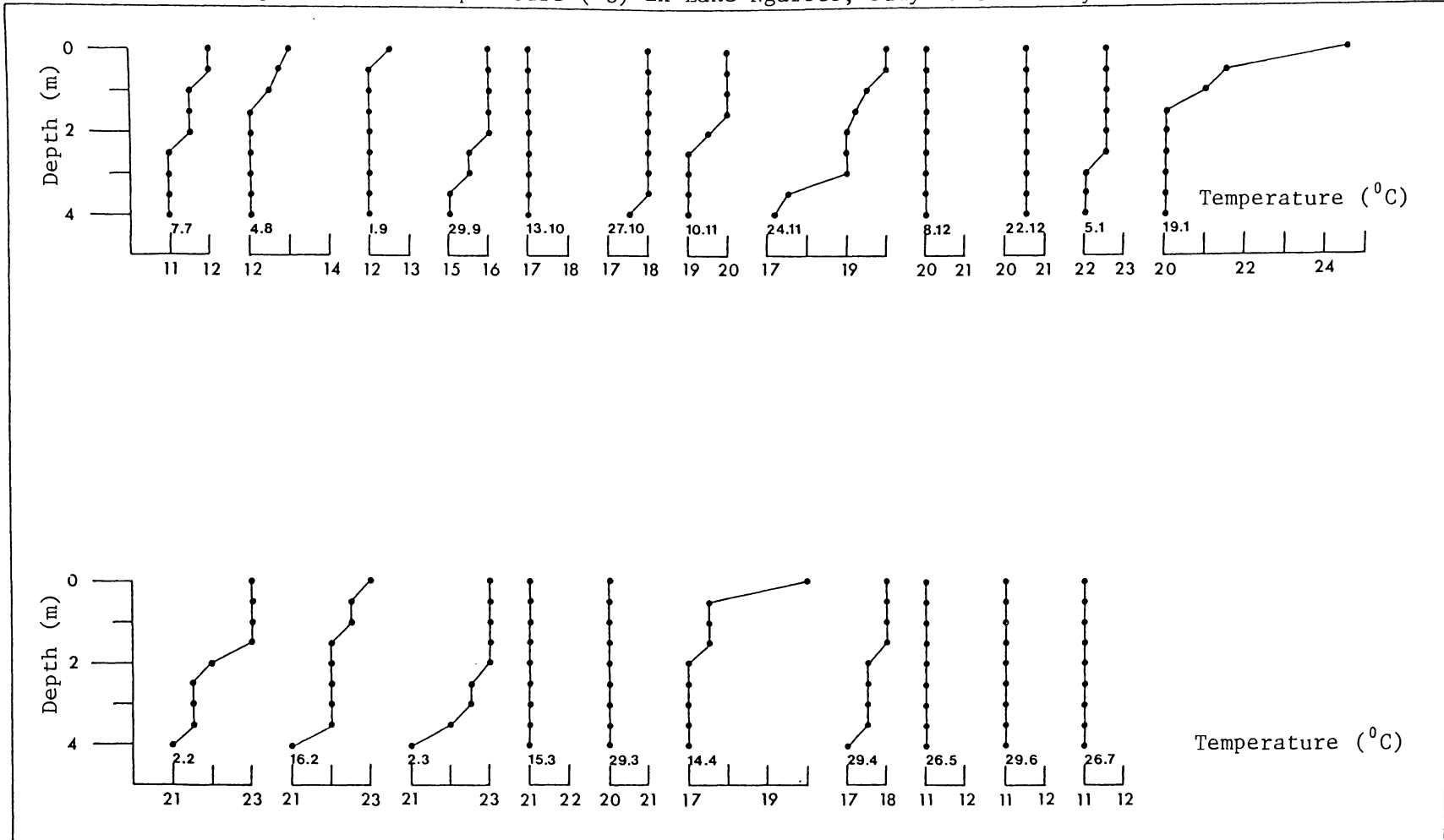


Fig. 3/5 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Mangahia, July 1983 to July 1984

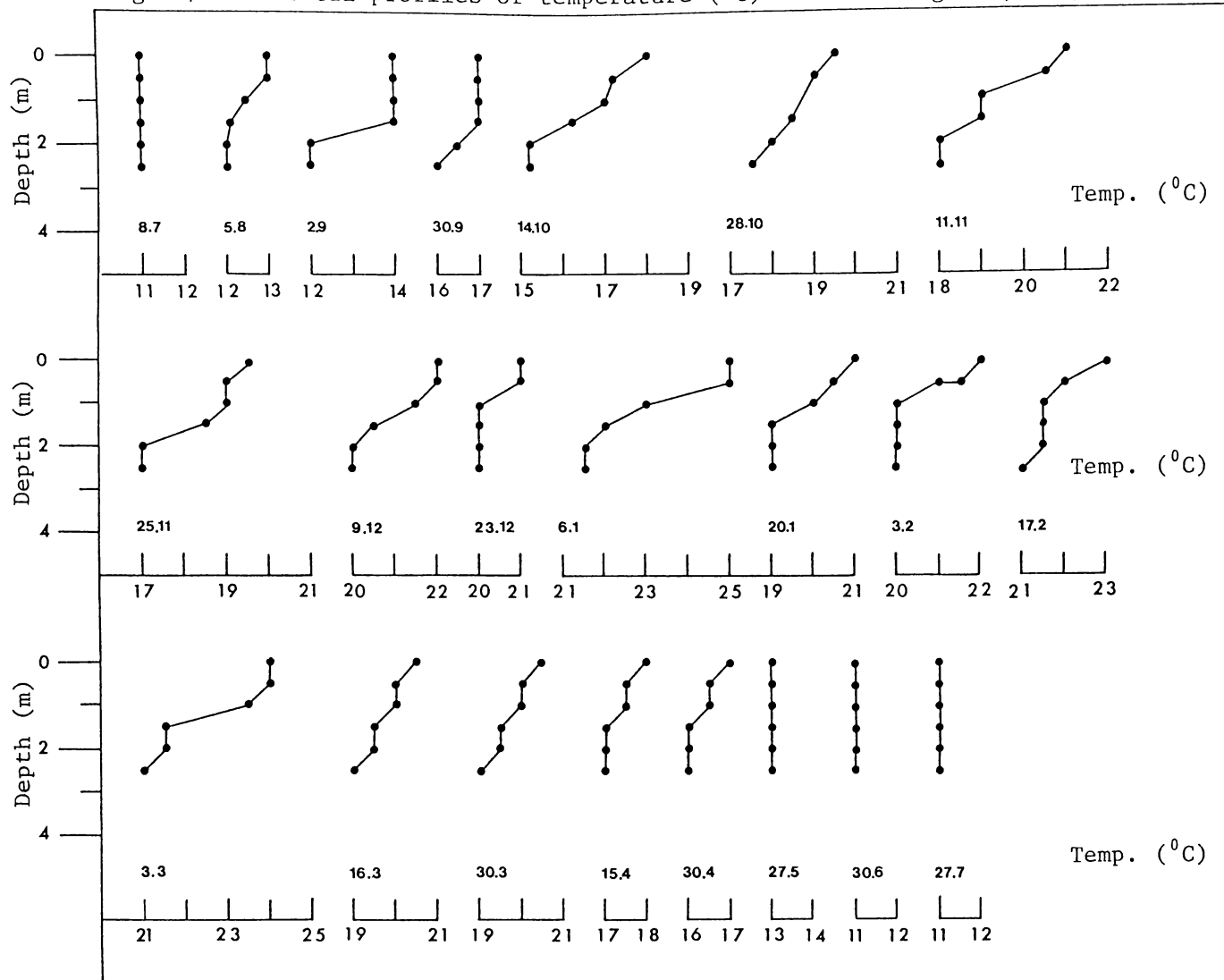


Fig. 3/6 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Mangakaware, July 1983 to July 1984.

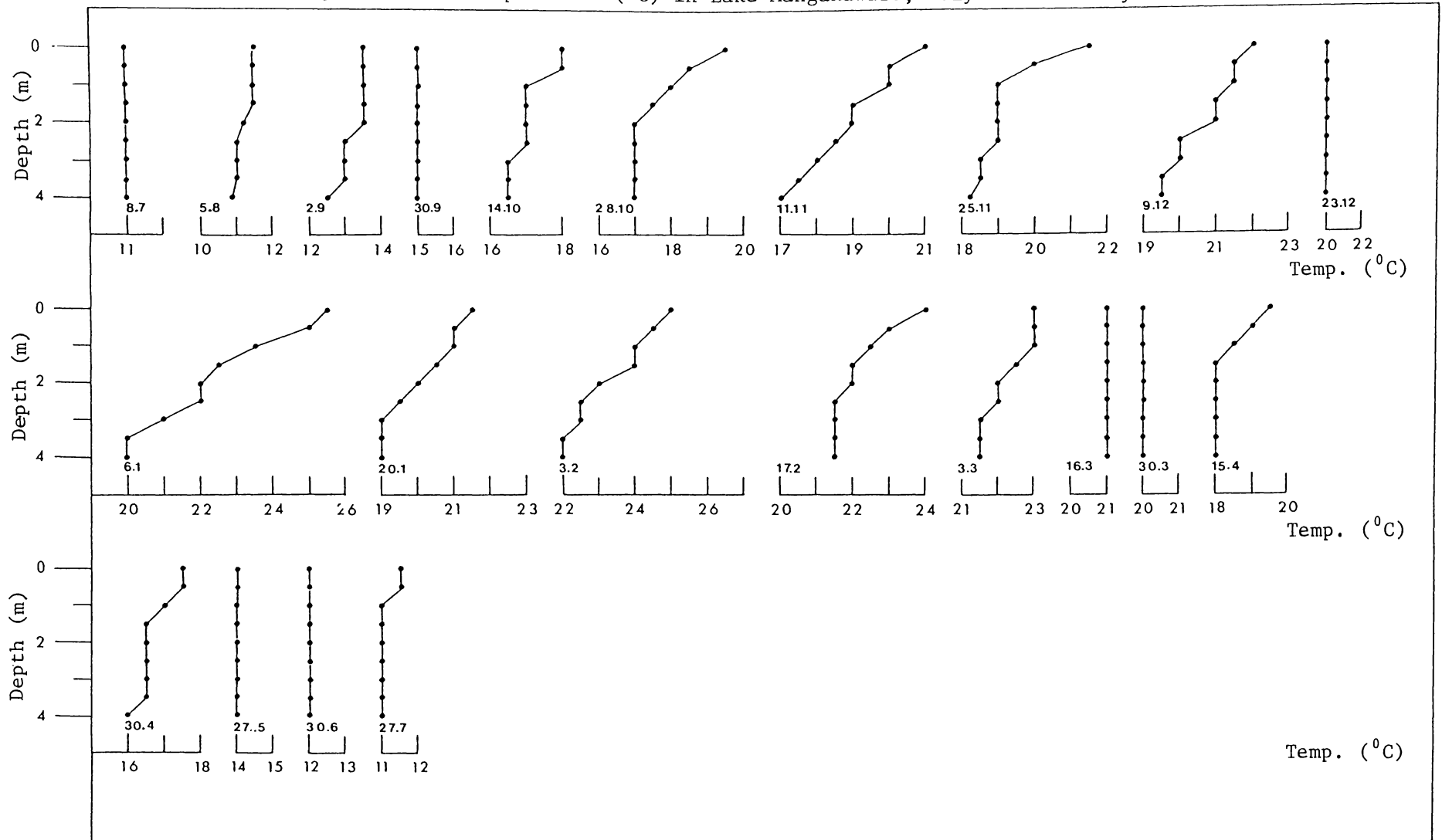
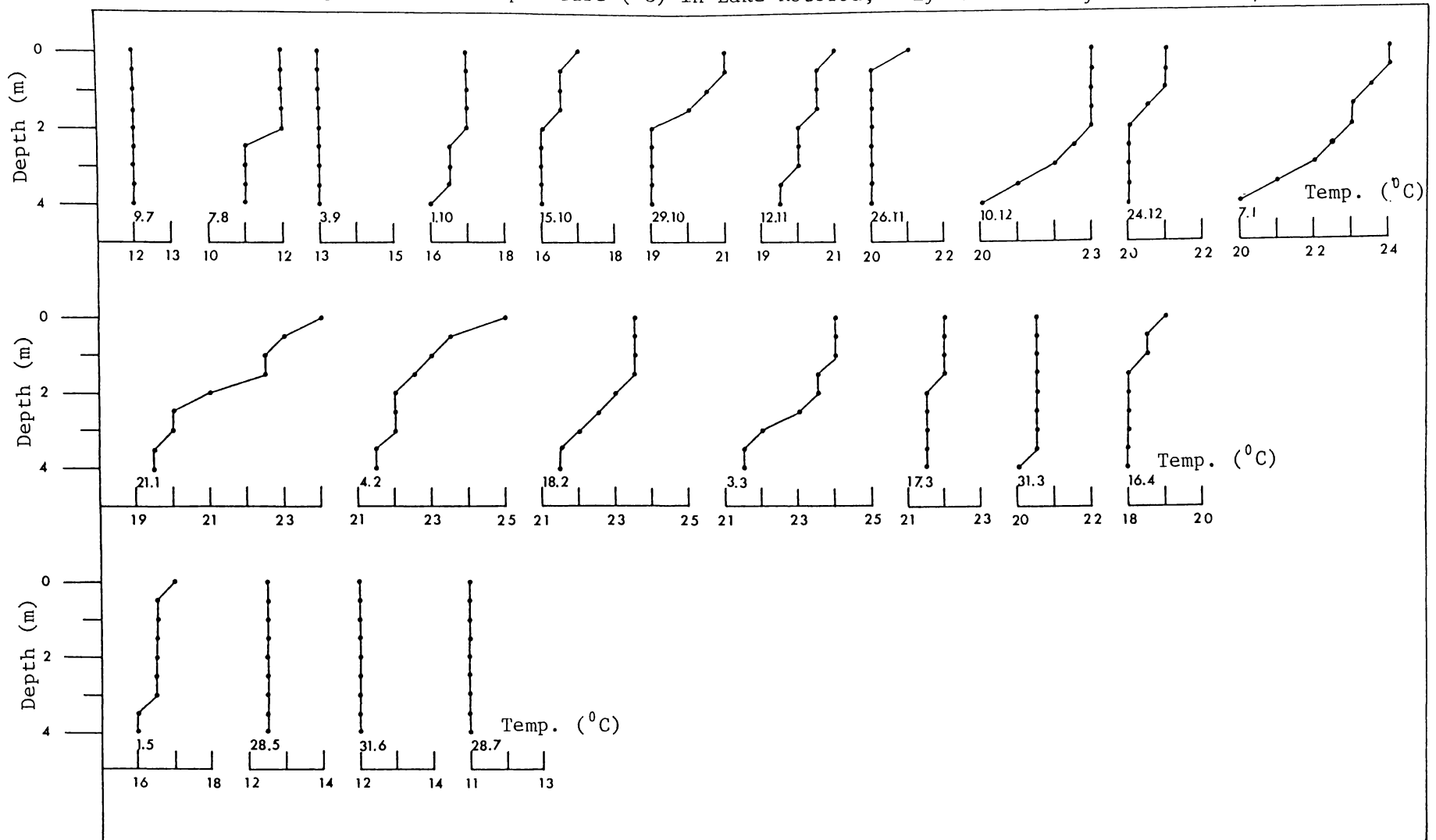


Fig. 3/7 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Rotoroa, July 1983 to July 1984



mid-October, and again during November and January, as evidenced by decreased bottom temperatures. Similarly, mixing was apparent in Lake Mangakaware, in both late December and January; and in Lake Rotoroa, in mid-January. A more frequent sampling interval may have revealed an even greater number of interruptions.

Lake Mangakaware was also characterised by complex and unstable temperature profiles during 1985 (Greenwood, 1987), and both the mean surface temperature (18.6°C) and the range of surface temperatures (11 to 26°C) were almost identical to those recorded during the present study (Table 3/0).

In Lake Rotomanuka South, sampling commenced on 13.10.83, three months after other study lakes, and at this time the surface temperature was 18°C, and the lake was weakly stratified. Although the shape of the profiles changed frequently throughout summer, there was no evidence that complete mixing occurred prior to autumn 1984 (Fig. 3/8). However, in terms of the shallow nature of the greater part of the lake, this seems highly unlikely.

The mean temperatures of both surface and bottom waters of the polymictic lakes are given in Table 3/0.

3.2 OXYGEN

A low mean oxygen saturation of the bottom waters of Lake Rotomanuka North (24.9%) (the lowest of the series), reflects the long period of summer stratification recorded in the lake. The hypolimnion became almost depleted of oxygen in early summer (1.0 g m³ [8.12.83]; 0.4 g m³ [22.12.83]) and, although minor increases were recorded in January, this condition continued until late autumn 1984 (Fig. 3/9). The mean oxygen saturation of the surface waters (0.5 m) was 93%, and supersaturation occurred on five occasions, generally in mid-summer. Several small, positive heterograde curves were recorded in early summer (13.10.83 to 8.12.83).

Low mean oxygen saturation of the bottom waters was also recorded in Lake Rotokauri (30% [Table 3/0]), despite the previously discussed mixing which occurred in summer. Anomalous dissolved oxygen concentrations of the surface waters on 17.3.84 (Fig. 3/10) (24.5% saturation at 0.5 m), presumably were caused by decomposition of dense macrophyte beds (largely *Egeria densa*), which had been sprayed with herbicide on 22.12.83, and were in an advanced state of decay. Positive heterograde curves occurred in early summer, but were not

Fig. 3/8 Vertical profiles of temperature ($^{\circ}\text{C}$) in Lake Rotomanuka South, October 1983 to July 1984

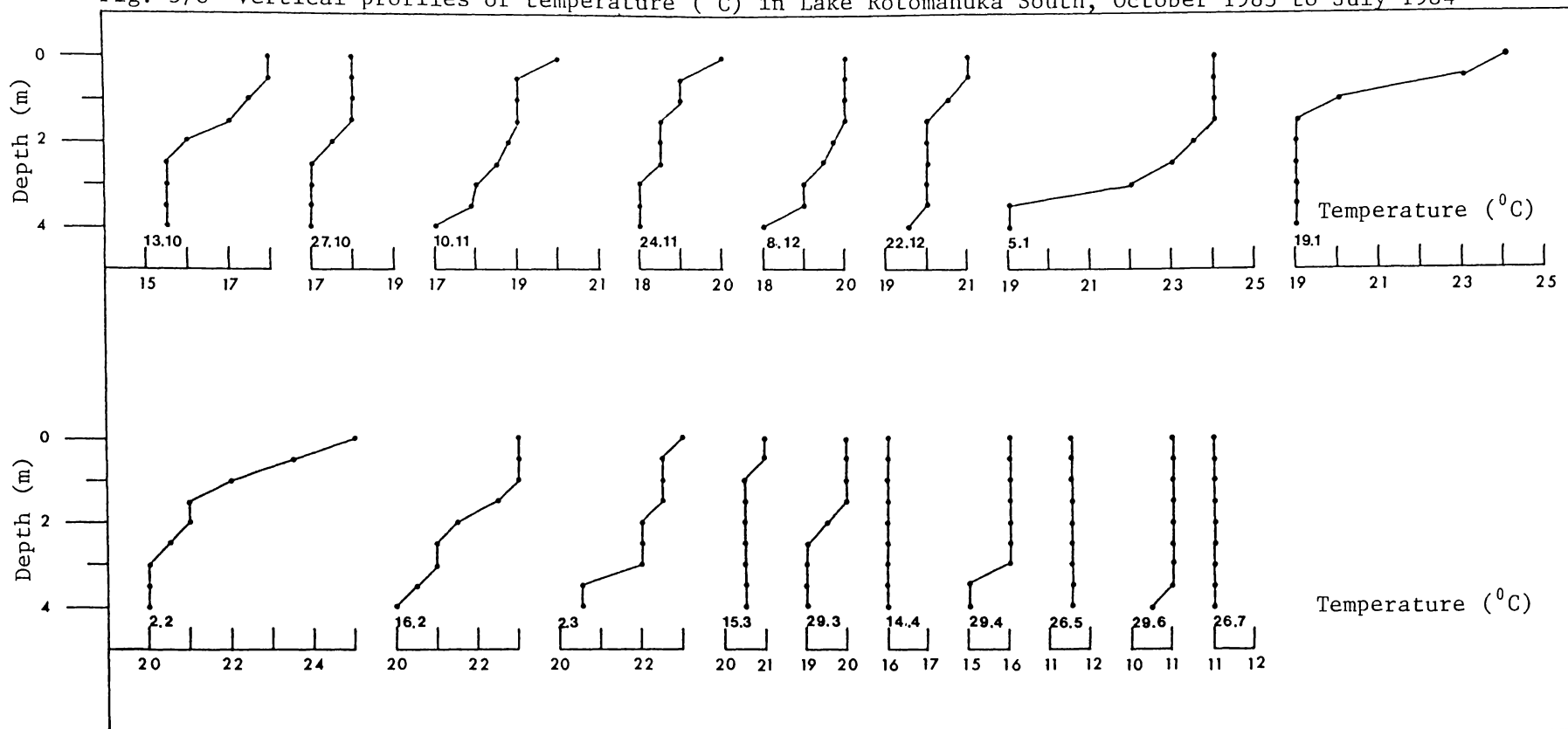


Fig. 3/9 Vertical profiles of dissolved oxygen concentrations (g m^{-3}) in Lake Rotomanuka North, July 1983 to July 1984

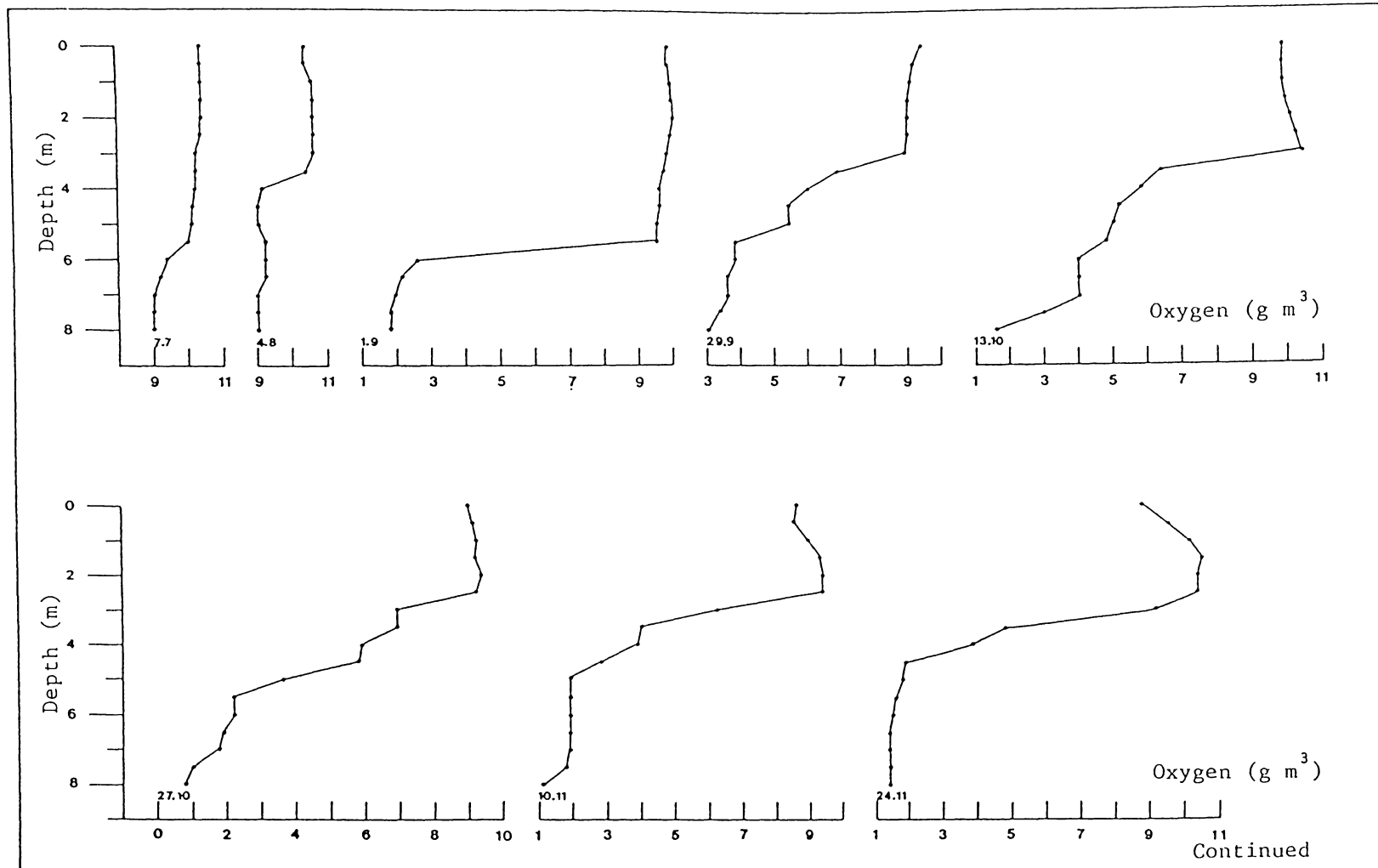


Fig. 3/9 continued

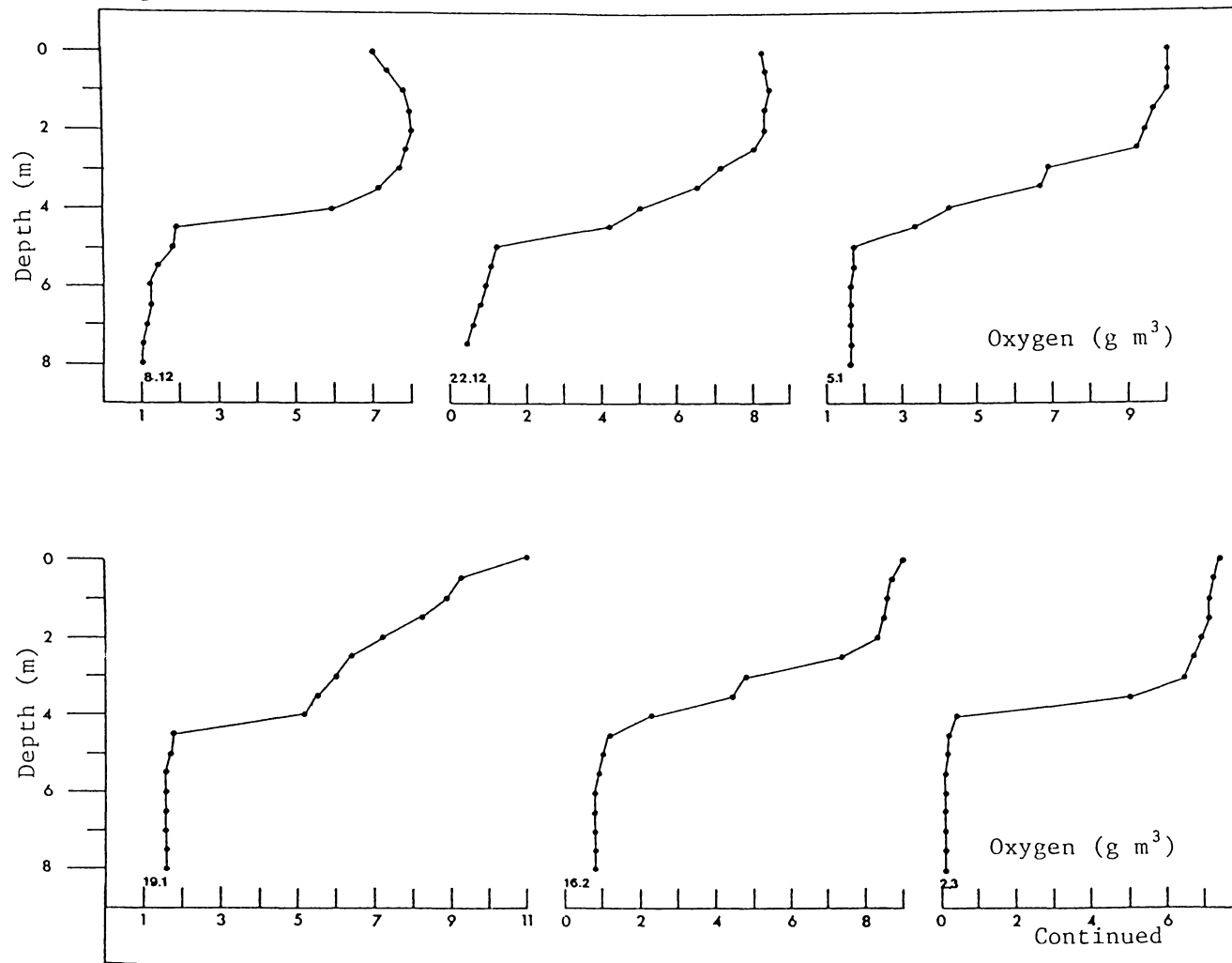


Fig. 3/9 continued

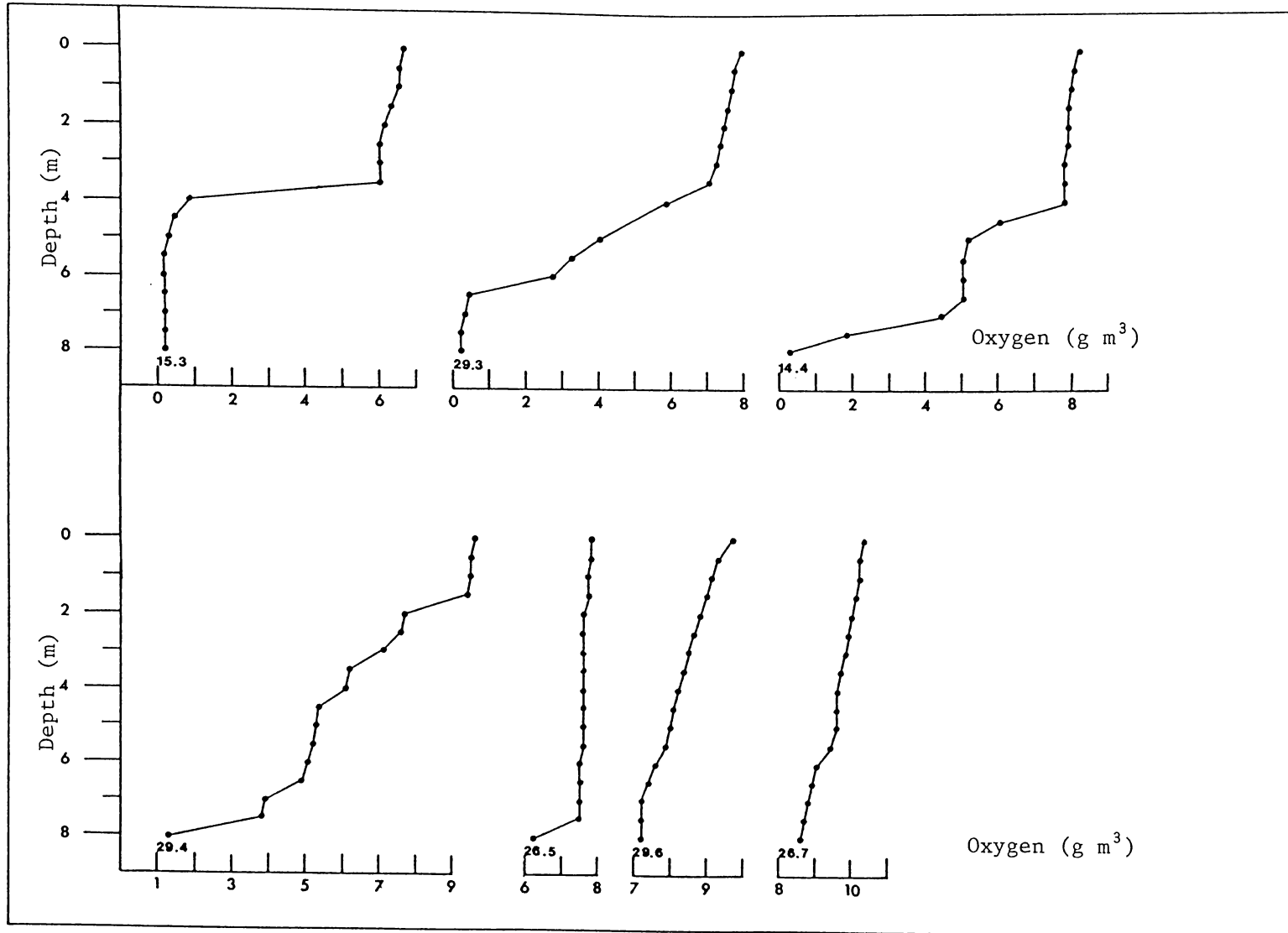
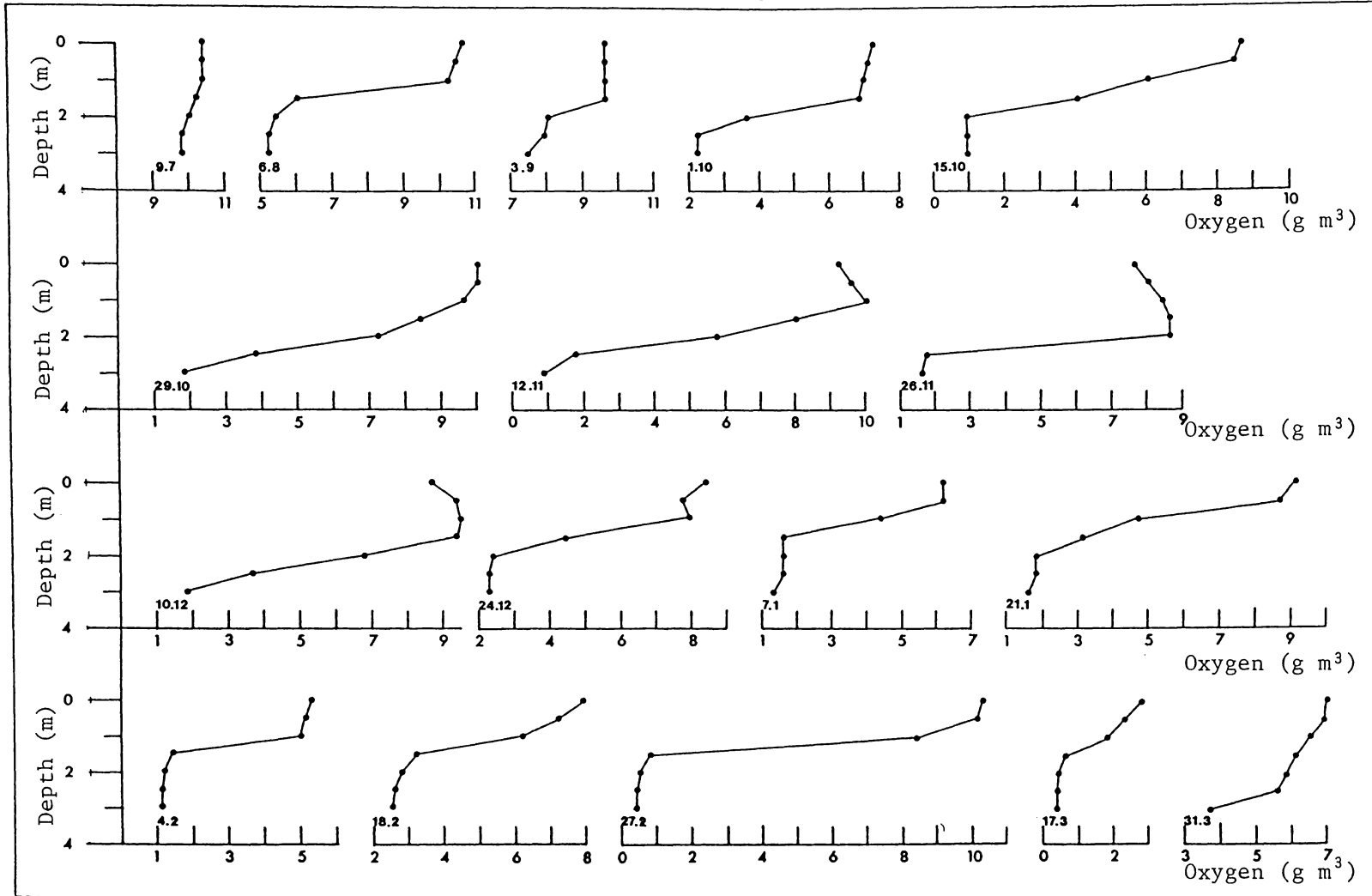
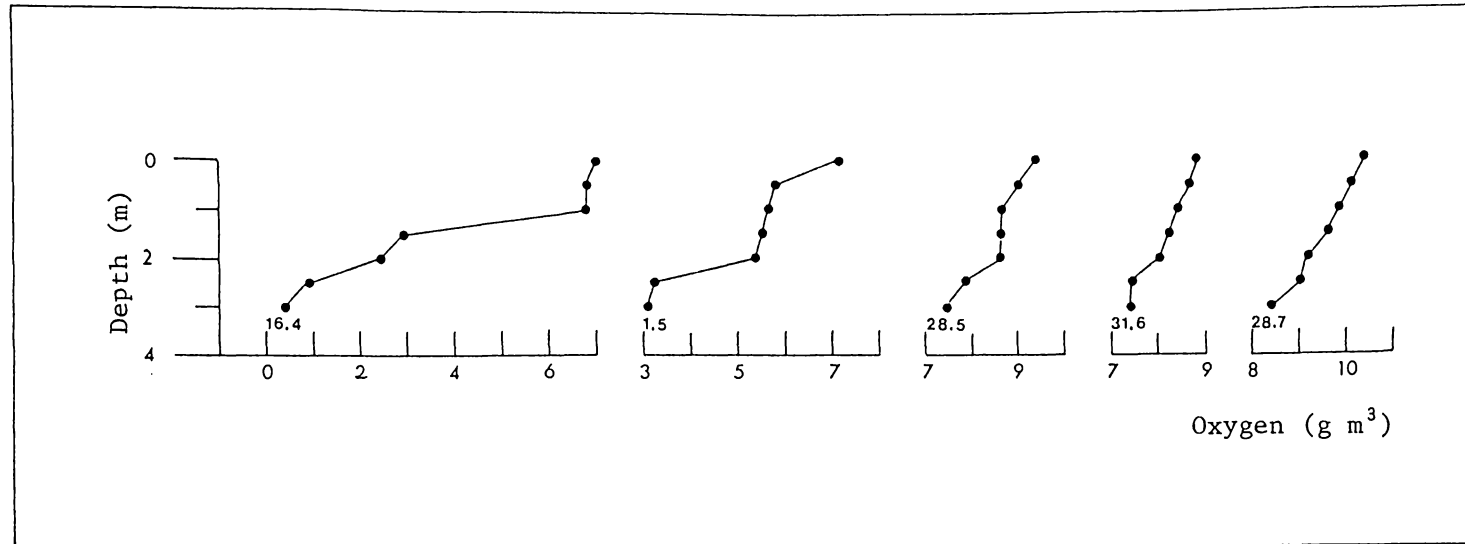


Fig. 3/10 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Rotokauri, July 1983 to July 1984



Continued

Fig. 3/10 continued



accompanied by high saturation (maximum 107%), suggesting that surface photo-inhibition of photosynthesis may have been a causal factor.

Mean oxygen saturations of the bottom waters of the polymictic lakes varied markedly, ranging from 42.9% (Lake Mangakaware) to 79.6% (Lake Kainui) (Table 3/0). The vertical profiles of dissolved oxygen concentrations in Lakes Mangakaware (Fig. 3/11), Mangahia (Fig. 3/12) and Maratoto (Fig. 3/13), are of special interest because, despite the vertical instability of their water columns throughout summer, there is considerable evidence of oxygen depletion in the bottom waters, suggestive of high oxygen demands by the sediments. In Lake Mangahia, particularly, this frequently extended throughout the water column, as evidenced by the low mean saturation at 0.5 m (81% [Table 3/0], the lowest of the series). In addition, supersaturation occurred on only one occasion (102% [8.12.83]), coincident with the maximum density of *Closterium acutum* var. *variabile* (13,944 pu ml⁻¹ [Fig. 6/7]). Oxygen saturation of the surface waters of Lake Maratoto was also relatively low (mean 88.8%), with supersaturation occurring on only six occasions, despite the absence of a period of stable summer stratification. Low values were also recorded during 1979 (Etheredge, 1983).

The vertical profiles of dissolved oxygen concentrations in Lake Ngaroto are given in Fig. 3/14. The mean oxygen saturation of the surface waters (100.8%) was higher than that of any other study lake, undoubtedly due to its morphometry (particularly its shallow nature and relatively large surface area; Table 1/0), together with the frequently high densities of *Microcystis aeruginosa* (Chapter 6.5.5; Fig. 6/24). Despite this, however, oxygen saturation at 4 m was relatively low on several occasions (e.g., 15% [19.1.84], 17% [2.2.84], and 23% [16.2.84]), again suggestive of high oxygen demands by the sediments.

In contrast, vertical profiles of dissolved oxygen concentrations in Lakes Rotoroa (Fig. 3/15) and Kainui (Fig. 3/16) were less variable, with little or no evidence of high oxygen demands in the bottom waters. Their mean oxygen saturations for the bottom waters (72.8 and 79.6%, respectively), were the two highest of the series, with supersaturation occurring in the latter on four occasions.

The vertical profiles of dissolved oxygen concentrations in Lake Rotomanuka South are given in Fig. 3/17. The bottom waters were almost

Fig. 3/11 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Mangakaware, July 1983 to July 1984

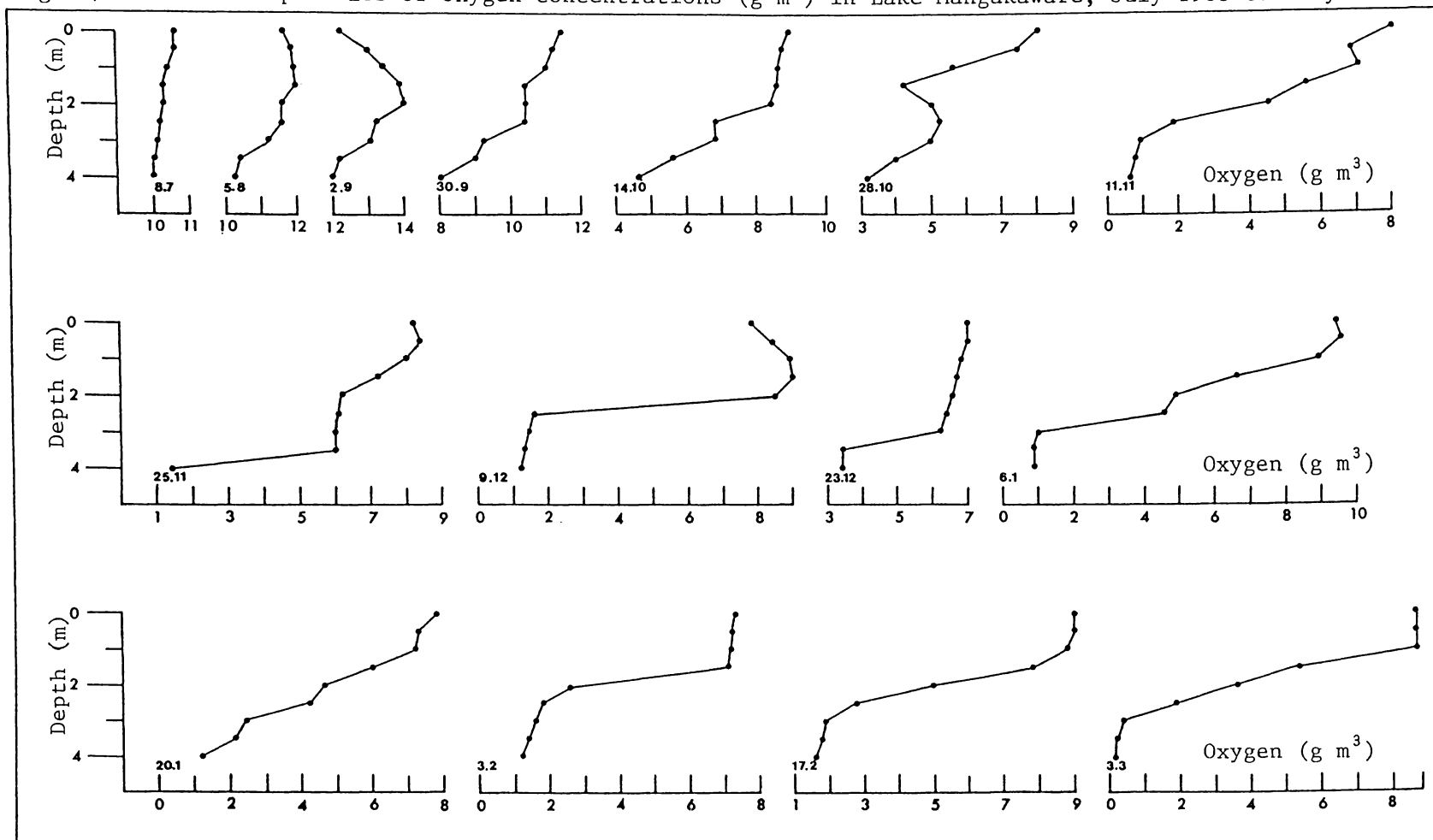


Fig. 3/11 continued

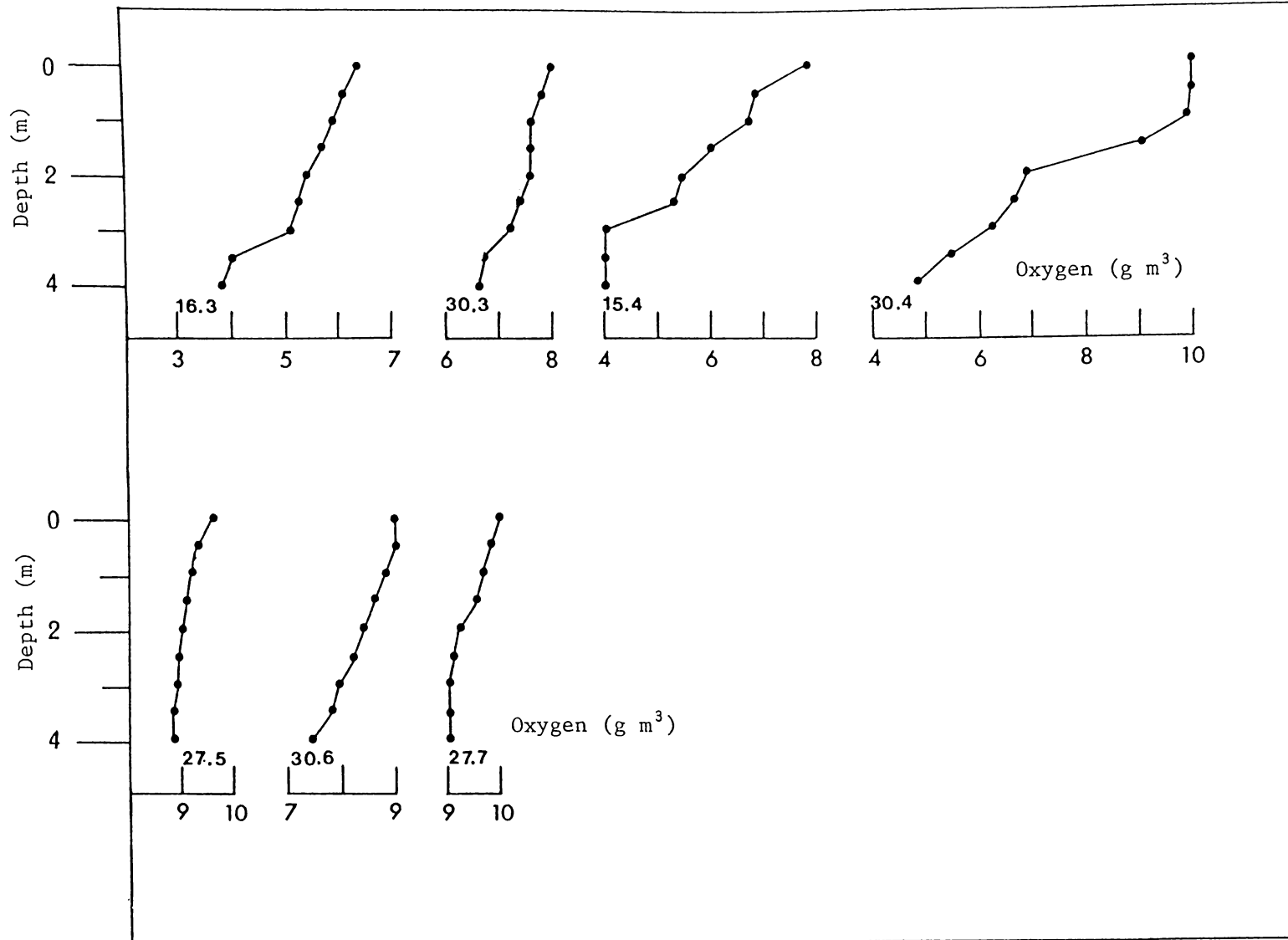


Fig. 3/12 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Mangahia, July 1983 to July 1984

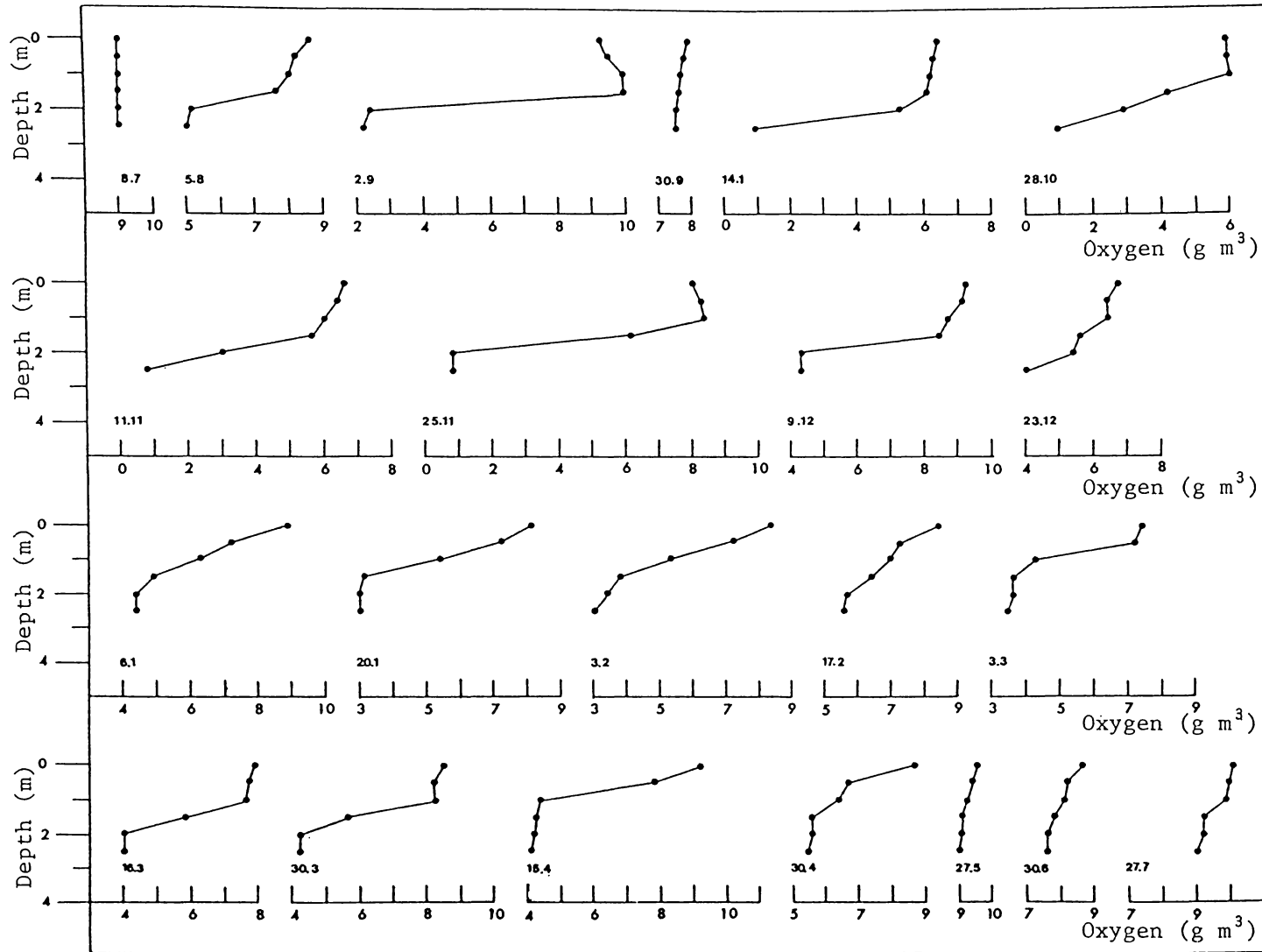


Fig. 3/13 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Maratoto, July 1983 to July 1984

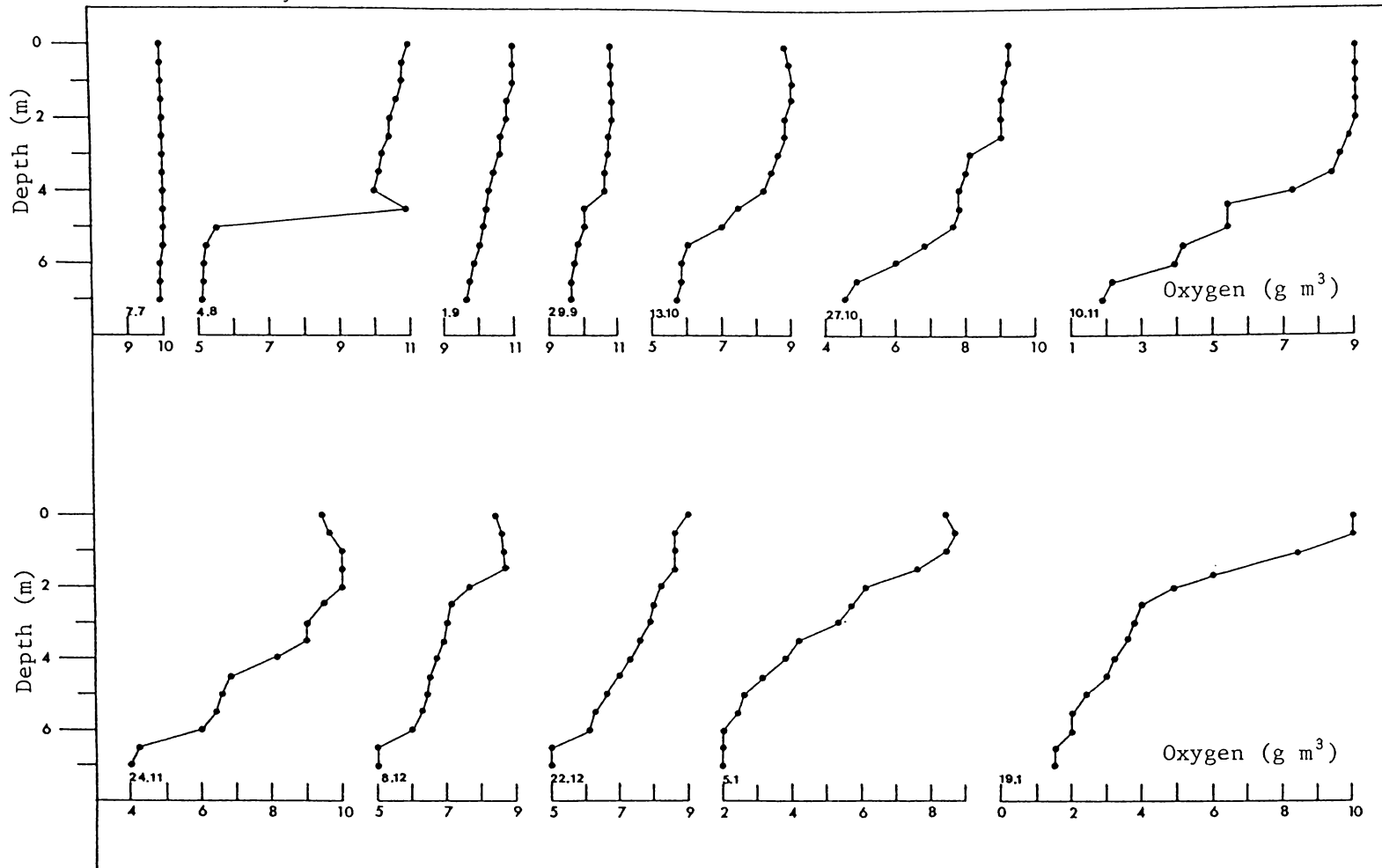


Fig. 3/13 continued

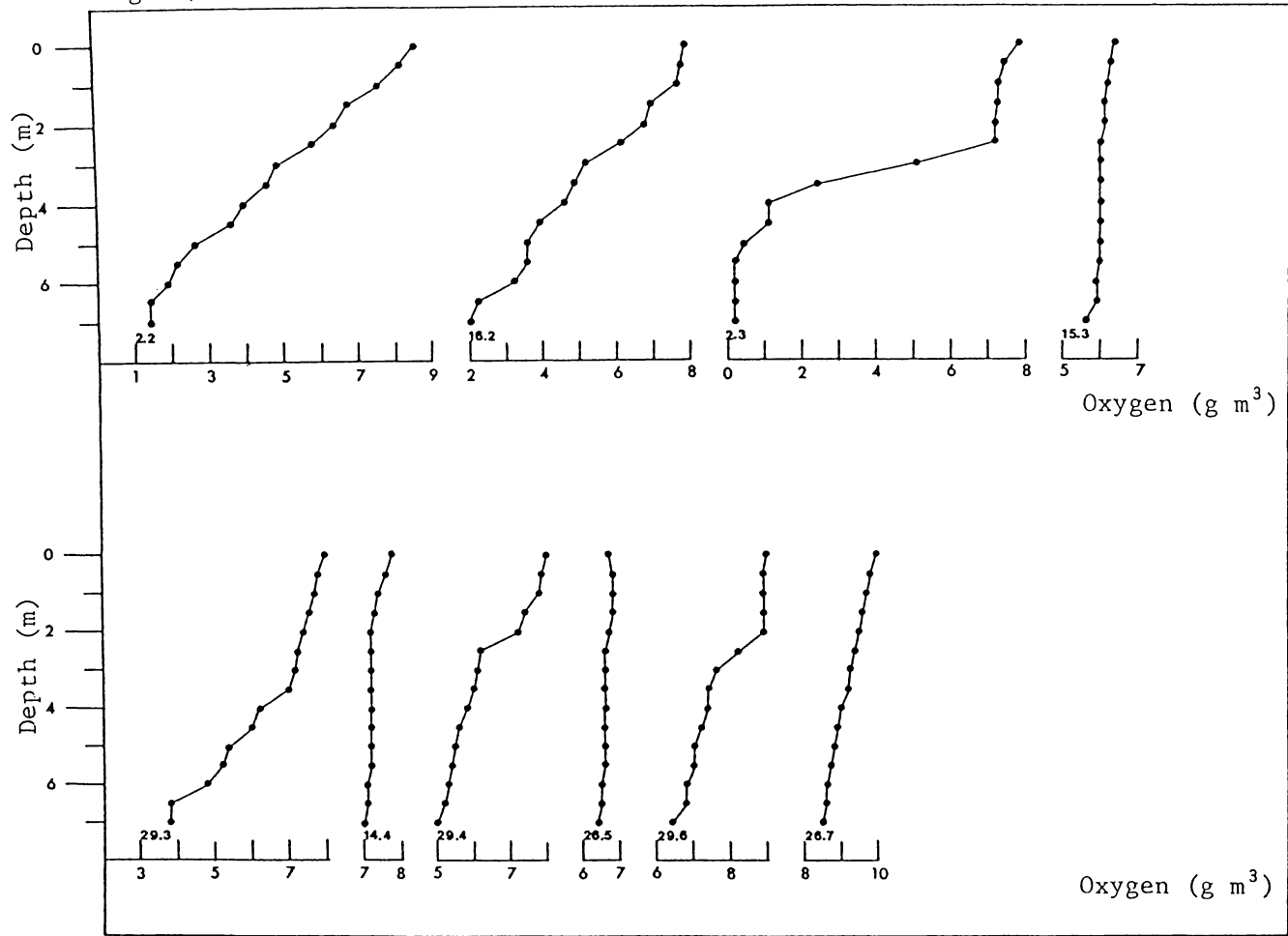


Fig. 3/14 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Ngaroto, July 1983 to July 1984

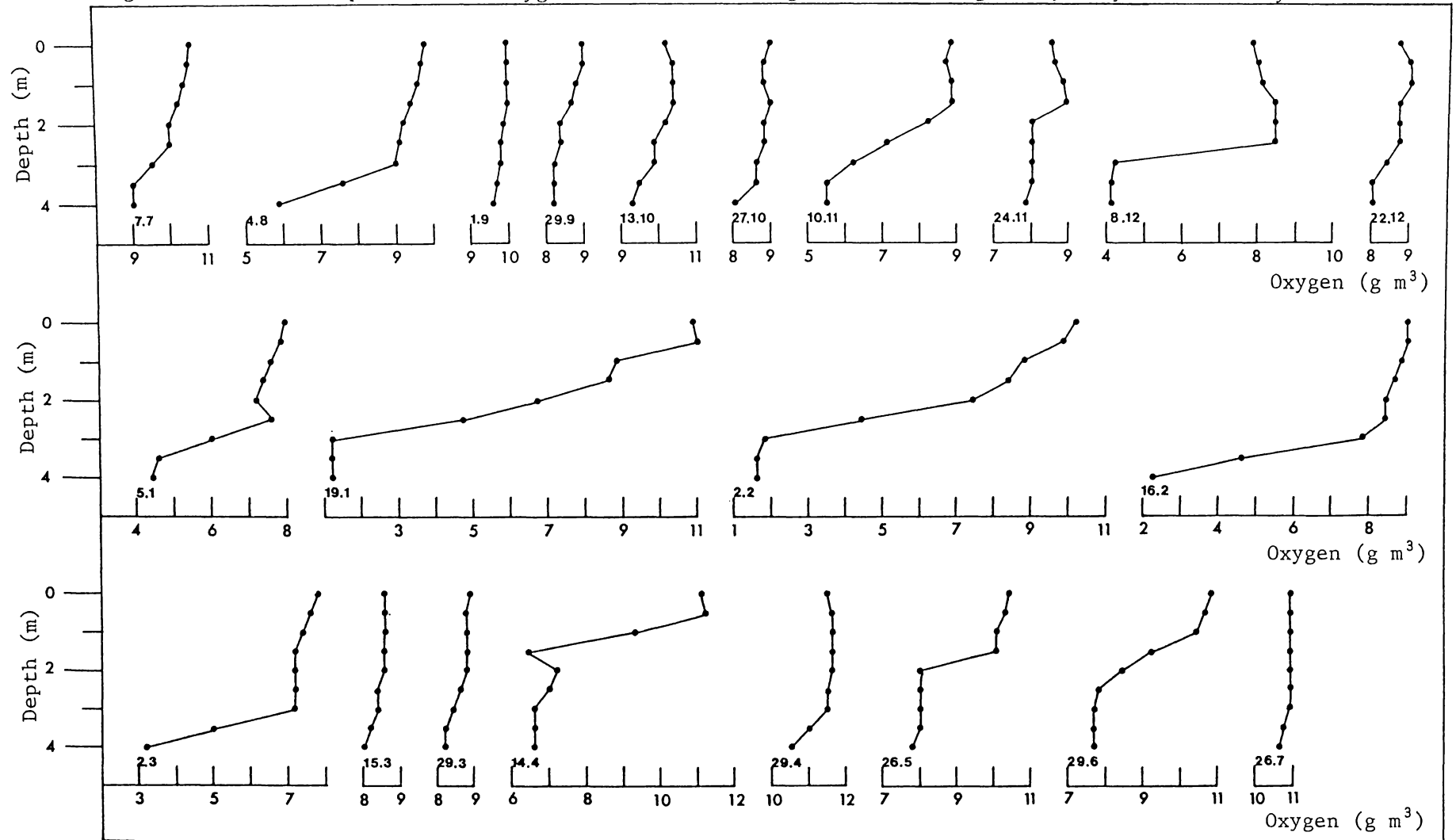


Fig. 3/15 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Rotoroa, July 1983 to July 1984

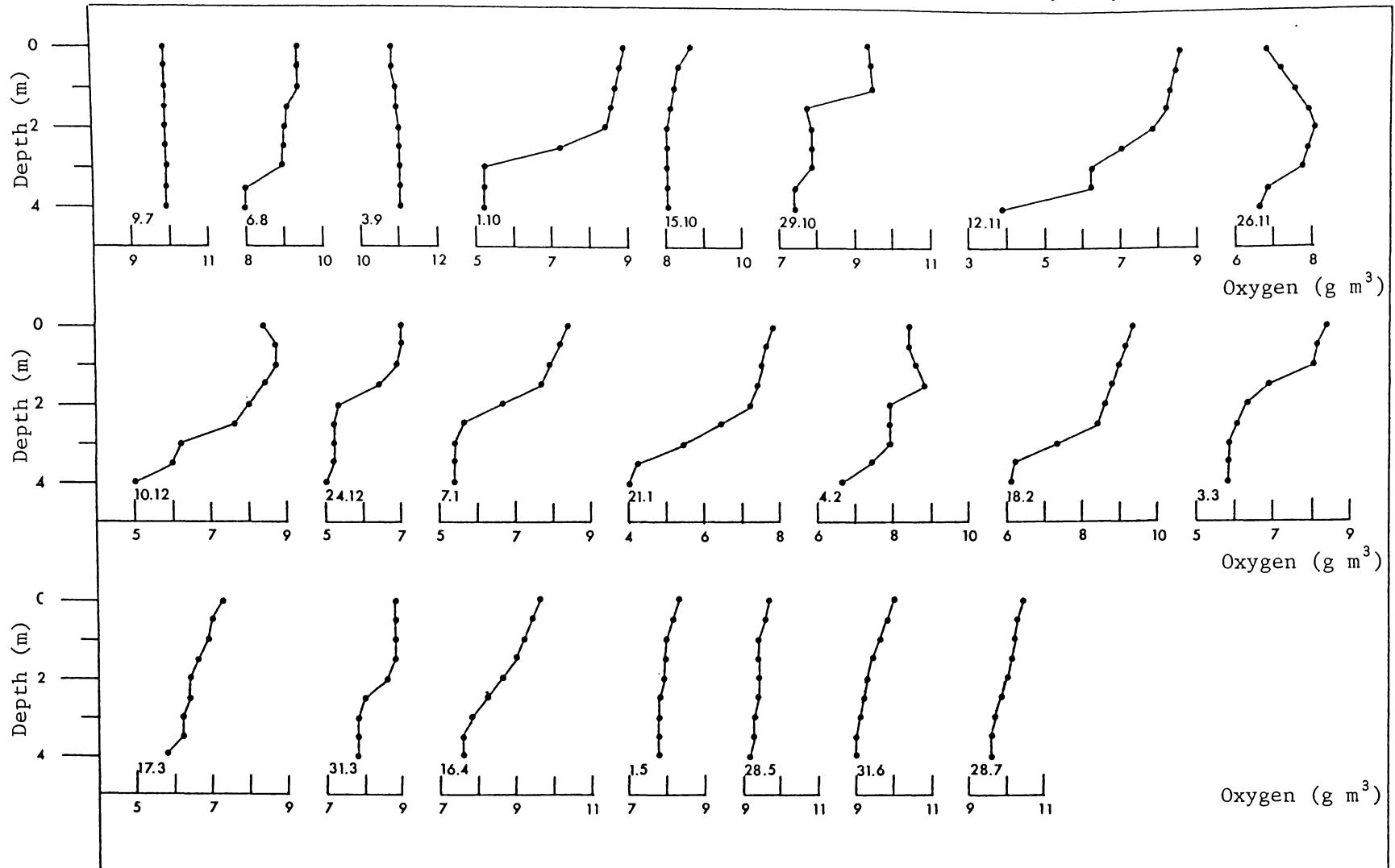


Fig. 3/16 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Kainui, July 1983 to July 1984

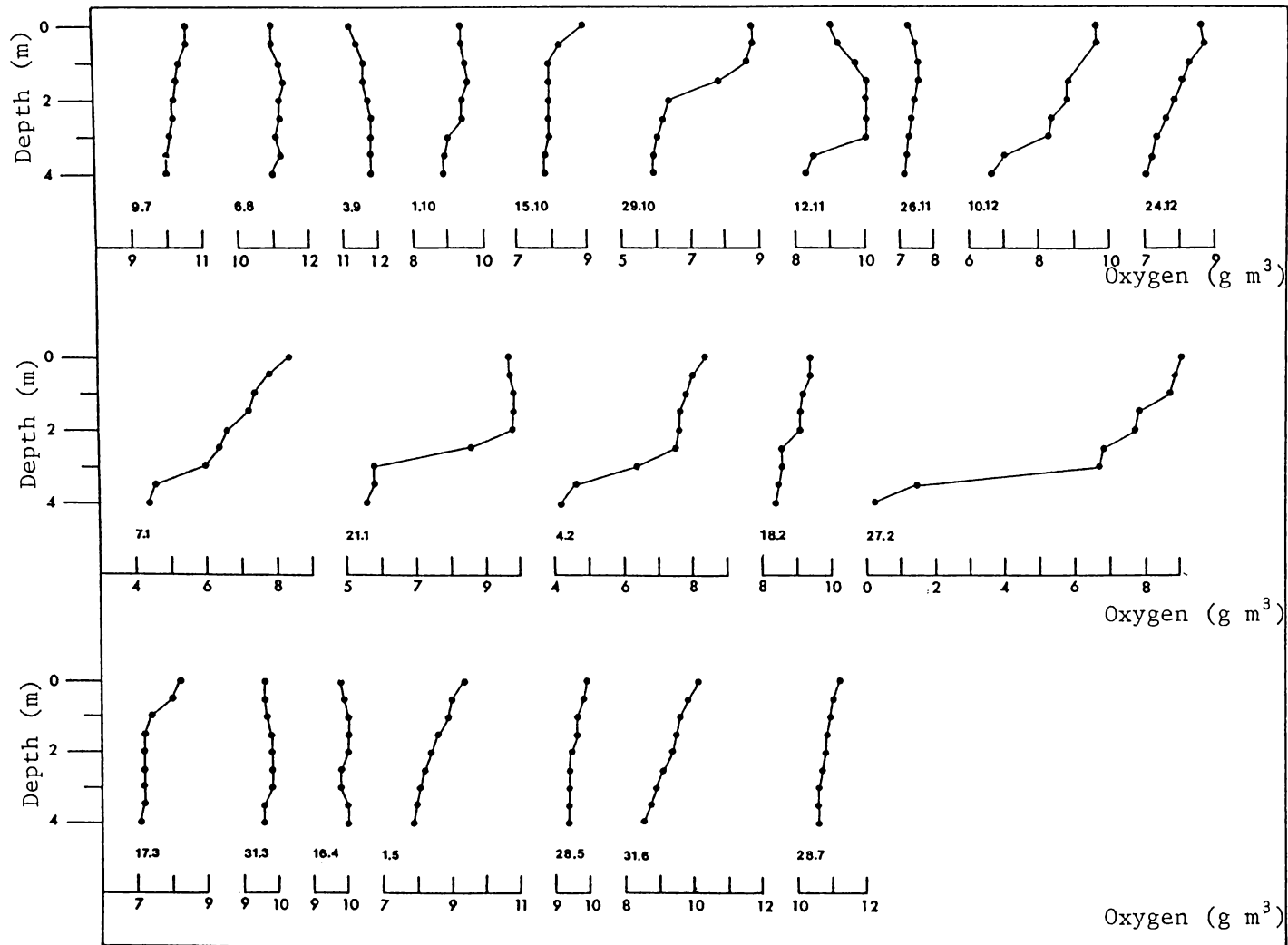


Fig. 3/17 Vertical profiles of oxygen concentrations (g m^{-3}) in Lake Rotomanuka South, October 1983 to July 1984

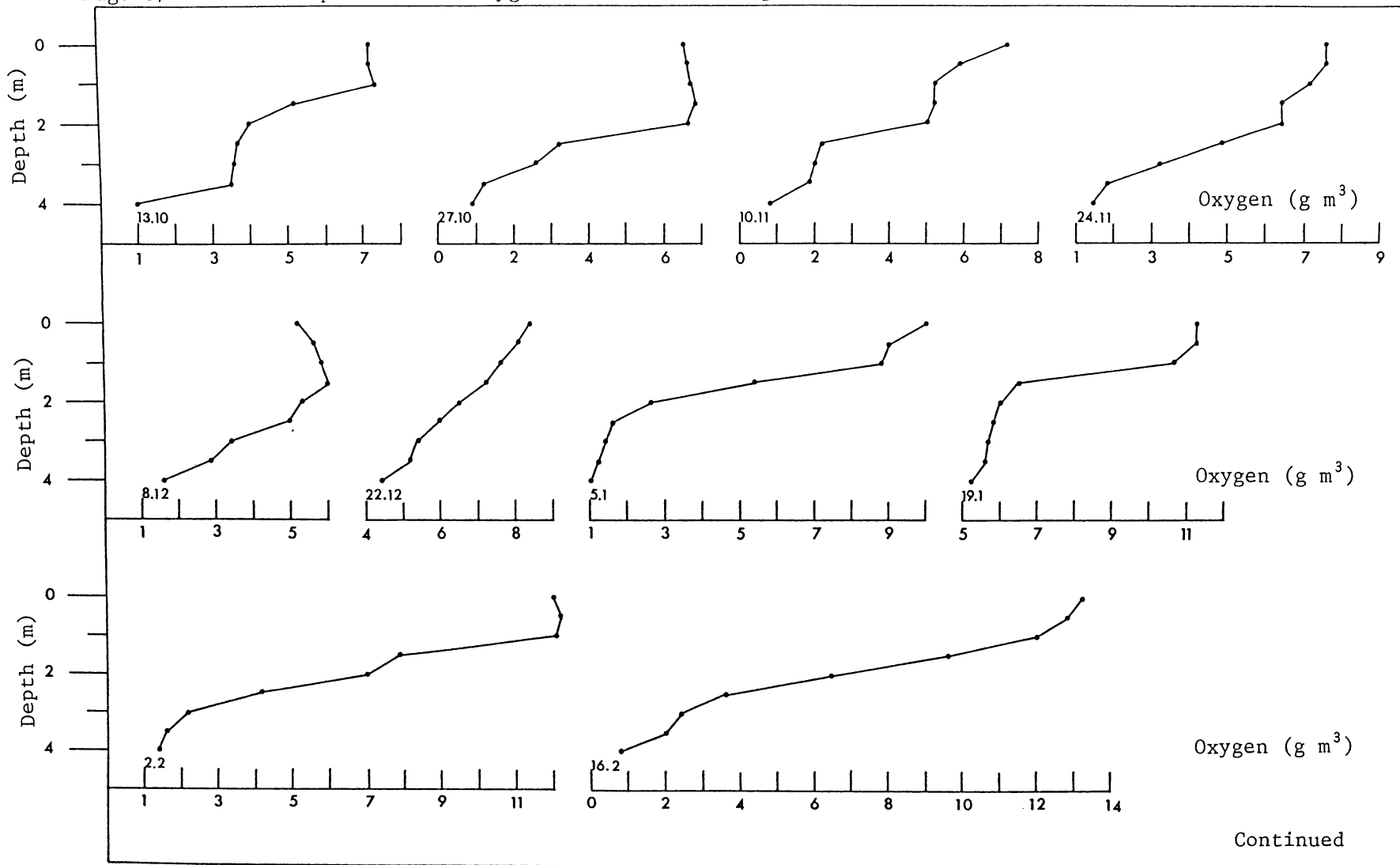
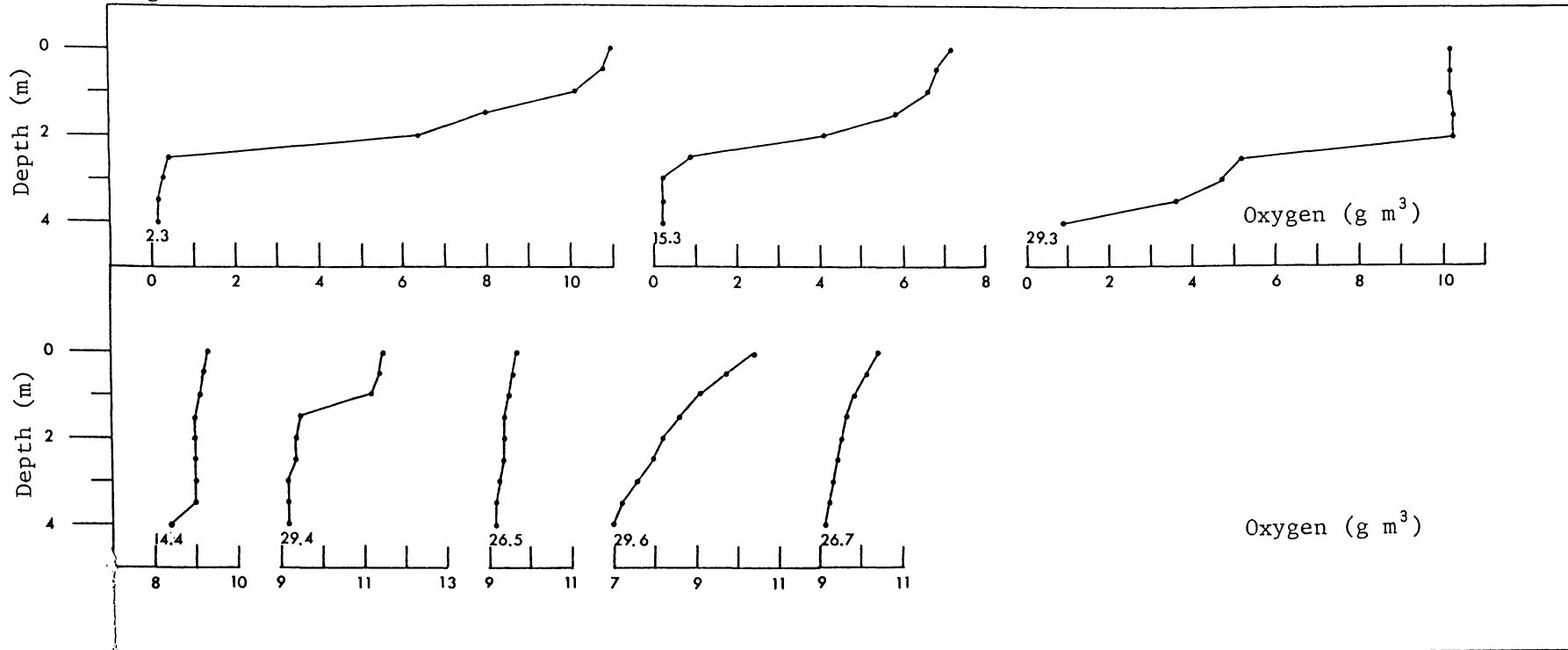


Fig. 3/17 continued



anoxic for considerable periods of time; for example, between 13.10.83 and 12.4.84, saturation was > 20% on only two occasions. In marked contrast, saturation at 0.5 m was \geq 130% on four occasions (131% [19.1.84]; 142% [2.2.84]; 150% [16.2.84]; 130% [1.3.84]). These high values coincided with a *Microcystis aeruginosa* bloom (Chapter 6.1.8.5; Fig. 6/40; Plate 9), and did not occur in any other study lake.

3.3 NUTRIENTS

No attempt was made to determine the water chemistry of the study lakes in detail; however, spring and summer chemical analyses indicated that there was a wide range of ionic composition (Tables 3/1 to 3/8). The cationic sequence in all lakes, except Ngaroto, was $\text{Na}^+ > \text{Ca}^{2+} > \text{K}^+ > \text{Mg}^{2+}$; Lake Ngaroto exhibited surprisingly high levels of Ca^{2+} (13.88 and 13.11 g m⁻³) which resulted in the atypical arrangement of $\text{Ca}^{2+} > \text{Na}^+$. A second minor exception occurred in Lake Maratoto where, during the summer survey, $\text{Mg}^{2+} > \text{K}^+$. The sequence of anions was not as consistent; in Lakes Kainui, Rotokauri, Rotomanuka North and Rotoroa $\text{Cl}^- > \text{SO}_4^{2-}$ but, in sharp contrast, very high concentrations of SO_4^{2-} were recorded in both Lakes Ngaroto (38.3 and 35.7 g m⁻³) and Mangahia (28.6 and 25.8 g m⁻³).

Wide ranges of both nitrate and ammonia concentrations were also present (Table 3/9), with especially high concentrations of the former occurring in spring in Lakes Ngaroto (583 mg m⁻³) and Mangahia (515 mg m⁻³). Relatively low values were recorded in Lakes Kainui (17 mg m⁻³) and Rotomanuka North (39 mg m⁻³). The maximum ammonia concentration (594 mg m⁻³) occurred at 2.5 m in Lake Mangahia; the oxygen saturation was 8.5%. Lake Rotoroa also exhibited high concentrations in both spring (281 mg m⁻³) and summer (537 mg m⁻³). The lowest concentration (9 mg m⁻³) occurred during spring in Lakes Rotomanuka North and Rotokauri. The highest TKN and DTKN concentrations (2315 and 2050 mg m⁻³, respectively) were also recorded in Lake Mangahia.

Not unexpectedly, the nine lakes also differed with regard to phosphorus concentrations (Table 3/9). The pattern was similar to that of nitrogen, and in particular nitrate; the highest levels of TP were recorded in Lakes Ngaroto (122 mg m⁻³) and Mangahia (108 mg m⁻³), and the lowest (10 mg m⁻³) was recorded in Lake Rotomanuka North. High DRP concentrations occurred in Lakes Mangakaware, Kainui, Mangahia and Ngaroto (13, 12, 11 and 8 mg m⁻³, respectively), and lower values in

Plate 9

1. *Microcystis aeruginosa* bloom in Lake Rotomanuka South.
2. *Microcystis aeruginosa* accumulating in drain at southern end of Lake Rotomanuka South.

Plate 9



TABLE 3/1 Some major and minor ion concentrations from the surface waters of Lake Kainui, 3 September and 12 November, 1983

Ion	Units	Date	
		3.9.83	12.11.83
Chloride	g m ³	12.8	20.6
Sulphate	"	9.0	10.9
Silica	"	1.2	1.0
Sodium	"	7.33	10.47
Potassium	"	0.26	5.67
Magnesium	"	2.08	2.58
Calcium	"	3.93	5.92
Iron	"	0.27	0.35
Manganese	"	0.02	0.046

TABLE 3/2 Some major and minor ion concentrations from the surface waters of Lake Mangahia, 4 September and 11 November, 1983.

Ion	Units	Date	
		4.9.83	11.11.83
Chloride	g m ³	21.1	19.1
Sulphate	"	28.6	25.8
Silica	"	13.0	2.8
Sodium	"	12.04	10.43
Potassium	"	4.47	4.26
Magnesium	"	4.48	3.53
Calcium	"	8.04	7.28
Iron	"	3.18	3.4
Manganese	"	0.4	0.338

TABLE 3/3 Some major and minor ion concentrations from the surface waters of Lake Mangakaware, 4 September and 11 November 1983.

Ion	Units	Date	
		4.9.83	11.11.83
Chloride	g m ³	17.2	16.2
Sulphate	"	19.7	17.2
Silica	"	7.0	7.5
Sodium	"	6.65	10.14
Potassium	"	2.97	5.54
Magnesium	"	2.20	2.93
Calcium	"	5.45	7.71
Iron	"	0.27	0.91
Manganese	"	0.07	0.16

TABLE 3/4 Some major and minor ion concentrations from the surface waters of Lake Maratoto, 1 September and 10 November, 1983.

Ion	Units	Date	
		1.9.83	10.11.83
Chloride	g m ³	15.4	17.8
Sulphate	"	10.4	13.2
Silica	"	4.8	2.1
Sodium	"	9.23	10.24
Potassium	"	2.11	2.39
Magnesium	"	2.54	2.8
Calcium	"	2.82	3.69
Iron	"	0.59	0.75
Manganese	"	0.04	0.074

TABLE 3/5 Some major and minor ion concentrations from the surface waters of Lake Ngaroto, 1 September and 10 November, 1983.

Ion	Units	Date	
		1.9.83	10.11.83
Chloride	g m ³	16.5	17.6
Sulphate	"	38.3	35.7
Silica	"	5.9	2.6
Sodium	"	12.1	10.71
Potassium	"	5.82	5.79
Magnesium	"	4.43	4.06
Calcium	"	13.88	13.11
Iron	"	0.49	0.28
Manganese	"	1.0	0.245

TABLE 3/6 Some major and minor ion concentrations from the surface waters of Lake Rotokauri, 3 September and 12 November, 1983.

Ion	Units	Date	
		3.9.83	12.11.83
Chloride	g m ³	19.1	18.0
Sulphate	"	14.9	15.4
Silica	"	3.0	3.1
Sodium	"	10.16	12.13
Potassium	"	2.62	3.73
Magnesium	"	2.32	3.25
Calcium	"	6.38	8.01
Iron	"	0.13	0.07
Manganese	"	0.02	0.014

TABLE 3/7 Some major and minor ion concentrations from the surface waters of Lake Rotomanuka North, 1 September and 10 November, 1983.

Ion	Units	Date	
		1.9.83	10.11.83
Chloride	g m ³	18.9	19.1
Sulphate	"	14.8	22.2
Silica	"	0.9	1.6
Sodium	"	6.55	4.07
Potassium	"	3.61	2.46
Magnesium	"	2.35	1.53
Calcium	"	7.84	7.54
Iron	"	0.1	0.04
Manganese	"	0.01	0.007

TABLE 3/8 Some major and minor ion concentrations from the surface waters of Lake Rotoroa, 3 September and 12 November, 1983.

Ion	Units	Date	
		3.9.83	12.11.83
Chloride	g m ³	14.9	17.7
Sulphate	"	4.2	5.2
Silica	"	0.4	0.7
Sodium	"	6.18	10.62
Potassium	"	1.83	3.11
Magnesium	"	1.08	1.71
Calcium	"	4.42	6.53
Iron	"	0.28	0.47
Manganese	"	0.06	0.067

Table 3/9 Nitrogen and phosphorus concentrations (mg m^{-3}) of the surface waters (0.5 m) of 8 of the 9 study lakes, 5 September and 10 November 1983.

Lake	Total Phosphorus (mg m^{-3})		Total Dissolved Phosphorus (mg m^{-3})		Dissolved Reactive Phosphorus (mg m^{-3})		Ammonia-nitrogen (mg m^{-3})		Nitrate-nitrogen (mg m^{-3})		Total Kjeldahl Nitrogen (mg m^{-3})		Dissolved Total Kjeldahl Nitrogen (mg m^{-3})	
	5 Sept.	10 Nov.	5 Sept.	10 Nov.	5 Sept.	10 Nov.	5 Sept.	10 Nov.	5 Sept.	10 Nov.	5 Sept.	10 Nov.	5 Sept.	10 Nov.
Kainui	37	45	16	29	9	12	13	99	17	36	815	1240	795	*
Mangahia	73	108	17	61	5	11	176	594	515	241	1315	2315	1495	2050
Mangakaware	38	85	*	44	*	13	24	87	144	311	990	1220	655	950
Maratoto	24	30	16	30	7	1	45	249	299	154	1170	1595	845	1240
Ngaroto	51	122	20	26	20	8	83	116	583	92	1265	1795	840	915
Rotokauri	9	17	5	17	3	7	9	40	176	44	320	555	320	705
Rotomanuka North	23	10	6	7	6	3	9	30	41	39	700	590	570	640
Rotoroa	17	14	12	17	3	4	281	537	91	62	725	1175	1000	*
* no data available														

Lakes Maratoto (1 mg m³) and Rotomanuka North (3 mg m³).

3.4 pH AND SECCHI DISC TRANSPARENCY

The widely differing concentrations of DHM in the study lakes (as evidenced by the degree of staining) were reflected in a broad range of pHs (surface waters), (Table 3/10). The most darkly-stained lakes, Maratoto and Mangahia, were also the most acidic, with ranges of 5.1 to 6.1 and 5.8 to 6.8, respectively. The minimum pH of Lake Maratoto is of special significance, because it is higher than that reported in earlier studies (Boubée, 1983; Etheredge, 1983; McCabe, 1985), and thus may be significant in terms of the floristic changes which appear to be occurring (see Chapter 5). Water clarity was low in Lakes Maratoto (Fig. 3/21) and Mangahia (Fig. 3/22) (mean Secchi disc transparencies 0.58 and 0.31 m, respectively), and there was little evidence of seasonality.

Lakes Kainui and Mangakaware, which are both moderately stained, had broadly similar pH ranges, 6.1 to 7.6 and 6.5 to 7.8, respectively, the former being similar to that reported by McCabe (1985). Unpredictable changes in water transparency were characteristic of both Lakes Mangakaware (Fig. 3/25) and Kainui (Fig. 3/26). The annual mean values were 1.04 and 0.76 m, respectively, and, in the case of the former, was slightly lower than that reported for the period January 1985 to March 1986 (1.25 m) (Greenwood, 1987).

The effects of DHM are less obvious in Lakes Rotomanuka North, Rotokauri and Rotoroa. The apparent water colour in these lakes is brown-green to clear and, not unexpectedly, their ranges of pH were relatively similar, being 6.8 to 8.2, 7.0 to 8.0, and 7.3 to 8.1, respectively. Mean Secchi disc transparencies were relatively high in these lakes (Rotomanuka North [(3.0 m), Rotokauri [2.05 m] and Rotoroa [(1.9 m)]). Although water clarity fluctuated irregularly in all three lakes (Figs. 3/18 to 3/20, respectively), values generally decreased during summer.

A fourth group, comprised of Lakes Ngaroto and Rotomanuka South, has yellow-brown turbid waters. Their pHs were consistently higher than those of other study lakes (ranges 8.2 to 9.0 and 8.4 to 9.4, respectively); the maximum of the latter coinciding with a *Microcystis aeruginosa* bloom (Chapter 6.8.2). These lakes also had low transparency (means 0.45 and 0.54 m, respectively) but, unlike the darkly-stained lakes, displayed distinct temporal variations, with

Table 3/10 A selection of morphometric and physico-chemical data from the nine study lakes, July 1983 to July 1984. The lakes are listed from left to right in increasing order of surface pH values.

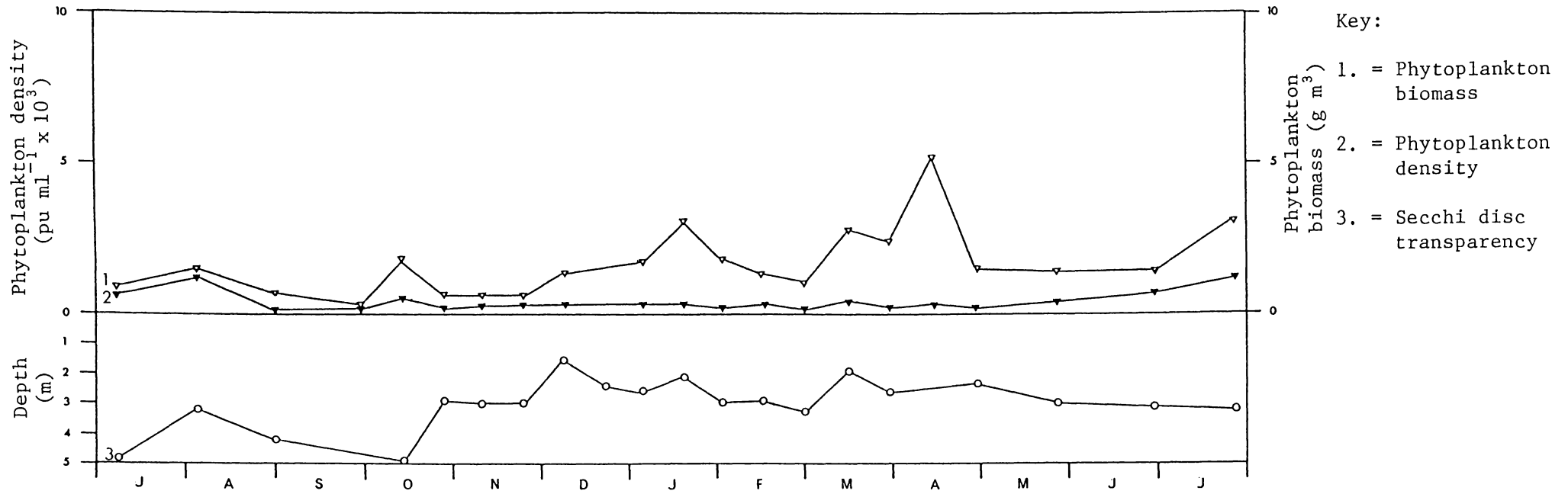
	Lake								
	MA*	MH	KA	MK	RR	RK	RMN	NG	RMS†
Maximum depth (m)	7.1	2.3	6.7	4.8	6.0	4.0	8.7	4.0	5.0
Mean secchi disc transparency (m) (n = 22)	0.58	0.31	0.76	1.04	1.9	2.05	3.0	0.45	0.54
Absorption @ 270 nm (filtered), spring 1983	0.82	0.76	0.4	0.28	0.1	0.13	0.17	0.2	n.d.**
Absorption @ 270 nm (unfiltered), spring 1983	0.86	0.95	0.44	0.3	0.12	0.14	0.17	0.25	n.d.
Absorption @ 400 nm (filtered), spring 1983	0.1	0.1	0.04	0.03	0.01	0.01	0.01	0.02	n.d.
Absorption @ 400 nm (unfiltered), spring 1983	0.13	0.19	0.06	0.05	0.02	0.02	0.02	0.06	n.d.
Absorption @ 270 nm (filtered) summer 1984	1.2	1.43	0.56	0.51	0.18	0.21	0.14	0.35	0.65
Absorption @ 270 nm (unfiltered), summer 1984	n.d.	1.45	0.57	0.51	n.d.	0.21	0.23	0.44	0.66
Absorption @ 400 nm (filtered), summer 1984	0.16	0.21	0.07	0.08	0.03	0.02	0.02	0.04	0.09
Absorption @ 400 nm (unfiltered), summer 1984	0.16	0.22	0.07	0.08	0.03	0.02	0.02	0.11	0.1
Median surface pH	5.5	6.4	7.0	7.2	7.6	7.8	7.9	8.3	9.1
Surface pH range	5.1 - 6.8	5.8 - 6.8	7.5 - 7.8	6.5 - 7.8	7.7 - 8.1	7.0 - 8.0	6.8 - 8.2	7.2 - 9.0	8.4 - 9.8
Conductivity (25°C) (µmho/cm), spring 1983	96	161	80	149	102	154	157	175	n.d.
Conductivity (25°C) (µmho/cm), summer 1984	114	140	128	137	114	141	153	176	191
Apparent water colour	dark brown	dark brown	moderate brown	moderate brown	brown green, clear	brown green, clear	brown green, clear	yellow brown, turbid	yellow brown, turbid
	Group I		Group II		Group III		Group IV		

* Key KA = L. Kainui
MH = L. Mangahia
MK = L. Mangakavare
MA = L. Maratoto
NG = L. Ngaroto
RK = L. Rotokauri
RMN = L. Rotomanuka North
RMS = L. Rotomanuka South
RR = L. Rotoroa

** n.d. = no data available

† = October 1983 to July 1984

Fig. 3/18 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Rotomanuka North, July 1983 to July 1984.



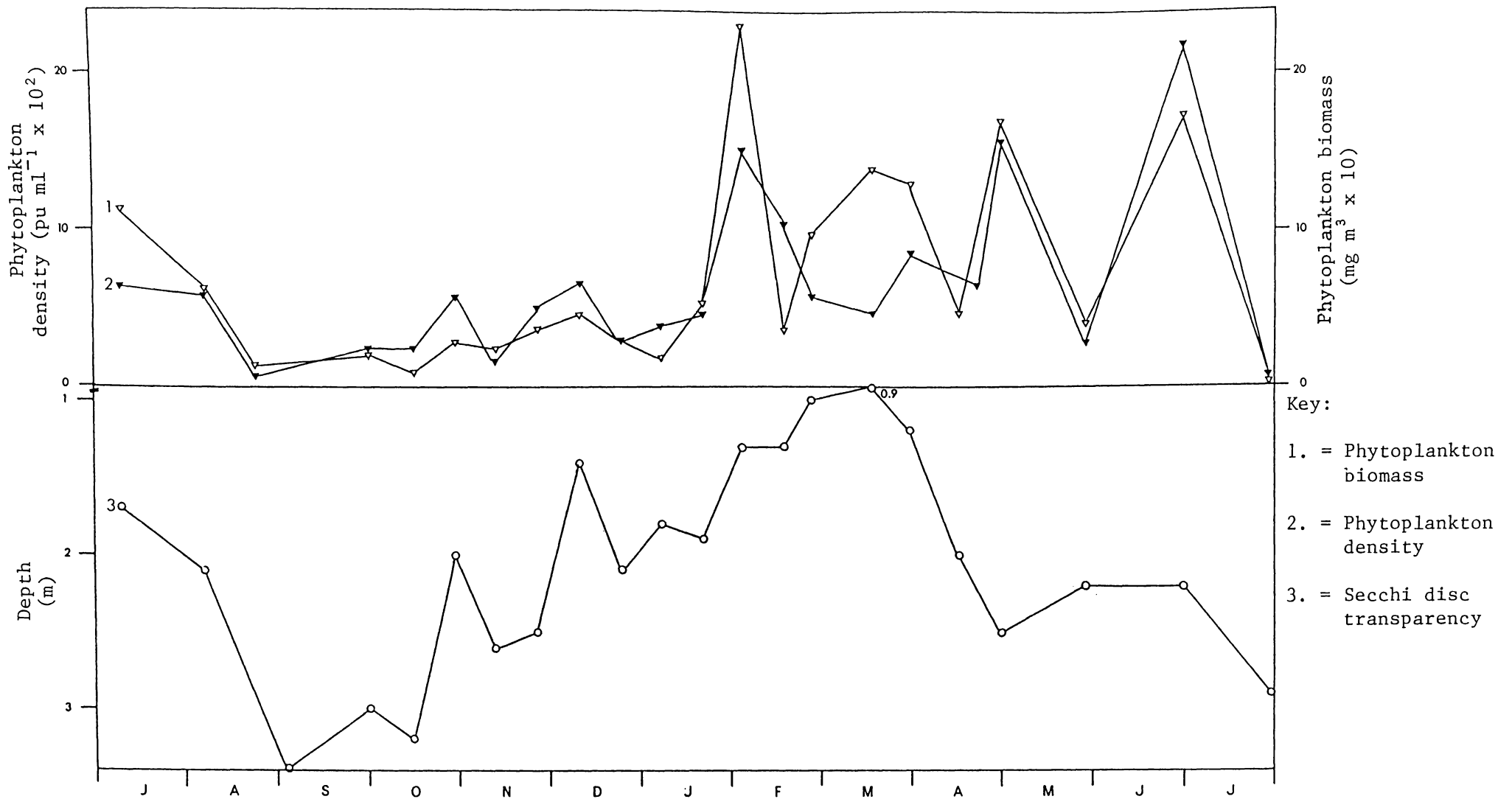
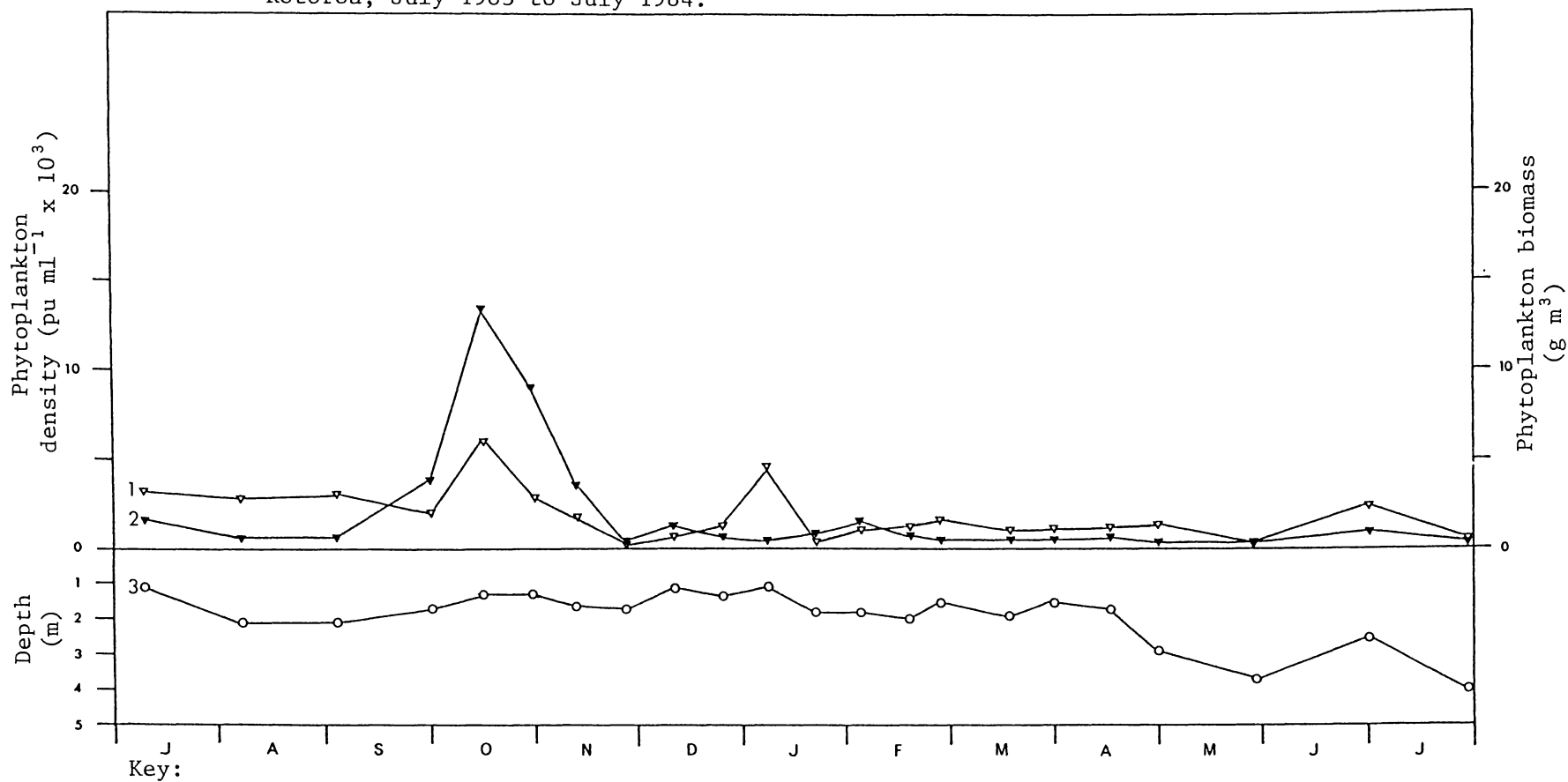


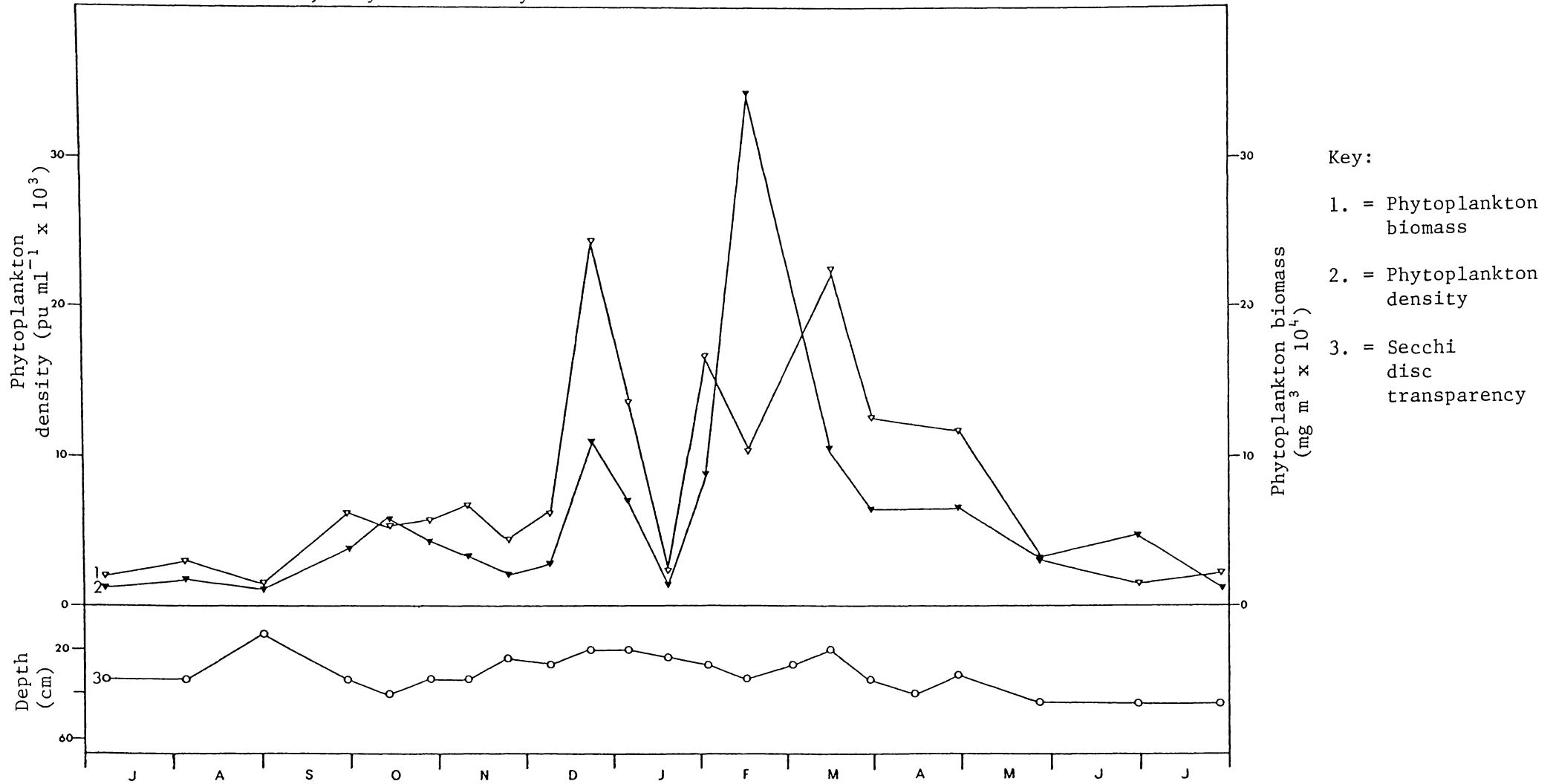
Fig. 3/19 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Rotokauri, July 1983 to July 1984.

Fig. 3/20 Temporal variations in Secchi disc transparency, and phytoplankton standing crop in Lake Rotoroa, July 1983 to July 1984.



- Key:
- 1. = Phytoplankton biomass
 - 2. = Phytoplankton density
 - 3. = Secchi disc transparency

Fig. 3/21 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Maratoto, July 1983 to July 1984.



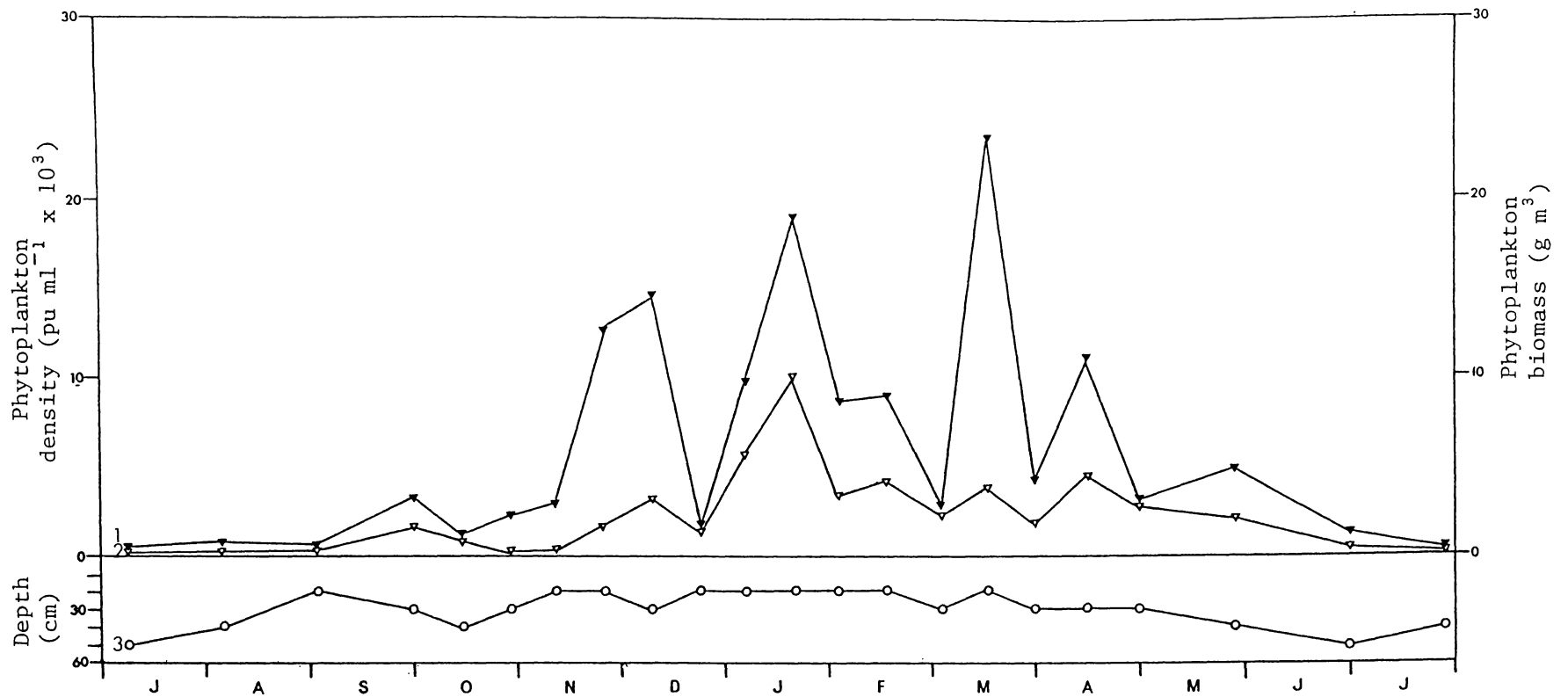
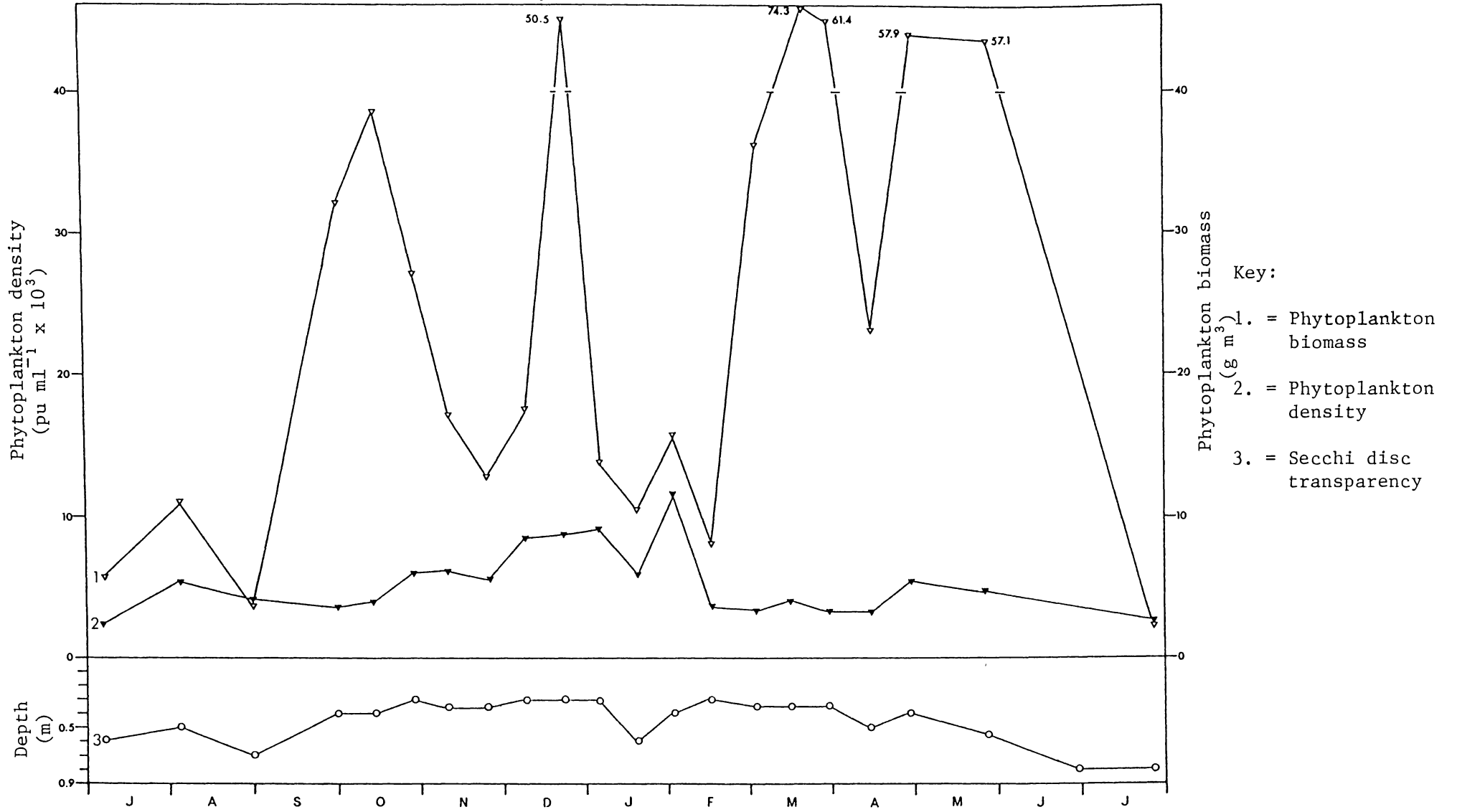


Fig. 3/22 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Mangahia, July 1983 to July 1984.

Key:

- 1. = Phytoplankton density
- 2. = Phytoplankton biomass
- 3. = Secchi disc transparency

Fig. 3/23 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Ngaroto, July 1983 to July 1984.



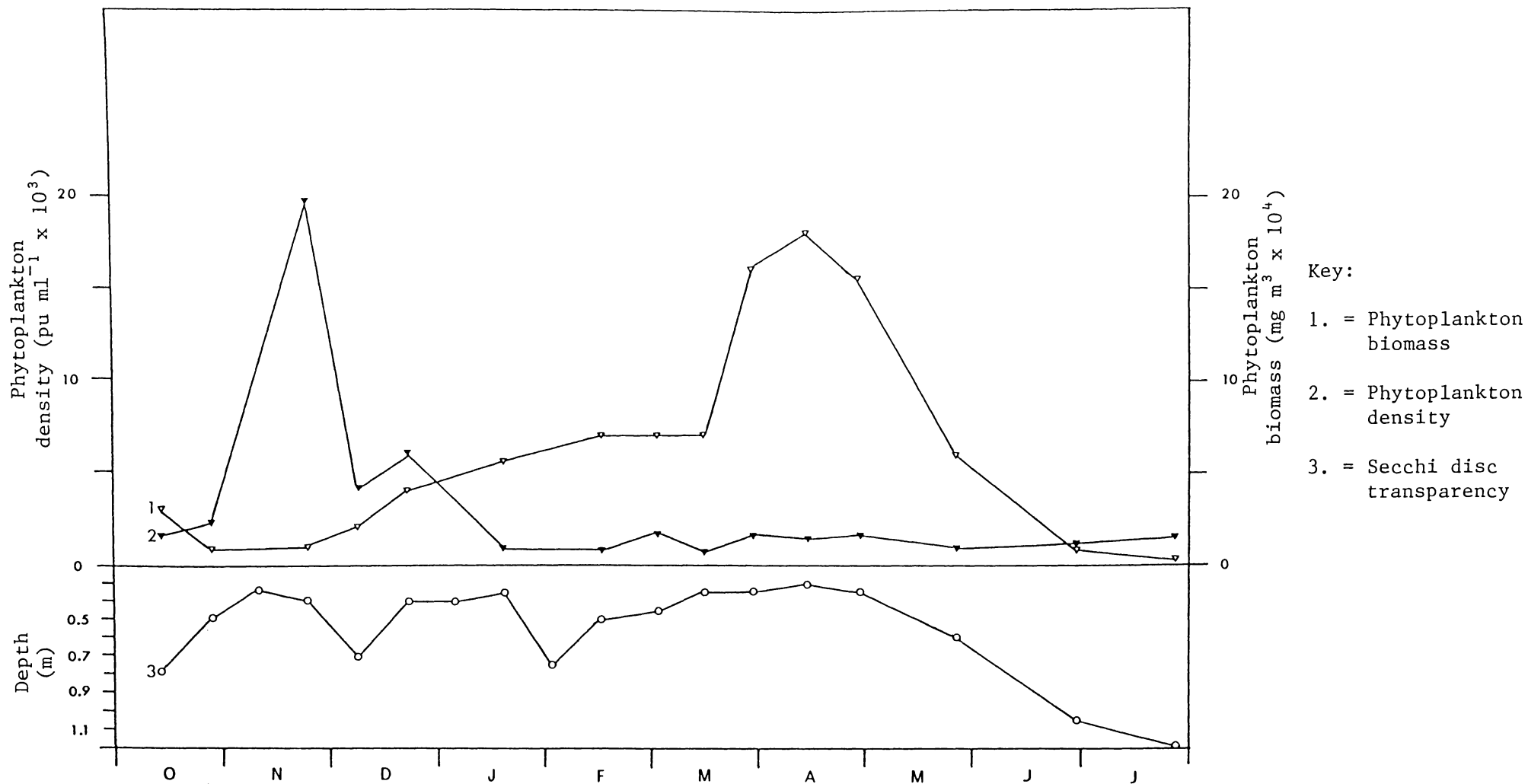


Fig. 3/24 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Rotomanuka South, October 1983 to July 1984.

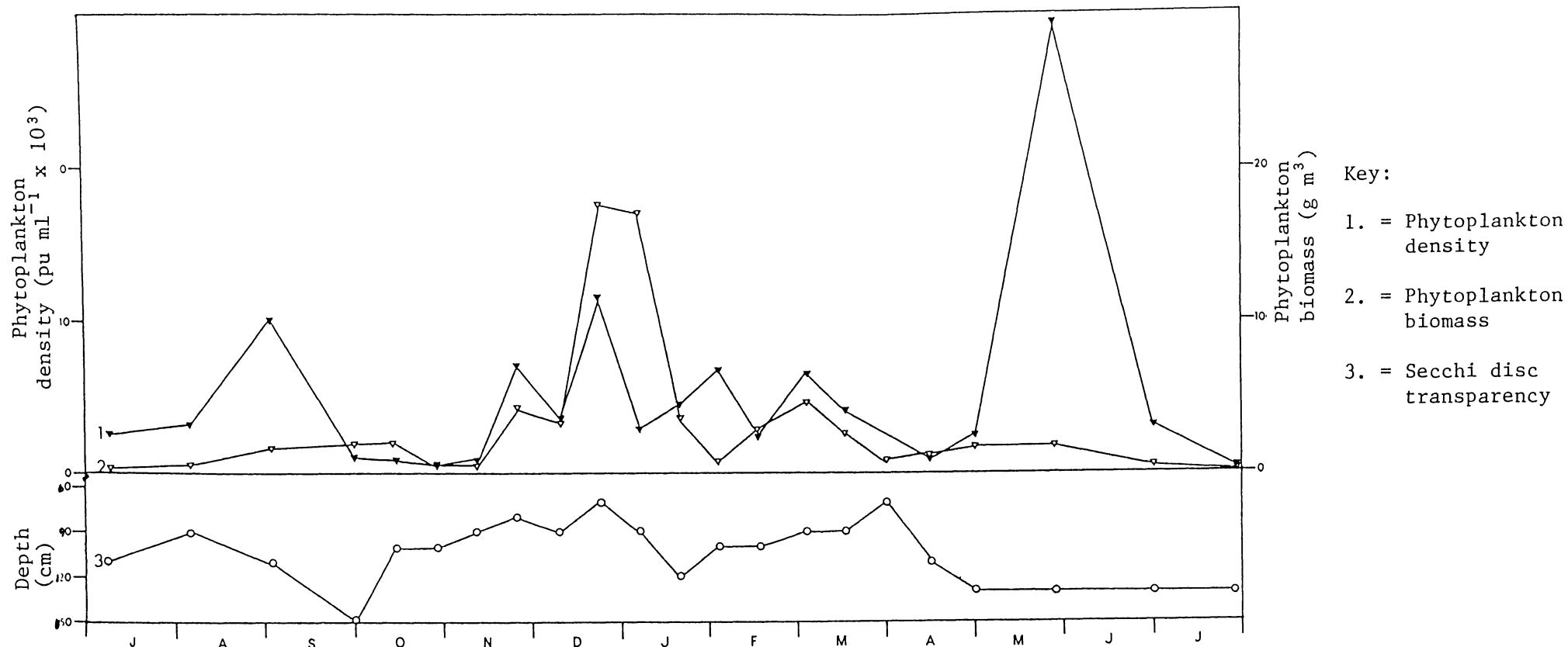


Fig. 3/25 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Mangakaware, July 1983 to July 1984.

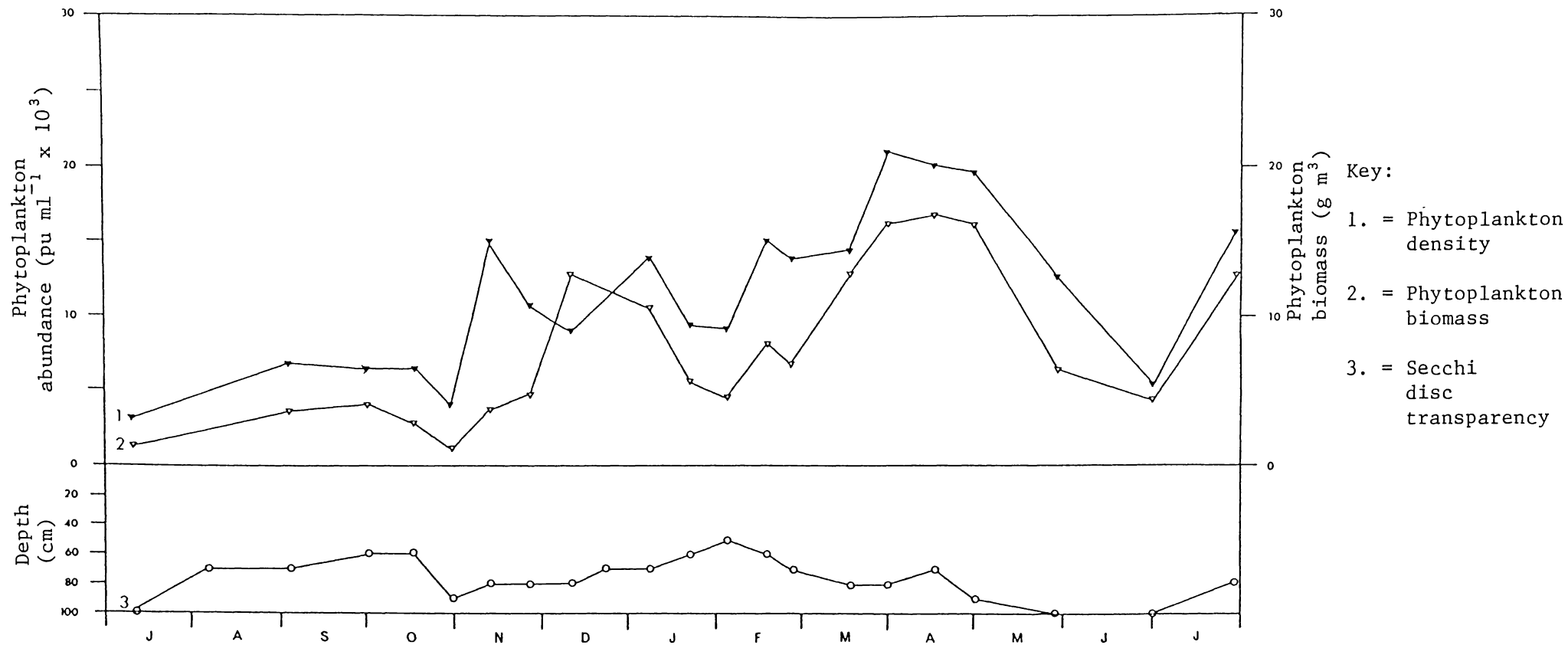


Fig. 3/26 Temporal variations in Secchi disc transparency and phytoplankton standing crop in Lake Kainui, July 1983 to July 1984.

consistently lower summer and autumnal values, except during January, when total phytoplankton densities were relatively low (Figs. 3/23 and 3/24, respectively).

Temporal variations in mean phytoplankton densities and biomass throughout the study period are also given in Figs. 3/18 to 3/26, and it is of interest that neither was significantly correlated ($p \geq 0.05$) with mean Secchi disc transparency in any of the four most darkly-stained lakes (Maratoto, Mangahia, Kainui and Mangakaware). However, in both Lakes Ngaroto and Rotomanuka South, in which *Microcystis aeruginosa* was present in high concentrations, total biomass and Secchi disc transparency showed significant negative correlations ($r = -0.531$, $p \leq 0.02$, $n = 21$ and $r = -0.705$, $p \leq 0.01$, $n = 15$, respectively).

3.5 DISCUSSION

In terms of the revised lake mixing classification of Lewis (1983), the study lakes, as a result of differing morphometries and exposure to wind, belong to one of two categories. Lake Rotomanuka North mixed completely only once during the year, and is therefore warm monomictic. It is both the most sheltered and the deepest lake in the series. The thermal regimes of the remainder are best described as discontinuous, warm polymictic systems, although Lakes Rotokauri and Rotomanuka South displayed continuous water column stability for reasonably lengthy periods throughout summer. The former is also more sheltered from wind than other study lakes, a factor which, together with the presence of dense beds of aquatic macrophytes, may explain its greater resistance to mixing.

New Zealand's characteristically vigorous winds have been associated with late formation of the thermocline within the warming period, and the production of deep epilimnia in lakes of varying depths (Green *et al.*, 1987). Their impact on relatively shallow lakes, such as those in the Waikato area, is extremely significant. The typically short-lived stratification exhibited by the majority of the study lakes, comparatively low annual temperature ranges of both the surface and bottom waters, (although the range is high compared to other New Zealand lakes because of their small size and stained waters [see below]), and unpredictable temperature/oxygen profiles, indicate that wind must play a key role in regulating their physico-chemical regimes. Furthermore, as the degree of mixing of a water column (and

consequently interaction between sediments, bottom waters and the photic zone) is inextricably inter-related to phytoplankton community dynamics, the wind, in association with the shallow nature of the lakes, may be considered a major causal factor in the episodic nature of many of the phytoplankton population cycles (Chapter 6).

A notable feature present in several of the polymictic lakes, but particularly Lakes Mangakware (Fig. 3/6 [11.11.83]), Kainui (Fig. 3/3 [3.3.84]) and Rotoroa (Fig. 3/7 [12.11.83]), was 'step structuring' of the temperature profile (Imberger, 1985), probably caused by successions of diurnal heating (accentuated in the darkly-stained waters) and convectional episodes. However, in each instance, there was no opportunity for maturation of an 'older', basal water-body, because it was immediately followed by a further period of complete mixing of the water column.

Annual temperature ranges of both the surface and bottom waters, showed minimal differences within the group (Table 3/0), but were markedly higher than those recorded from other deeper New Zealand lakes (see Green *et al.*, 1987). More importantly, however, such temperature ranges were low in comparison to those recorded in lakes of similar latitude within continental regimes (see Green *et al.*, [1987]; Fig. 8, p. 80), a feature which may permit significant winter phytoplankton growth and production (see Chapter 7). Undoubtedly, this is caused by the ameliorating influence of New Zealand's mild, oceanic climate (Jolly & Irwin, 1975; Green *et al.*, 1987). The highest temperatures at 0.5 m were recorded during early and mid-January in all study lakes, except Lake Rotokauri, where it was recorded in early March. The lowest temperatures (9.5 to 11°C) persisted for longer periods than summer maxima, frequently up to two months.

In the nine study lakes, oxygen saturation at 0.5 m ranged from 62 to 150% and, in general, surface waters were slightly undersaturated for the greater part of the year (mean 92.3%). This is in strong contrast to conditions in many other New Zealand lakes, where levels of oxygen in the surface waters markedly exceed 100% saturation throughout summer and, in addition, if phytoplankton productivity is high, supersaturation throughout periods of low temperatures is not unusual (e.g., Jolly, 1968; McColl, 1972; Green, 1975a; Cassie & Freeman, 1980). The relatively lower saturations in the small, Waikato

lakes, presumably are a direct result of their humic content, and thus concomitant chemical and photochemical oxidations (Gjessing & Gjerdahl, 1970). However, suspended particulate matter (originating from bottom sediments and suspended during the frequent mixing episodes) is probably also important. The highest mean oxygen saturation (100.3%) was recorded in Lake Ngaroto (Table 3/0), and the relatively large surface area of this lake (Table 1/0), together with high densities of *Microcystis aeruginosa*, were probably the main causal factors. Highest saturation occurred in early and mid-summer in both Lakes Rotomanuka North and Rotokauri, but no seasonal pattern was evident in the other seven lakes. Both Lakes Kainui and Ngaroto were supersaturated at 0.5 m in July, and the former, plus Lakes Maratoto and Mangakaware, were also supersaturated throughout August, September and October, suggesting that rapid phytoplankton growth continued throughout winter.

The grand mean oxygen saturation of the bottom waters was 49.9%. However, when Lakes Rotomanuka North and Rotokauri were excluded from the analysis, then the grand mean was 55.7%. This is a relatively low value, in terms of the instability of the water columns of the polymictic lakes, and once more, relatively high concentrations of DHM are probably a major causal factor, together with high oxygen demands of the rich, organic sediments. The lowest mean values, not unexpectedly, occurred in Lakes Rotomanuka North (24.9%) and Rotokauri (30.0%), but low levels were also recorded in Lakes Rotomanuka South (2.2%), Maratoto, Mangakaware and Kainui (all 2.3%). The highest oxygen saturation of the bottom waters was recorded in Lakes Kainui and Ngaroto (112 and 110%, respectively), both of which had minimal water column stability.

Sub-surface oxygen maxima were recorded at times in Lakes Mangahia, Mangakaware, Maratoto, Rotokauri, and Rotoroa. Vertical distribution investigations of phytoplankton in Lake Rotomanuka North (Etheredge, 1983), showed that the favoured positions of *Cryptomonas* spp. and some euglenoids, were low in the water column. These taxa were also abundant in the above lakes (Chapter 4), and thus may be partially responsible for such maxima. However, inhibition of photosynthesis in the surface layers cannot be discounted as another causal factor.

While high oxygen demands of the sediments appear to be a notable feature of the polymictic lakes, their significance in terms of

nutrient regeneration is unclear. However, it is highly probable that they permit regular, internal nutrient loading, which may explain some of the high nutrient concentrations in lakes such as Ngaroto and Mangahia, and in addition, may be a very significant factor in the maintenance of the high levels of productivity recorded during the present study (see Chapter 7.1). However, varying land-use practices in close proximity to the lakes must also influence nutrient concentrations.

Brown-stained lakes have been of interest since Naumann (1917, 1918, 1920) and Thienemann (1918, 1921, 1925) produced the first ecological classifications of lakes. Naumann included a humus lake with low productivity in his scheme, as a subtype of northern European lakes, but it was Thienemann who introduced the term 'dystrophic' to describe lakes of varying trophic status with acidic, darkly-stained water. However, there has been a spectacular lack of clarity in both its definition and usage, probably because of Naumann's assertion that humic lakes were oligotrophic (Etheredge, 1983). Despite early documentation of some highly productive, darkly-stained lakes in Scandinavia (and the proposal to categorise such systems as 'mixotrophic'; Järnefelt, 1925), Wisconsin (Juday & Birge, 1932) and northern Germany (Ohle, 1934), confusion continues. For example, Round (1981; p. 277) defines dystrophic lakes as 'those with nutrient-poor, brown peaty water'. Berg & Petersen (1956), in their review of lake typology, concluded that dystrophic lakes did not form a unified group. However, both Järnefelt (1958) and Hansen (1962) have since indicated that dystrophic systems are fundamentally different from the oligotrophic-eutrophic series, forming a supplementary and separate category. This supported the earlier view of Strøm (1931; p. 500) who stated that 'it will be apparent that not only are all chemical and biological processes atypical in real dystroph lakes, but that even small amounts of active humus change the character of large and deep lakes'

In Europe, the most comprehensive long-term studies on brown-stained lakes have been in Finland (e.g., Järnefelt, 1925; Ilmavirta & Kotimaa, 1974; Ilmavirta *et al.*, 1984; Keskitab, 1977; Ilmavirta 1980, 1982, 1983, 1984a), where flagellates are the important biomass contributors, especially in the darkest and most oligotrophic lakes, and species periodicity changes rapidly (Ilmavirta, 1982).

Some detailed work has been done on humic lakes in both Canada and the United States of America (particularly the eastern states) (e.g., Janus & Duthie, 1979; Stoneburner & Smock, 1980; Earle *et al.*, 1986), but phytoplankton communities influenced by artificial acidification (e.g., acid precipitation [Yan & Stokes, 1978; Wilcox & DeCosta, 1982; Havens & DeCosta 1984, 1985; Janicki & DeCosta, 1984], or mine drainage [Kwiatkowski & Roff, 1976; Yan & Strus, 1980; DeCosta *et al.*, 1983; Bleiwas *et al.*, 1984; Brezonik *et al.*, 1984]), have received more attention.

In the Southern Hemisphere, there is very little information about phytoplankton community structure and regulation in brown-stained lakes: however, several studies on some small dystrophic, meromictic Tasmanian lakes have recently been completed (e.g., King & Tyler, 1981; Baker *et al.*, 1985; Croome & Tyler, 1986).

It has long been realised that DHM can determine, to a considerable extent, the biological characteristics of coloured lakes (e.g., Strøm, 1931). The relationships between DHM and both decreased light attenuation and ambient pH are well documented (Shapiro, 1957; Stewart & Wetzel, 1981). DHM can promote phytoplankton growth (Prakash & Rashid, 1968; Nechutova & Tichy, 1970; Prakash *et al.*, 1973; Prakash *et al.*, 1975; Giesy, 1976) but also, as a result of its excellent metal complexing abilities (Ghosh & Schnitzer, 1980), may inhibit the bioavailability of essential trace metals. In addition, DHM is known to influence some enzyme systems (Loomis & Battaile, 1966), and its ability to alter phosphorus cycling has been discussed (Stewart & Wetzel, 1982).

No direct measurements of water colour or humic content were made during this study; instead, combined physico-chemical data (Table 3/10) were used to give an indirect assessment of the allochthonous humic content of the study lakes. On this basis they have been divided into four broad categories. Lakes Maratoto and Mangahia, which both appear very darkly-stained, were classified as dystrophic; light absorbtion at both 270 and 400 nm was relatively high, differences between filtered and unfiltered samples were minor, and both Secchi disc transparencies and pHs were low. A detailed investigation of the optical properties of Lake Maratoto by Howard-Williams & Vincent (1984, 1985), also indicated that this lake is highly humic. Little particulate matter was present, high absorbance occurred at the blue

end of the spectrum, and absorbance increased exponentially with wavelength.

Lakes Kainui and Mangakaware form the second group; both are moderately stained, with relatively high absorbance at 270 and 400 nm, and low mean Secchi disc transparencies in relation to their maximum depths. They were not classified as dystrophic because of their approximately neutral surface pHs.

Lakes Rotoroa, Rotokauri and Rotomanuka North, with brown-green to almost clear water, comprise the third category. Their mean Secchi disc transparencies were relatively high, light absorbance was markedly lower than that of other groups, and their median surface pHs were very similar.

The fourth group contains Lakes Ngaroto and Rotomanuka South, the yellow-brown coloured lakes which differed markedly from others in the series. not only in terms of colour, high surface pHs and conductivity, but also turbidity (Table 3/11). Comparatively high turbidity and pHs, plus the relatively low mean Secchi disc transparencies, are undoubtedly caused by the combined effects of morphometry (both lakes have extensive areas of relatively shallow water [≤ 2.5 m]) and an abundance of cyanophytes, in particular *Microcystis aeruginosa* (Chapters 6.1.5.5, and 6.1.8.5).

These groupings provide the basis for community analyses and discussion in the following chapters.

TABLE 3/11 Turbidity in Formazin Turbidity Units (FTU) of some of the study lakes. * = data from Davies-Colley (1983).

Lake	Date	Turbidity (FTU)
Kainui	September 1983	2.7
	November 1983	2.6
Mangahia	September 1983	15.0
	November 1983	4.5
Mangakaware	September 1983	2.1
	November 1983	2.2
Maratoto	September 1983	2.7
	November 1983	4.0
Ngaroto	July 1982	6.3*
	September 1983	5.4
	November 1983	8.3
Rotokauri	September 1983	1.1
	November 1983	1.3
Rotomanuka North	September 1983	0.4
	November 1983	1.2
Rotomanuka South	November 1983	4.1
Rotoroa	July 1982	2.7*
	September 1983	2.0
	November 1983	2.3

CHAPTER FOUR

COMPOSITIONAL ANALYSES OF THE PHYTOPLANKTON COMMUNITIES OF THE NINE STUDY LAKES

4.1 INTRODUCTION

Phytoplankton communities are generally complex assemblages of numerous co-existing species interacting at both intra- and inter-specific levels, and also with herbivores, sometimes other autotrophs, and the physico-chemical regime.

Both equilibrium and non-equilibrium models (Hutchinson 1941, 1953, 1961, 1967; Richerson *et al.*, 1970; Stewart & Levin, 1973; Petersen, 1975) have been proposed to explain high phytoplankton α diversity although, to some extent, this apparent contradiction, 'the paradox of the plankton' (Hutchinson, 1961), has recently been dispelled by field tests of the predation hypothesis in clear water lakes (see Chapter 8), and/or niche diversification (Harris *et al.*, 1983).

Generally, resource competition (resulting from specific physico-chemical regimes and grazing pressures) is probably central to the determination of phytoplankton species diversity, but the experimental studies necessary to detail such causal mechanisms with precision are problematical because of the naturally occurring variations in both temporal and spatial scales (Tilham *et al.*, 1982). Such competition, however, is probably of lesser importance in lakes characterised by frequent, large-scale, temporal environmental fluctuations (as in the majority of the study lakes [Chapter 3]), because of the continual disruption of progress towards competitive exclusion (Harris *et al.*, 1983). Such interference has been considered causal in the maintenance of high α diversity in other types of ecosystems. Connell (1978), for example, proposed an 'intermediate disturbance' hypothesis to explain high species numbers in both tropical forests and coral reefs, suggesting that disturbance caused increased species richness by providing previously unavailable resources, which were then utilised by 'new' species dispersed into the perturbed environment from distant populations. In phytoplankton communities, allochthonous supplies of potential colonists would not be essential to maintain high α

diversity, because of the generally large 'hidden flora' (Rahat & Dor, 1968).

Marked differences in α diversity and species composition frequently occur between lakes. Traditionally, explanations have invoked water chemistry as a key factor (e.g., Whipple & Jackson, 1899; Pearsall 1930, 1932; Patrick, 1948), but more recent studies have emphasised the importance of a large suite of variables, together with the complex nature of their inter-relationships. A key problem facing limnologists, however, is the 'identification of correct temporal and spatial scales by which to explain community structure' (Harris, 1980; p. 882), because correlations between environmental parameters and community structure rarely exist owing to time lags in community responses to perturbations in the environment (Allen *et al.*, 1977). However, if floras are specialised and/or exhibit unique attributes, it is possible to associate specific regulatory factors with particular characteristics. For example, dystrophic communities generally are characterised by low α diversity, a paucity of cyanophytes, acidobiontic diatom species, and numerous flagellates (see Chapter 5.5).

This chapter gives a structural analysis of the phytoplankton communities of each of the study lakes, and is followed by a comparative analysis of all nine lakes discussed in relation to physico-chemical regimes and morphometry (Chapter 5). The impact of zooplankton grazing on phytoplankton community composition is discussed in Chapter 8.

Throughout the present study, a major phytoplankton species is defined as one with a mean contribution of $\geq 0.1\%$ of the mean total density or biomass. Biomass analyses omit species with a mean density $< 1 \text{ pu ml}^{-1}$.

4.2 COMMUNITY COMPOSITION

4.2.1 LAKE KAINUI

4.2.1.1 Species Composition

108 species, belonging to 58 genera, were found in Lake Kainui, and an analysis of their mean density and biomass contributions is given in Table 4/0. Chlorophytes contributed the largest number of species (53 [49%]), with the Euchlorophyceae being particularly well represented (33 species [30%]). The proportions of the Zygothyceae, Diatomophyceae and Cyanophyceae were relatively similar (18, 17 and

TABLE 4/0 Mean density and biomass contributions of the phytoplankton in Lake Kainui, July 1983 to July 1984; n = 20. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Volvocaceae				
<i>Gonium pectorale</i>	0.2			
<i>Pandorina morum</i>	0.2			
Spondylomoraceae				
<i>Spondylomorom quarternarium</i>	0.2			
Chlorococcales				
Oocystaceae				
<i>Ankistrodesmus bibraianus</i>	102.5	9	25.7	18
<i>A. fusiformis</i>	0.2			
<i>A. gracilis</i>	124.6	8	14.9	20
<i>Kirchneriella obesa</i>	0.8			
<i>Monoraphidium contortum</i>	0.4			
<i>M. irregulare</i>	0.2			
<i>M. komarkovae</i>	4.4	29	0.5	35=
<i>M. minutum</i>	1.7	43	0.02	44
<i>M. tortile</i>	22.5	16	0.3	37
<i>Nephrocytium agardhianum</i>	4.7	27	11.4	21
<i>N. limneticum</i>	2.5	36=	1.8	27
<i>Oocystis lacustris</i>	0.2			
<i>O. solitaria</i>	0.2			
<i>Raphidocelis contorta</i>	2.0	41	0.05	42
Micractiniaceae				
<i>Micractinium pusillum</i>	0.5			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	33.4	12	426.5	4
<i>Dictyosphaerium ehrenbergianum</i>	9.1	21	0.2	38=
<i>D. pulchellum</i>	0.9			
<i>Dimorphococcus lunatus</i>	2.5	36=	0.7	33=
Scenedesmaceae				
<i>Coelastrum cambricum</i>	0.4			
<i>C. microporum</i>	2.5	36=	1.4	29=
<i>C. reticulatum</i>	28.1	13	53.9	13
<i>Scenedesmus acutiformis</i>	2.2	40	0.5	35=
<i>S. intermedius</i>	0.1			
<i>S. quadricauda</i>	595.3	5	148.8	7
<i>Tetrastrum staurogeniaforme</i>	0.2			
<i>T. triangulare</i>	1.4	44	0.06	41
Hydrodictyaceae				
<i>Pediastrum duplex</i>	6.5	24	2.3	25
<i>P. tetras</i>	9.2	20	0.7	33=
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	5.9	25	0.1	40

TABLE 4/0 continued

Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium</i> sp.	0.04			
Zygothyceae				
Zygnematales				
Zygnemataceae				
<i>Spirogyra</i> sp. A	0.2			
<i>Mougeotia</i> sp. B	1.3	45	1.0	31
Desmidiaceae				
<i>Closterium acutum</i>	0.4			
<i>C. a.</i> var. <i>variabile</i>	991.0	3	59.5	12
<i>C. gracile</i>	27.4	14	145.8	8
<i>C. parvulum</i>	0.2			
<i>C. setaceum</i>	4.2	30=	22.0	19
<i>Cosmarium contractum</i>	0.2			
<i>Staurastrum arcuatum</i>	211.3	7	750.3	3
<i>S. avicula</i>	7.4	22	25.9	17
<i>S. brachiatum</i>	918.1	4	381.0	5
<i>S. chaetopus</i> ?	220.7	6	261.7	6
<i>S. leptocladum</i> var. <i>insigne</i>	6.7	23	2.1	26
<i>S. tohopekaligense</i> var. <i>minus</i>	5.0	26	10.8	22
<i>S. subradians</i> forma ?	0.2			
<i>S. sp. C.</i>	2863.1	2	764.4	2
<i>Staurodesmus cuspidatus</i>				
<i>St. dejectus</i>				
<i>St. mammillatus</i>	5192.0	1	4428.8	1
<i>St. mucronatus</i> var. <i>subtriangularis</i>	9.9	19	9.4	
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	2.9	34	1.1	29=
Dinobryaceae				
<i>Dinobryon cylindricum</i>	0.2			
Synuraceae				
<i>Mallomonas tonsurata</i>	0.6			
Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Pseudostaurastrum hastatum</i>	0.2			
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	0.6			
<i>A. granulata</i>	11.2	18	62.1	11
<i>A. g.</i> var. <i>angustissima</i>	4.2	30=	4.9	24
<i>Cyclotella stelligera</i>	4.6	28	1.1	29=
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	0.6			
<i>Fragilaria ulna</i>	0.2			
<i>Tabellaria fenestrata</i>	0.1			
<i>T. flocculosa</i>	25.0	15	41.3	14

TABLE 4/0 continued

Eunotiales				
Eunotiaceae				
<i>Eunotia curvata</i>	0.2			
<i>E. diodon</i>	0.2			
<i>E. pectinalis</i>	0.2			
<i>E. p.</i> var. <i>minor</i>	0.2			
<i>E. p.</i> var. <i>undulata</i>	0.2			
<i>E. tenella</i>	0.2			
Achnanthes				
Athnanthaceae				
<i>Cocconeis placentula</i>	0.2			
Naviculales				
Naviculaceae				
<i>Frustulia rhomboides</i> var. <i>saxonica</i>	0.2			
<i>Gomphonema truncatum</i>	0.08			
<i>Pinnularia gentilis</i>	0.2			
Epithemiaceae				
<i>Epithemia argus</i>	0.2			
Nitzschiaceae				
<i>Hantzschia amphioxys</i>	0.4			
<i>Nitzschia acicularis</i>	3.0	33	0.8	32
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa elachista</i>	0.2			
<i>Aphanothece nidulans</i>	0.2			
<i>Chroococcus dispersus</i>	2.8	35	0.04	43
<i>C. d.</i> var. <i>minor</i>	1.8	42	0.01	45
<i>C. limneticus</i>	0.8			
<i>Merismopedia elegans</i>	0.3			
<i>M. minima</i>	14.6	17	0.2	38=
<i>Microcystis aeruginosa</i>	4.0	32	41.2	15
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	0.6			
<i>A. flos-aquae</i>	0.3			
<i>A. minutissima</i> ?	0.4			
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.2			
<i>Oscillatoria curviceps</i>	0.1			
<i>O. geminata</i>	0.1			
<i>O. limnetica</i>	0.6			
<i>O. planctonica</i>	0.1			
<i>O. splendida</i>	0.2			
<i>O. subbrevis</i>	0.2			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Euglena oxyuris</i>	0.2			
<i>Phacus glaber</i>	0.2			

TABLE 4/0 continued

<i>P. rudicola</i>	0.2			
<i>P. suecicus</i>	0.2			
<i>Trachelomonas dangeardiana</i>	0.4			
<i>T. hispida</i>	0.2			
<i>T. planctonica</i>	0.4			
<i>T. volvocina</i>	60.6	11	107.1	9
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	0.4			
<i>C. marssonii</i>	65.3	10	28.8	16
<i>C. ovata</i>				
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium cinctum</i>	2.3	39	89.9	10
<i>P. inconspicuum</i>	0.7			
Ceratiaceae				
<i>Ceratium hirundinella</i>	0.4			
Dinococcales				
Phytodiniaceae				
<i>Tetradinium intermedium</i>	0.2			
RAPHIDOPHYTA				
Raphidophyceae				
Raphidomonadales				
Vacuolariaceae				
<i>Vacuolaria</i> sp.	0.4			

16%, respectively), but all other classes were represented by relatively low numbers (Table 4/1).

4.2.1.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 20)

The community was totally dominated by zygophytes, in terms of both abundance (10,459 pu ml⁻¹ [90%]) and biomass (6,853 mg m³ [86%]). The contributions of the Euchlorophyceae to the mean total density (8%) and biomass (9%) were relatively similar; those of other classes were minimal (Table 4/2).

4.2.1.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 20)

Of the 28 major taxa recorded from Lake Kainui (Table 4/3), 20 (71%) were chlorophytes. With one exception (*Scenedesmus quadricauda*), the 9 most abundant species were desmids. *Staurodesmus cuspidatus*, *S. dejectus* and *S. mammillatus*, the 3 most abundant species, were counted collectively because of their taxonomic similarity and their extraordinarily high densities; their mean proportion was 45%. Other important desmids were *Staurastrum* sp. C (25%), *Closterium acutum* var. *variabile* (9%) and *Staurastrum brachiatum* (8%). The most important euchlorophyte was *Scenedesmus quadricauda*, followed by *Ankistrodesmus gracilis* and *A. bibrainus*. However, despite their relatively low proportions (Table 4/3), their mean densities were 596, 125 and 103 pu ml⁻¹, respectively. Cryptophytes (*Cryptomonas marssonii* and *C. ovata*) and one euglenophyte (*Trachelomonas volvocina*) were also relatively common (Table 4/0).

The most abundant desmids were also the dominant species in terms of biomass; the 7 highest ranking species (Table 4/3) together comprised 83% of the mean standing crop. *Botryococcus braunii*, with a mean biomass contribution of 5%, was the only important non-desmid species (Table 4/3).

4.2.1.4 Size Distribution

Most species (41 [36%]) belonged to the 41 to 63 µm size fraction; the two other important groups were the 21 to 40 µm fraction (32

TABLE 4/1 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Kainui, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	33	30.5
Ulothricophyceae	1	0.9
Zygophyceae	19	17.5
CHROMOPHYTA		
Chrysophyceae	3	2.8
Diatomophyceae	18	16.7
Xanthophyceae	1	0.9
CYANOPHYTA		
Cyanophyceae	17	15.7
EUGLENOPHYTA		
Euglenophyceae	8	7.4
PYRRHOPHYTA		
Cryptophyceae	3	2.8
Dinophyceae	4	3.7
RAPHIDOPHYTA		
Raphidophyceae	1	0.9
TOTAL	<u>108</u>	<u>99.8</u>

TABLE 4/2 Mean distribution of plankton units and biomass amongst the major taxa in Lake Kainui, July 1983 to July 1984; mean values < 1 pu ml⁻¹ are excluded from the analyses (n = 20).

Taxon	Pu ml ⁻¹		Biomass	
	Number	Proportion (%)	mg m ³	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	966	8.3	690	8.7
Zygophyceae	10,459	89.8	6,863	86.5
CHROMOPHYTA				
Chrysophyceae	4	0.03	1	0.01
Diatomophyceae	52	0.4	110	1.4
CYANOPHYTA				
Cyanophyceae	27	0.2	41	0.5
EUGLENOPHYTA				
Euglenophyceae	62	0.5	107	1.3
PYRRHOPHYTA				
Cryptophyceae	66	0.5	29	0.4
Dinophyceae	4	0.03	90	1.1
TOTAL	<u>11,640</u>	<u>99.8</u>	<u>7,931</u>	<u>99.9</u>

species [28%]) and the net plankton (22 species [19%]). Most species in the 41 to 63 μm fraction were eukaryotes or cyanophytes (13 [32%] and 12 species [29%], respectively), while diatoms were the most common species in the other two major fractions (22 and 32%, respectively) (Table 4/4).

4.2.2 Lake Mangahia

4.2.2.1 Species Composition

Table 4/5 lists the 125 species, belonging to 69 genera, found in Lake Mangahia, and gives an analysis of their mean density and biomass contributions. Most were chlorophytes (37 species [30%]), but diatoms (21 species [17%]), euglenophytes (19 species [15%]) and zygophytes (16 species [13%]) were also important (Table 4/6).

4.2.2.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 22)

The Diatomophyceae was the most important class in terms of both abundance (2677 pu ml⁻¹ [42%]) and biomass (1232 mg m³ [53%]). The Zygothryx and the Eukaryophyceae (27 and 23%, respectively), were numerically important but, in terms of biomass, their mean proportions were low (8 and 4%, respectively). Conversely, the Euglenophyceae, which ranked second in terms of biomass (855 mg m³ [35%]), made up only 5% of the mean total number of pu ml⁻¹ (Table 4/7).

4.2.2.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 22)

Of the 29 major species (plus 1 variety), the majority (14 [48%]) were chlorophytes. Numerically, the most important taxa were *Aulacosira distans* (36%), *Closterium acutum* var. *variabile* (24%) and *Chlorella* sp. (16%), with *Aulacosira granulata* var. *angustissima* and *Trachelomonas volvocina* contributing 6 and 5%, respectively. The major contributors to the mean standing crop, in terms of biomass, were *Aulacosira distans* (31%), *Trachelomonas volvocina* (24%) and *Aulacosira granulata* var. *angustissima* (16%) (Table 4/8).

TABLE 4/3 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Kainui, July 1983 to July 1984 (n = 20).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Oocystaceae		
<i>Ankistrodesmus bibraianus</i>	0.9	0.3
<i>A. gracilis</i>	1.0	0.2
<i>Monoraphidium tortile</i>	0.2	-
<i>Nephrocytium agardhianum</i>	-	0.1
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	0.3	5.4
Scenedesmaceae		
<i>Coelastrum reticulatum</i>	0.2	0.7
<i>Scenedesmus quadricauda</i>	5.1	1.9
Zygophyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	8.5	0.7
<i>C. gracile</i>	0.2	1.8
<i>C. setaceum</i>	-	0.3
<i>Staurastrum arcuatum</i>	1.8	9.5
<i>S. avicula</i>	-	0.3
<i>S. brachiatum</i>	7.9	4.8
<i>S. chaetopus</i> ?	1.9	3.3
<i>S. tohopekaligense</i> var. <i>minus</i>	-	0.1
<i>S. sp C</i>	24.6	9.6
<i>Staurodesmus cuspidatus</i>	44.6	55.8
<i>St. dejectus</i>		
<i>St. mammillatus</i>		
<i>St. mucronatus</i> var. <i>subtriangularis</i>		
-	-	0.1
CHROMOPHYTA		
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira granulata</i>	-	0.8
Diatomales		
Diatomaceae		
<i>Tabellaria flocculosa</i>	0.2	0.5
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Merismopedia minima</i>	0.1	-
<i>Microcystis aeruginosa</i>	-	0.5

TABLE 4/3 continued

EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Trachelomonas volvocina</i>	0.5	1.3
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas marssonii</i>]		
<i>C. ovata</i>]	0.6	0.4
Dinophyceae		
Peridinales		
Peridiniaceae		
<i>Peridinium cinctum</i>	-	1.1
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass.		

TABLE 4/4 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Kainui, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	22	19.5
Nannoplankton	41 - 63	41	36.3
	21 - 40	32	28.3
	11 - 20	15	13.3
	6 - 10	2	1.8
Ultraplankton	≤ 5	1	0.8
Total		<u>113</u>	<u>100.0</u>

TABLE 4/5 Mean density and biomass contributions of the phytoplankton in Lake Mangahia, July 1983 to July 1984; n = 22. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Volvocaceae				
<i>Eudorina elegans</i>	0.2			
<i>Pandorina morum</i>	0.2			
Chlorococcales				
Chlorococcaceae				
<i>Tetraedron minimum</i>	0.5			
Oocystaceae				
<i>Ankistrodesmus fusiformis</i>	0.6			
<i>Chlorella</i> sp.	1034.7	3	29.0	9
<i>Monoraphidium contortum</i>	6.7	19	0.1	43
<i>M. komarkovae</i>	0.5			
<i>M. minutum</i>	4.7	24	0.07	45
<i>M. tortile</i>	62.0	10	0.8	36=
<i>Oocystis lacustris</i>	0.3			
<i>Pachycladella umbrina</i>	0.09			
<i>Raphidocelis contorta</i>	63.2	9	1.6	26=
<i>Treubaria planctonica</i>	0.2			
<i>T. setigera</i>	0.2			
Micractiniceae				
<i>Golenkinia radiata</i>	0.2			
<i>Micractinium pusillum</i>	0.4			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	0.5			
<i>Dictyosphaerium pulchellum</i>	0.2			
<i>Dimorphococcus lunatus</i>	0.4			
Scenedesmaceae				
<i>Actinastrum hantzschii</i>	3.4	26	0.7	37=
<i>Coelastrum microporum</i>	5.5	22	2.8	23
<i>C. reticulatum</i>	0.09			
<i>Crucigenia fenestrata</i>	0.7			
<i>Crucigeniella apiculata</i>	1.7	34	0.7	37=
<i>C. rectangularis</i>	2.4	29=	1.0	33
<i>Scenedesmus acuminatus</i>	1.3	40	1.2	31=
<i>S. acutiformis</i>	2.2	32	1.2	31=
<i>S. intermedius</i>	5.1	23	2.3	24
<i>S. opoliensis</i>	18.2	17	20.2	12
<i>S. quadricauda</i>	110.0	7	27.6	10
<i>S. sempervirens</i>	0.7			
<i>Tetrastrum heteracanthum</i>	38.3	11	3.0	22
<i>T. staurogeniaforme</i>	28.7	15	1.9	25
<i>T. triangulare</i>	33.4	12	1.3	28=

TABLE 4/5 continued

Hydrodictyaceae				
<i>Pediastrum duplex</i>	1.0	43=	0.4	39=
<i>P. tetras</i>	3.7	25	0.2	41=
<i>Sorastrum spinulosum</i>	0.04			
Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Bulbochaete</i> sp.	0.2			
<i>Oedogonium undulatum</i>	0.4			
Zygophyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	0.09			
<i>M.</i> sp. D	0.09			
<i>Spirogyra</i> sp. A	0.2			
Desmidiaceae				
<i>Closterium aciculare</i>	2.4	29=	12.1	14
<i>C. acutum</i> var. <i>variabile</i>	1508.2	2	87.5	6
<i>C. diana</i> var. <i>pseudodiana</i>	0.2			
<i>C. gracile</i>	181.9	6	91.1	5
<i>C. moniliferum</i>	0.2			
<i>C. parvulum</i>	0.2			
<i>Cosmarium lundelli</i> var. <i>ellipticum</i>	0.2			
<i>Pleurotaenium minutum</i>	0.2			
<i>P. trabecula</i>	0.4			
<i>Staurostrum chaetopus</i> ?	7.4	18	8.8	17=
<i>S.</i> sp. B	2.4	29=	0.9	35
<i>Staurodesmus dejectus</i>	1.0	43=	1.3	28=
<i>St. glaber</i> var. <i>limnophilus</i>	3.0	27=	4.5	21
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	30.2	13	11.5	16
<i>Biocosoeca petiolata</i>	0.2			
Chrysamoebaceae				
<i>Chrysamoeba radians</i>	0.4			
Dinobryaceae				
<i>Dinobryon cylindricum</i>	1.5	36=	0.2	41=
Synuraceae				
<i>Mallomonas acaroides</i>	1.5	36=	0.8	36=
<i>M. akrokomos</i>	1.4	38=	1.3	28=
<i>M. tonsurata</i>	24.0	16	23.1	11
<i>Synura uvella</i>	0.5			
Xanthophyceae				
Misochococcales				
Pleurichloridaceae				
<i>Tetradriella jovetii</i>	1.4	38=	0.1	43=
Sciadiaceae				
<i>Centrtractus belonophorus</i>]	1.0	43=	4.7	20
<i>C. africanus</i>]				
Diatomophyceae				
Coscinodiscales				

TABLE 4/5 continued

Coscinodiscaceae				
<i>Aulacosira distans</i>	2284.7	1	776.2	1
<i>A. granulata</i>	1.6	35	8.8	17=
<i>A. g. var. augustissima</i>	345.7	4	387.5	3
<i>Cyclotella meneghiniana</i>	0.4			
<i>C. stelligera</i>	6.6	20	1.6	26=
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	0.9			
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	3.0	27=	0.4	39=
<i>Tabellaria fenestrata</i>	1.9	33	7.4	19=
<i>T. flocculosa</i>	29.2	14	52.1	7
Eunotiales				
Eunotiaceae				
<i>Eunotia curvata</i>	0.2			
<i>E. diodon</i>	0.09			
<i>E. naegeli</i>	0.09			
<i>E. pectinalis</i>	0.6			
<i>E. p. var. minor</i>	0.2			
<i>E. p. var. undulata</i>	0.09			
<i>E. serpentina</i>	0.09			
Achnanthales				
Achnanthaceae				
<i>Cocconeis placentula</i>	0.6			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	0.2			
<i>Anomoeoneis serians</i>	0.09			
<i>Cymbella minuta</i>	0.3			
<i>Frustulia rhomboides</i> var. <i>saxonica</i>	0.09			
<i>Gomphonema truncatum</i>	0.2			
<i>Pinnularia gentilis</i>	0.09			
<i>P. gibba</i>	0.09			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa elachista</i>	0.03			
<i>Chroococcus dispersus</i> var. <i>minor</i>	0.6			
<i>Gomphosphaeria lacustris</i>	6.0	21	29.1	8
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	0.4			
<i>A. spiroides</i> var. <i>tumida</i>	0.3			
<i>Cylindrospermum minutissimum</i>	0.4			
<i>Lyngbya limnetica</i>	0.4			
<i>Oscillatoria agardhii</i>	0.2			
<i>O. limnetica</i>	0.09			
<i>O. limosa</i>	0.09			
<i>O. splendida</i>	0.2			
<i>O. subbrevis</i>	0.2			

TABLE 4/5 continued

EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Astasia harrisii</i>	0.2			
<i>Euglena acus</i>	1.2	41=	11.7	15
<i>E. oxyuris</i>	1.2	41=	254.5	4
<i>E. proxima</i>	0.09			
<i>E. sanguinea</i>	0.2			
<i>E. tripteris</i>	0.2			
<i>Lepocinclis ovum</i>	0.09			
<i>Phacus helicoides</i>	0.4			
<i>P. longicauda</i>	0.3			
<i>P. pleuronectes</i>	0.4			
<i>P. pyrum</i>	0.2			
<i>P. suecicus</i>	0.7			
<i>P. tortus</i>	0.2			
<i>Trachelomonas cylindrica</i>	0.2			
<i>T. hexangulata</i>	0.4			
<i>T. hispida</i> var. <i>coronata</i>	0.4			
<i>T. planctonica</i>	0.09			
<i>T. playfairi</i>	0.4			
<i>T. volvocina</i>	333.0	5	588.4	2
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	0.2			
<i>C. marssonii</i>	91.2	8	14.3	13
<i>C. ovata</i>				
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium cinctum</i>	0.4			
<i>P. pusillum</i> tab. <i>conjunctum</i>	0.2			
Ceratiaceae				
<i>Ceratium hirundinella</i>	0.2			
Dinococcales				
Phytodiniaceae				
<i>Cystodinium cornifax</i>	0.4			

TABLE 4/6 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Mangahia, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	37	29.6
Ulothricophyceae	2	1.6
Zygophyceae	16	12.8
CHROMOPHYTA		
Chrysophyceae	8	6.4
Diatomophyceae	21	16.8
Xanthophyceae	3	2.4
CYANOPHYTA		
Cyanophyceae	12	9.6
EUGLENOPHYTA		
Euglenophyceae	19	15.2
PYRRHOPHYTA		
Cryptophyceae	3	2.4
Dinophyceae	4	3.2
TOTAL	<u>125</u>	<u>100</u>

TABLE 4/7 Mean distribution of plankton units and biomass amongst the major taxa in Lake Mangahia, July 1983 to July 1984; mean values < 1 pu ml⁻¹ are excluded from the analyses (n = 22).

Taxon	Pu ml ⁻¹		Biomass	
	Number	Proportion (%)	mg m ³	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	1,432	22.6	96	3.9
Zygophyceae	1,708	27.0	206	8.3
CHROMOPHYTA				
Chrysophyceae	60	0.9	37	1.5
Diatomophyceae	2,677	42.3	1,234	49.8
Xanthophyceae	2	0.03	6	0.2
CYANOPHYTA				
Cyanophyceae	9	0.1	29	1.2
EUGLENOPHYTA				
Euglenophyceae	340	5.4	855	34.5
PYRRHOPHYTA				
Cryptophyceae	91	1.4	855	34.5
Dinophyceae	1	0.01	14	0.6
TOTAL	<u>6,320</u>	<u>99.7</u>	<u>2,477</u>	<u>100</u>

TABLE 4/8 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Mangahia, July 1983 to July 1984 (n = 22).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Oocystaceae		
<i>Chlorella</i> sp.	16.4	1.2
<i>Monoraphidium tortile</i>	1.0	-
<i>Raphidocelis contorta</i>	1.0	-
Scenedesmaceae		
<i>Coelastrum microporum</i>	-	0.1
<i>Scenedesmus opoliensis</i>	0.3	0.8
<i>S. quadricauda</i>	1.7	1.1
<i>Tetrastrum heteracanthum</i>	0.6	0.1
<i>T. staurogeniaforme</i>	0.4	-
<i>T. triangulare</i>	0.5	-
Zygophyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium aciculare</i>	-	0.5
<i>C. acutum</i> var. <i>variabile</i>	23.9	3.5
<i>C. gracile</i>	2.9	3.7
<i>Staurastrum chaetopus</i> ?	0.1	0.3
<i>Staurodesmus glaber</i> var. <i>limnophilus</i>	-	0.1
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.5	0.5
Synuraceae		
<i>Mallomonas tonsurata</i>	0.4	0.9
Xanthophyceae		
Mischococcales		
Sciadiaceae		
<i>Centrित्रactus africanus</i>	-	0.2
<i>C. belonophorus</i>		
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira distans</i>	36.1	31.3
<i>A. granulata</i>	-	0.3
<i>A. g.</i> var. <i>angustissima</i>	5.5	15.6
<i>Cyclotella stelligera</i>	0.1	-
Diatomales		
Diatomaceae		
<i>Tabellaria fenestrata</i>	-	0.3
<i>T. flocculosa</i>	0.5	2.1

TABLE 4/8 continued

CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Gomphosphaeria lacustris</i>	-	1.2
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Euglena acus</i>	-	0.5
<i>E. oxyuris</i>	-	10.3
<i>Trachelomonas volvocina</i>	5.3	23.7
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas marssonii</i>	1.4	0.6
<i>C. ovata</i>		
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

4.2.2.4 Size Distribution

The majority of species were large; the GALD of 85% of all taxa \geq was 21 μm . The net plankton and the 41 to 63 μm fraction each contained 30% of the total taxa, while a further 26% belonged to the 21 to 40 μm group. The GALD of 5 species (4%) was less than 10 μm (Table 4/9). The majority (29%) of net plankton species were zygophytes, and in particular, larger species of *Closterium*. The two larger nannoplanktonic fractions were dominated by euchlorophyte species (29 and 36%, respectively).

4.2.3 Lake Mangakaware

4.2.3.1 Species Composition

The mean density and biomass contributions of the 165 species, belonging to 63 genera, found in Lake Mangakaware are listed in Table 4/10. The largest classes were the Euchlorophyceae (46 species [28%]) and the Diatomophyceae (38 species [23%]). Other important classes were the Zygothryxaceae (23 species [14%]), followed by the Euglenophyceae (19 species [11%]) and the Cyanophyceae (15 species [9%]) (Table 4/11).

4.2.3.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 21)

The most important class, in terms of abundance, was the Euchlorophyceae (2497 pu ml⁻¹ [50%]), followed by the Diatomophyceae (1153 pu ml⁻¹ [23%]) and the Euglenophyceae (408 pu ml⁻¹ [8%]). However, in terms of biomass, the pattern was markedly different; the proportions of euglenophytes and dinoflagellates were broadly similar (32% [1139 mg m³] and 27% [948 mg m³], respectively), while the diatoms, with a mean contribution of 16% [548 mg m³] were ranked third. In contrast to its numerical dominance, the Euchlorophyceae made up only 4% (156 mg m³) of the mean total biomass (Table 4/12).

4.2.3.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 21)

Although most of the 51 major species were chlorophytes (23 [45%]), only two (*Monoraphidium contortum* and *Closterium acutum* var. *variabile*) were numerically important (27 and 6% of the mean total density, respectively). Two diatom species, *Acanthoceros zachariasii*

TABLE 4/9 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Mangahia, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	38	29.7
Nannoplankton	41 - 63	38	29.7
	21 - 40	33	25.8
	11 - 20	14	10.9
	6 - 10	4	3.1
Ultraplankton	≤ 5	1	0.8
Total		<u>128</u>	<u>100</u>

TABLE 4/10 Mean density and biomass contributions of the phytoplankton in Lake Mangakaware, July 1983 to July 1984; n = 21. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Chlamydomonaceae				
<i>Chlamydomonas</i> sp. A	0.4			
Volvocaceae				
<i>Eudorina elegans</i>	0.8			
<i>Gonium pectorale</i>	0.8			
<i>Pandorina morum</i>	0.3			
<i>Volvox aureus</i>	0.1			
Chlorococcales				
Chlorococcaceae				
<i>Schroederia setigera</i>	0.4			
<i>Tetraedron minimum</i>	0.1			
Palmellaceae				
<i>Sphaerocystis schroeteri</i>	0.3			
Hormotilaceae				
<i>Palmodictyon viride</i>	149.3	9	42.1	10
Oocystaceae				
<i>Ankistrodesmus falcatus</i>	1.0	61=	0.2	56=
<i>A. gracilis</i>	1.6	50=	0.1	58=
<i>A. spiralis</i>	0.8			
<i>Kirchneriella lunaris</i>	0.7			
<i>K. obesa</i>	15.4	26	5.9	31
<i>Monoraphidium contortum</i>	1346.1	1	24.2	18
<i>M. griffithii</i>	1.9	48	0.2	56=
<i>M. irregulare</i>	2.2	46	0.1	58=
<i>M. komarkovae</i>	101.7	14	11.7	25
<i>M. minutum</i>	7.4	31	0.1	58=
<i>M. tortile</i>	376.3	5	4.5	36
<i>Nephrocytium agardhianum</i>	0.9			
<i>Oocystis lacustris</i>	5.4	35	1.3	46=
<i>Raphidocelis contorta</i>	17.8	22	4.7	34=
<i>Rhombocystis complanata</i>	140.7	10	18.4	21
Micractiniaceae				
<i>Micractinium pusillum</i>	0.1			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	1.3	54=	27.9	16
<i>Dictyosphaerium ehrenbergianum</i>	2.1	47	0.1	58=
<i>D. pulchellum</i>	0.1			
<i>D. subsolitarium</i> ?	179.0	8	2.9	42=
<i>Dimorphococcus lunatus</i>	1.3	54=	0.04	63=
Scenedesmaceae				
<i>Actinastrum hantzschii</i>	16.4	23=	3.4	41
<i>Coelastrum indicum</i>	0.1			

TABLE 4/10 continued

<i>C. microporum</i>	1.3	54=	0.7	50
<i>C. reticulatum</i>	1.2	58=	2.2	45
<i>Crucigenia fenestrata</i>	0.2			
<i>Scenedesmus acuminatus</i>	0.2			
<i>S. denticulatus</i>	0.1			
<i>S. ecornis</i>	0.1			
<i>S. opoliensis</i>	0.3			
<i>S. quadricauda</i>	2.4	44	0.5	51=
<i>Tetrastrum heteracanthum</i>	0.2			
<i>T. staurogeniaforme</i>	0.4			
<i>T. triangulare</i>	115.0	13	4.4	37
Hydrodictyaceae				
<i>Pediastrum duplex</i>	0.1			
<i>P. tetras</i>	0.5			
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	2.3	45	0.04	63=
Ulothricophyceae				
Ulothricales				
Ulothricaceae				
<i>Ulothrix</i> sp.	0.1			
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium undulatum</i>	0.1			
<i>O.</i> sp.	0.1			
Zygophyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	0.2			
<i>Spirogyra</i> sp.	0.04			
Mesotaeniaceae				
<i>Gonatozygon brebissonii</i>	0.04			
<i>G. kinahanii</i>	0.04			
Desmidiaceae				
<i>Closterium aciculare</i>	0.2			
<i>C. acutum</i> var. <i>variabile</i>	286.5	6	18.0	22
<i>C. gracile</i>	5.7	34	2.9	42=
<i>C. pronum</i>	0.2			
<i>Phymatodocis nordstedtiana</i>	0.4			
<i>Staurastrum arcuatum</i>	8.3	30	35.0	12
<i>S. chaetopus</i> ?	3.0	40=	3.7	38=
<i>S. cingulum</i> var. <i>obesum</i>	0.8			
<i>S. leptocladum</i> var. <i>insigne</i>	4.5	36	1.3	46=
<i>S. muticum</i> var. <i>victoriense</i>	0.04			
<i>S. pinque</i>	1.8	49	7.6	29=
<i>S.</i> sp. A	0.6			
<i>S.</i> sp. B	32.6	18	21.8	19
<i>Staurodesmus cuspidatus</i> }				
<i>St. dejectus</i> }	22.9	20	111.1	5
<i>S. glaber</i> var. <i>limnophilus</i>	6.4	33	10.0	26
<i>St. leptodermus</i> var. <i>subcorniculatus</i>	0.04			
<i>St. mucronatus</i> var. <i>subtriangularis</i>	2.7	43	25.0	17
<i>St. spetsbergensis</i>	0.1			
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				

TABLE 4/10 continued

Chrysococcaceae				
<i>Chrysococcus rufescens</i>	12.3	27	4.7	34=
Dinobryaceae				
<i>Dinobryon cylindricum</i>	227.4	7	32.7	13
<i>D. sociale</i>	0.04			
Synuraceae				
<i>Chrysosphaerella longispina</i>	6.9	32	20.9	20
<i>Mallomonas akrokomos</i>	1.3	54=	1.3	46=
<i>Synura uvella</i>	139.1	11	31.2	14
Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Goniochloris smithii</i>	0.2			
<i>Pseudostaurastrum</i> sp. A	1.1	60	0.4	53=
Sciadiaceae				
<i>Centritractus belonophorus</i>]				
<i>C. africanus</i>]	2.9	42	13.5	24
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	24.4	19	8.5	28
<i>A. granulata</i>	0.2			
<i>A. g.</i> var. <i>angustissima</i>	3.0	40=	3.5	40
<i>Cyclotella meneghiniana</i>	0.1			
<i>C. stelligera</i>	120.4	12	28.4	15
<i>Melosira varians</i>	0.1			
Rhizosoleniales				
Rhizosoleniaceae				
<i>Rhizosolenia eriensis</i>	11.4	28	9.8	27
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	541.7	2	406.3	3
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	380.1	4	60.8	8
<i>Fragilaria capucina</i>	0.2			
<i>F. delicatissima</i>	3.1	39	2.9	42=
<i>F. ulna</i>	1.4	52=	6.4	30
<i>F. u.</i> var. <i>acus</i>	0.04			
<i>Tabellaria fenestrata</i>	0.4			
<i>T. flocculosa</i>	9.2	29	14.7	23
Eunotiales				
Eunotiaceae				
<i>Eunotia camelus</i>	0.1			
<i>E. curvata</i>	0.04			
<i>E. diodon</i>	0.04			
<i>E. formica</i>	0.2			
<i>E. naegeli</i>	0.2			
<i>E. pectinalis</i>	1.0	61=	0.4	53=
<i>E. p.</i> var. <i>undulata</i>	0.2			
Achnanthales				
Achnanthaceae				
<i>Achnanthes linearis</i>	50.1	17	5.3	33
<i>Cocconeis placentula</i>	0.2			

TABLE 4/10 continued

Naviculales				
Naviculaceae				
<i>Cymbella minuta</i>	0.08			
<i>Diploneis oblongella</i>	0.2			
<i>Frustulia rhomboides</i> var. <i>capitata</i>	0.2			
<i>F. r.</i> var. <i>saxonica</i>	0.2			
<i>Gomphonema truncatum</i>	0.08			
<i>Gyrosigma acuminatum</i>	0.1			
<i>Pinnularia abaujensis</i>	0.2			
<i>P. braunii</i>	0.08			
<i>P. brevicostata</i>	0.1			
<i>P. microstauron</i>	0.04			
<i>P. viridis</i>	0.04			
<i>Stauroneis phoenicenteron</i>	0.1			
Epithemiaceae				
<i>Epithemia sorex</i>	0.04			
<i>Rhopalodia gibba</i>	0.04			
Nitzschiaceae				
<i>Hantzschia amphioxys</i>	0.1			
<i>Nitzschia acicularis</i>	3.6	37	1.0	49
Surirellaceae				
<i>Stenopterobia intermedia</i>	0.04			
<i>Surirella linearis</i>	0.04			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Chroococcus dispersus</i>	3.5	38	0.05	62
<i>C. minutus</i>	0.3			
<i>Gomphosphaeria lacustris</i>	0.2			
<i>Merismopedia minima</i>	0.8			
<i>M. tenuissima</i>	0.8			
<i>Microcystis aeruginosa</i>	1.4	52=	107.9	6
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	0.3			
<i>A. flos-aquae</i>	0.04			
<i>A. minutissima</i> ?	0.3			
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.2			
<i>Oscillatoria agardhii</i>	0.2			
<i>O. limnetica</i>	0.4			
<i>O. limosa</i>	0.2			
<i>O. subbrevis</i>	0.4			
<i>O. tenuis</i>	0.1			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Euglena acus</i>	0.08			
<i>E. oxyuris</i>	0.6			
<i>Lepocinclis marssonii</i>	0.1			

TABLE 4/10 continued

<i>L. ovum</i>	1.2	58=	5.7	32
<i>Phacus glaber</i>	1.3	54=	0.4	53=
<i>P. pleuronectes</i>	0.7			
<i>P. pyrum</i>	0.2			
<i>P. raciborski</i>	0.2			
<i>P. suecicus</i>	1.6	50=	0.5	51=
<i>P. s. var. oidon</i>	0.4			
<i>Trachelmonas armata var. inevoluta</i>	0.1			
<i>T. dangeardiana</i>	0.2			
<i>T. dybowski</i>	0.2			
<i>T. globularis var. punctata</i>	0.1			
<i>T. hexangulata</i>	0.2			
<i>T. hispida var. coronata</i>	0.9			
<i>T. mirabilis var. obesa</i>	0.2			
<i>T. planctonica</i>				
<i>T. playfairi</i>				
<i>T. volvocina</i>	399.5	3	1132.5	1
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	60.3	16	184.7	4
<i>C. marssonii</i>				
<i>C. ovata</i>	85.1	15	39.9	11
Dinophyceae				
Peridinales				
Gymnodiniaceae				
<i>Gymnodinium fuscum</i>	0.2			
Peridiniaceae				
<i>Peridinium centenniale</i>	0.4			
<i>P. cinctum + P. willei</i>	22.4	21	878.1	2
<i>P. inconspicuum</i>	0.2			
<i>P. pusillum tab. conjunctum</i>	16.4	23=	66.6	7
<i>P. umbonatum tab. conjunctum var. inaequale</i>	1.0	61=	3.7	38=
<i>P. willei</i>				
RAPHIDOPHYTA				
Raphidophyceae				
Raphidomonadales				
Vacuolariaceae				
<i>Vacuolaria sp.</i>	16.1	25	53.4	9

TABLE 4/11 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Mangakaware, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	46	27.9
Ulothricophyceae	3	1.8
Zygophyceae	23	13.9
CHROMOPHYTA		
Chrysophyceae	6	3.6
Diatomophyceae	38	23.0
Xanthophyceae	4	2.4
CYANOPHYTA		
Cyanophyceae	15	9.1
EUGLENOPHYTA		
Euglenophyceae	19	11.5
PYRRHOPHYTA		
Cryptophyceae	3	1.8
Dinophyceae	7	4.2
RAPHIDOPHYTA		
Raphidophyceae	1	0.6
TOTAL	<u>165</u>	<u>99.8</u>

TABLE 4/12 Mean distribution of plankton units and biomass amongst the major taxa in Lake Mangakaware, July 1983 to July 1984; mean values $< 1 \text{ pu ml}^{-1}$ are excluded from the analyses (n = 21).

Taxon	Pu ml ⁻¹		Biomass	
	Number	Proportion (%)	mg m ³	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	2,497	49.5	156	4.4
Zygophyceae	377	7.5	236	6.7
CHROMOPHYTA				
Chrysophyceae	387	7.7	91	2.6
Diatomophyceae	1,153	22.9	548	15.6
Xanthophyceae	4	0.08	14	0.4
CYANOPHYTA				
Cyanophyceae	9	0.2	108	3.1
EUGLENOPHYTA				
Euglenophyceae	408	8.1	1,139	32.4
PYRRHOPHYTA				
Cryptophyceae	145	2.9	225	6.4
Dinophyceae	41	0.8	948	26.9
RAPHIDOPHYTA				
Raphidophyceae	16	0.3	53	1.5
TOTAL	<u>5,037</u>	<u>99.9</u>	<u>3,518</u>	<u>100</u>

(11%) and *Asterionella formosa* (8%) were also abundant, together with *Trachelomonas* spp. (*T. planctonica*, *T. playfairi*, and *T. volvocina* [8%]).

However, because of the small biovolumes of the most abundant chlorophytes, none was important in terms of biomass; instead, the three most important taxa were *Trachelomonas* spp. (*T. planctonica*, *T. playfairi* and *T. volvocina* [32%]), *Peridinium* spp. (*P. cinctum* and *P. willei* [25%]), followed by *Acanthoceros zachariasii* (12%) (Table 4/13).

4.2.3.4 Size Distribution

Phytoplankters belonging to the 21 to 40 μm size fraction were the most common (57 species [33%]), the majority of which were chlorophytes (26%). However, phytoplankton with GALDs $\geq 40 \mu\text{m}$ were also abundant. The combined net and 41 to 63 μm fractions together contained 93 species (55%). The GALD of 12% of all taxa was $\leq 20 \mu\text{m}$ (Table 4/14).

4.2.4 Lake Maratoto

4.2.4.1 Species Composition

123 species, belonging to 66 genera, were found in Lake Maratoto (Table 4/15), a 100% increase on the number recorded in 1979 by Etheredge (1983). The two most important classes were the Diatomophyceae (36 species [29%]) and the Euchlorophyceae (26 species [21%]); the Zygothryxaceae and the Cyanophyceae made up 14 and 11% of the species respectively, but the other 7 classes were poorly represented (Table 4/16).

4.2.4.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 20)

The Euchlorophyceae, with mean density and biomass contributions of 5742 pu ml⁻¹ (86%) and 71,605 mg m³ (99.8%) respectively, completely dominated the Lake Maratoto community. The Zygothryxaceae and Diatomophyceae made up 10 and 2% of the mean number of pu ml⁻¹, respectively but, in terms of biomass, these translated into insignificant proportions (Table 4/17).

TABLE 4/13 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Mangakaware, July 1983 to July 1984 (n = 21).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Hormotilaceae		
<i>Palmodictyon viride</i>	3.0	1.2
Oocystaceae		
<i>Kirchneriella obesa</i>	0.3	0.2
<i>Monoraphidium contortum</i>	26.7	0.7
<i>M. komarkovae</i>	2.0	0.3
<i>M. minutum</i>	0.1	-
<i>M. tortile</i>	7.5	0.1
<i>Oocystis lacustris</i>	0.1	-
<i>Raphidocelis contorta</i>	0.3	0.1
<i>Rhombocystis complanata</i>	2.8	0.5
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	-	0.8
<i>Dictyosphaerium subsolitarium</i> ?	3.5	-
Scenedesmaceae		
<i>Actinastrum hantzschii</i>	0.3	-
<i>Tetrastrum triangulare</i>	2.3	0.1
Zygophyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	5.7	0.5
<i>C. gracile</i>	0.1	-
<i>Staurastrum arcuatum</i>	0.2	1.0
<i>S. chaetopus</i> ?	-	0.1
<i>S. pinque</i>	-	0.2
<i>S. sp. B</i>	0.6	0.6
<i>Staurodesmus cuspidatus</i> }		
<i>St. dejectus</i> }	0.4	3.1
<i>St. glaber</i> var. <i>limnophilus</i>	0.1	0.3
<i>St. mucronatus</i> var. <i>subtriangularis</i>	-	0.7
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.2	0.1
Dinobryaceae		
<i>Dinobryon cylindricum</i>	4.5	0.9
Synuraceae		
<i>Chrysosphaerella longispina</i>	0.1	0.5
<i>Synura uvella</i>	2.8	0.9
Xanthophyceae		
Mischococcales		
Sciadiaceae		

TABLE 4/13 continued

<i>Centrtractus africanus</i>]		
<i>C. belonophorus</i>]	-	0.4
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira distans</i>	0.5	0.2
<i>A. granulata</i> var. <i>angustissima</i>	-	0.1
<i>Cyclotella stelligera</i>	2.4	0.8
Rhizosoleniales		
Rhizosoleniaceae		
<i>Rhizosolenia eriensis</i>	0.2	0.3
Biddulphiales		
Chaetoceraceae		
<i>Acanthoceras zachariasii</i>	10.7	11.5
Diatomales		
Diatomaceae		
<i>Asterionella formosa</i>	7.6	1.7
<i>Fragilaria ulna</i>	-	0.2
<i>Tabellaria flocculosa</i>	0.2	0.4
Achnanthes		
Achnantheaceae		
<i>Achnanthes linearis</i>	1.0	0.1
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Microcystis aeruginosa</i>	-	3.1
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Lepocinclis ovum</i>	-	0.2
<i>Trachelomonas planctonica</i>]		
<i>T. playfairi</i>]		
<i>T. volvocina</i>]	7.9	32.2
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas erosa</i>	1.2	5.2
<i>C. marssonii</i>]		
<i>C. ovata</i>]	1.7	1.1
Dinophyceae		
Peridinales		
Peridiniaceae		
<i>Peridinium cinctum</i> + <i>P. willei</i>	0.4	25.0
<i>P. pusillum</i> tab. <i>conjunctum</i>	0.3	1.9
<i>P. umbonatum</i> tab. <i>conjunctum</i> var. <i>inaequale</i>	-	0.1
<i>P. willei</i> (included in <i>P. cinctum</i>)		

TABLE 4/13 continued

RAPHIDOPHYTA		
Raphidophyceae		
Raphidomonadales		
Vacuolariaceae		
<i>Vacuolaria</i> sp.	0.3	1.5
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

TABLE 4/14 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Mangakaware, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	46	27.1
Nannoplankton	41 - 63	47	27.6
	21 - 40	57	33.5
	11 - 20	16	9.4
	6 - 10	3	1.8
Ultraplankton	≤ 5	1	0.6
Total		<u>170</u>	<u>100</u>

TABLE 4/15 Mean density and biomass contributions of the phytoplankton in Lake Maratoto, July 1983 to July 1984; n = 20. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Chlamydomonaceae				
<i>Chlamydomonas</i> sp. C	2516.8	2	143.4	3
Chlorococcales				
Chlorococcaceae				
<i>Tetraedron minimum</i>	0.2			
Palmellaceae				
<i>Sphaerocystis schroeteri</i>	1.4	20=	1.5	18
Oocystaceae				
<i>Ankistrodesmus falcatus</i>	0.4			
<i>A. gracilis</i>	0.8			
<i>Kirchneriella obesa</i>	0.8			
<i>Monoraphidium contortum</i>	2.9	17	0.04	26
<i>M. irregulare</i>	0.5			
<i>M. tortile</i>	159.9	4	1.9	17
<i>Oocystis lacustris</i>	0.2			
<i>Raphidocelis contorta</i>	0.9			
Micractiniaceae				
<i>Micractinium pusillum</i>	0.4			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	3050.5	1	71458.0	1
<i>Dictyosphaerium ehrenbergianum</i>	0.8			
<i>D. pulchellum</i>	0.8			
<i>D. subsolitarium</i> ?	1.0	25=	0.01	27
Scenedesmaceae				
<i>Actinastrum hantzschii</i>	0.4			
<i>Coelastrum indicum</i>	0.2			
<i>C. microporum</i>	0.4			
<i>C. reticulatum</i>	0.2			
<i>Scenedesmus acutus</i>	0.8			
<i>S. ecornis</i>	0.2			
<i>S. quadricauda</i>	1.0	25=	0.2	22=
Hydrodictyaceae				
<i>Pediastrum duplex</i>	0.2			
<i>P. tetras</i>	0.2			
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	0.6			
Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium undulatum</i>	0.2			

TABLE 4/15 continued

Zygomycetes				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	0.4			
Desmidiaceae				
<i>Actinotaenium wollei</i>	0.3			
<i>Closterium acutum</i> var. <i>variabile</i>	514.7	3	52.0	6
<i>C. gracile</i>	71.2	7	39.9	8
<i>C. parvulum</i>	0.1			
<i>C. pronum</i>	0.2			
<i>Cosmarium contractum</i>	0.1			
<i>Pleurotaenium trabecula</i>	0.2			
<i>Spondylosium pulchellum</i>	0.1			
<i>Staurastrum chaetopus</i> ?	0.1			
<i>S. gracile</i> forma	0.4			
<i>S. inflexum</i>	18.1	10	22.7	10
<i>S.</i> sp. A	0.4			
<i>S.</i> sp. B	25.0	9	18.4	12
<i>S.</i> sp. C	0.2			
<i>Staurodesmus dejectus</i>	0.2			
<i>St. glaber</i> var. <i>limnophilus</i>	10.4	13	10.2	13
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Dinobryaceae				
<i>Dinobyron cylindricum</i>	0.2			
Synuraceae				
<i>Mallomonas acaroides</i>	0.2			
<i>M. akrokomos</i>	0.8			
<i>M. tonsurata</i>	0.2			
<i>Synura uvella</i>	6.7	15	2.6	16
Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Pseudostaurastrum</i> sp. A	2.2	18=	1.0	19
Characiopsidiaceae				
<i>Peroniella planctonica</i>	2.2	18=	0.1	25
Sciadiaceae				
<i>Centritractus belonophorus</i>	0.4			
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	0.9			
<i>A. granulata</i>	15.0	11	83.0	4
<i>A. g.</i> var. <i>angustissima</i>	7.8	14	9.2	15
<i>Cyclotella meneghiniana</i>	0.1			
<i>C. stelligera</i>	0.3			
<i>Melosira varians</i>	0.1			
Rhizosoleniales				
Rhizosoleniaceae				
<i>Rhizosolenia eriensis</i>	0.4			
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	0.3			

TABLE 4/15 continued

Diatomales				
Diatomaceae				
<i>Fragilaria ulna</i>	0.5			
<i>F. u. var. acus</i>	0.2			
<i>Tabellaria fenestrata</i>	0.1			
<i>T. flocculosa</i>	90.2	5	162.4	2
Eunotiales				
Eunotiaceae				
<i>Eunotia camelus</i>	0.1			
<i>E. diodon</i>	0.1			
<i>E. flexuosa</i>	0.1			
<i>E. pectinalis</i>	1.2	23=	0.9	20
<i>E. p. var. minor</i>	1.3	22=	0.4	21
<i>E. p. var. undulata</i>	0.1			
Achnanthales				
Achnanthaceae				
<i>Achnanthes linearis</i>	0.3			
<i>Cocconeis placentula</i>	0.1			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	0.3			
<i>Anomoeoneis serians</i>	0.2			
<i>Cymbella minuta</i>	0.2			
<i>C. palustris</i>	0.1			
<i>Frustulia rhomboides</i> var. <i>saxonica</i>	0.4			
<i>Gomphonema acuminatum</i>	0.6			
<i>G. truncatum</i>	0.4			
<i>Navicula pupula</i>	0.1			
<i>N. subtilissima</i>	0.1			
<i>Pinnularia abaujensis</i>	0.1			
<i>P. a. var. linearis</i>	0.1			
<i>P. braunii</i>	0.2			
<i>P. brevicostata</i>	0.1			
<i>P. divergens</i>	0.2			
<i>P. gentilis</i>	0.2			
<i>P. gibba</i>	0.3			
<i>P. microstauron</i>	0.1			
Epithemiaceae				
<i>Epithemia sorex</i>	0.4			
Nitzschiaceae				
<i>Nitzschia acicularis</i>	0.3			
Surirellaceae				
<i>Stenopterobia intermedia</i>	0.1			
<i>Surirella linearis</i>	0.8			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa elachista</i>	1.2	23=	9.8	14
<i>A. e. var. conferta</i>	0.2			
<i>Chroococcus dispersus</i> var. <i>minor</i>	13.2	12	0.2	22=
<i>C. limneticus</i>	1.0	25=	0.2	22=
<i>C. minor</i>	0.8			
<i>C. turgidus</i>	0.4			
<i>Coelosphaerium kuetzingianum</i>	0.1			
<i>Microcystis aeruginosa</i>	0.3			

TABLE 4/15 continued

Nostocales				
Nostocaceae				
<i>Anabaena minutissima</i> ?	0.5			
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.2			
<i>Oscillatoria limnetica</i>	0.1			
<i>O. limosa</i>	0.1			
<i>O. planctonica</i>	0.1			
<i>O. splendida</i>	0.6			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Euglena acus</i>	0.2			
<i>E. oxyuris</i>	0.2			
<i>E. proxima</i>	0.2			
<i>Menoidium pellucidum</i>	0.1			
<i>Phacus hamatus</i>	0.1			
<i>P. helicoides</i>	0.2			
<i>P. pleuronectes</i>	0.4			
<i>P. suecicus</i>	0.2			
<i>Trachelomonas armata</i>	0.2			
<i>T. a. var. longispina</i>	0.3			
<i>T. planctonica</i> }				
<i>T. playfairi</i> }	42.6	8	61.2	5
<i>T. volvocina</i> }				
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	0.4			
<i>C. marssonii</i> }				
<i>C. ovata</i> }	86.0	6	37.5	9
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium cinctum</i> + <i>P. willei</i>	1.4	20=	48.4	7
<i>P. inconspicuum</i>	0.2			
<i>P. polonicum</i>	0.1			
<i>P. pusillum</i> tab. <i>conjunctum</i>	0.1			
<i>P. willei</i> (included in <i>P. cinctum</i>)				
<i>P. sp. B</i>	0.1			
RAPHIDOPHYTA				
Raphidophyceae				
Raphidomonadales				
Vacuolariaceae				
<i>Vacuolaria</i> sp.	4.4	16	22.3	11

TABLE 4/16 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Maratoto, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	26	21.1
Ulothricophyceae	1	0.8
Zygophyceae	17	13.8
CHROMOPHYTA		
Chrysophyceae	5	4.1
Diatomophyceae	36	29.3
Xanthophyceae	3	2.4
CYANOPHYTA		
Cyanophyceae	13	10.6
EUGLENOPHYTA		
Euglenophyceae	12	9.8
PYRRHOPHYTA		
Cryptophyceae	3	2.4
Dinophyceae	6	4.9
RAPHIDOPHYTA		
Raphidophyceae	1	0.8
TOTAL	<u>123</u>	<u>100.0</u>

TABLE 4/17 Mean distribution of plankton units and biomass amongst the major taxa in Lake Maratoto, July 1983 to July 1984; mean values $< 1 \text{ pu ml}^{-1}$ are excluded from the analyses ($n = 20$).

Taxon	Pu ml^{-1}		Biomass	
	Number	Proportion (%)	$\text{mg} \cdot \text{m}^3$	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	5,742	86.0	71,605	99.2
Zygophyceae	642	9.6	143	0.2
CHROMOPHYTA				
Chrysophyceae	8	0.1	3	0.004
Diatomophyceae	124	1.8	256	0.03
Xanthophyceae	5	0.07	1	0.001
CYANOPHYTA				
Cyanophyceae	19	0.3	10	0.01
EUGLENOPHYTA				
Euglenophyceae	45	0.7	61	0.08
PYRRHOPHYTA				
Cryptophyceae	86	1.2	37	0.05
Dinophyceae	2	0.03	48	0.07
RAPHIDOPHYTA				
Raphidophyceae	4	0.06	22	0.03
TOTAL	<u>6,677</u>	<u>99.9</u>	<u>72,186</u>	<u>99.9</u>

4.2.4.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 20)

The community, although containing 16 major species (plus 1 variety), was dominated by 3 taxa. In terms of abundance, the most important species were *Botryococcus braunii* (46%), *Chlamydomonas* sp. C (38%) and *Closterium acutum* var. *variabile* (8%). This concentration of dominance amongst a small number of species was even more apparent in terms of biomass. *Botryococcus braunii* made up 99% of the mean total biomass, while *Tabellaria flocculosa* and *Chlamydomonas* sp. C, which were ranked second and third, respectively, both contributed only 0.2% (Table 4/18).

4.2.4.4 Size Distribution

Most phytoplankters belonged to the larger size fractions; the net plankton was represented by 31 species [24%], and both the 41 to 63 and 21 to 40 μm fractions contained 32% of the total number of species. The remainder (12%) was distributed amongst the smaller fractions (Table 4/19).

4.2.5 Lake Ngaroto

4.2.5.1 Species Composition

72 genera, containing 166 species, were found in Lake Ngaroto (Table 4/20). Both the Eulichlorophyceae and the Diatomophyceae were well represented (51 [31%] and 42 species [25%], respectively), but with the exception of the Cyanophyceae (24 species [14%]), numbers in other classes were low (Table 4/21).

4.2.5.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 21)

Numerically, the flora consisted largely of diatoms (2600 pu ml^{-1} [48%]), eulichlorophytes (1241 pu ml^{-1} [23%]) and cyanophytes (1139 pu ml^{-1} [21%]). However, in terms of biomass, the cyanophytes were the overwhelming dominants (26,541 mg m^3 [84%]), with diatoms ranking second (2886 mg m^3 [9%]). The other eight classes were relatively insignificant (Table 4/22).

TABLE 4/18 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Maratoto, July 1983 to July 1984 (n = 20).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Volvocales		
Chlamydomonadaceae		
<i>Chlamydomonas</i> sp. C	37.7	0.2
Oocystaceae		
<i>Monoraphidium tortile</i>	2.4	-
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	45.7	99.0
Zygothyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	7.7	-
<i>C. gracile</i>	1.1	-
<i>Staurastrum inflexum</i>	0.3	-
<i>S.</i> sp. B	0.4	-
<i>Staurodesmus glaber</i> var. <i>limnophilus</i>	0.1	-
CHROMOPHYTA		
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira granulata</i>	0.2	0.1
<i>A. g.</i> var. <i>angustissima</i>	0.1	-
Diatomales		
<i>Tabellaria flocculosa</i>	1.3	0.2
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Chroococcus dispersus</i> var. <i>minor</i>	0.2	-
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Trachelomonas planctonica</i>	0.6	-
<i>T. playfairi</i>		
<i>T. volvocina</i>		

TABLE 4/18 continued

PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas marssonii</i> }		
<i>C. ovata</i> }	1.3	-
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

TABLE 4/19 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Maratoto, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	31	23.8
Nannoplankton	41 - 63	42	32.3
	21 - 40	41	31.5
	11 - 20	14	10.8
	6 - 10	2	1.5
Ultraplankton	≤ 5	0	0
Total		<u>130</u>	<u>99.9</u>

TABLE 4/20 Mean density and biomass contributions of the phytoplankton in Lake Ngaroto, July 1983 to July 1984; n = 21. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Chlamydomonaceae				
<i>Chlamydomonas</i> sp. A	0.2			
Chlorococcales				
Chlorococcaceae				
<i>Characium ornithocephalum</i>	0.2			
<i>Tetraedron minimum</i>	1.5	62=	0.2	62=
Oocystaceae				
<i>Ankistrodesmus bibraianus</i>	8.6	35=	2.2	40=
<i>A. falcatus</i>	24.8	20	3.7	34
<i>A. fusiformis</i>	14.3	29	1.6	45
<i>A. gracilis</i>	15.6	27	2.2	40=
<i>A. spiralis</i>	5.0	44=	0.4	58=
<i>Kirchneriella obesa</i>	3.0	52=	1.2	47=
<i>Lagerheima ciliata</i>	0.2			
<i>Monoraphidium contortum</i>	166.4	6	2.8	37=
<i>M. griffithii</i>	0.6			
<i>M. irregulare</i>	1.0	73=	0.03	72
<i>M. komarkovae</i>	3.0	52=	0.3	60=
<i>M. minutum</i>	7.9	39=	0.1	64=
<i>M. tortile</i>	0.7			
<i>Nephrocytium agardhianum</i>	0.7			
<i>N. limneticum</i>	0.2			
<i>Oocystis lacustris</i>	11.0	31	2.5	39
<i>O. solitaria</i>	1.3	65=	0.5	57
<i>Raphidocelis contorta</i>	86.8	11	2.2	40=
Micractiniaceae				
<i>Golenkinia radiata</i>	0.4			
<i>Micractinium bornhemiense</i>	1.1	70=	0.3	60=
<i>M. pusillum</i>	5.3	42	1.4	46
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	39.7	18	324.8	5
<i>Dictyosphaerium ehrenbergianum</i>	5.1	43	0.1	64
<i>D. pulchellum</i>	4.4	48	0.07	69
Scenedesmaceae				
<i>Actinastrum aciculare</i>	0.4			
<i>A. fluviatile</i>	2.8	55	0.6	54=
<i>A. hantzschii</i>	42.8	17	8.6	23
<i>Coelastrum cambricum</i>	0.2			
<i>C. indicum</i>	0.2			
<i>C. microporum</i>	9.3	34	5.2	30
<i>C. reticulatum</i>	10.0	32	18.0	14
<i>Crucigeniella apiculata</i>	16.8	26	2.8	37=
<i>C. rectangularis</i>	15.3	28	1.7	44
<i>C. truncata</i>	0.2			
<i>Scenedesmus acuminatus</i>	23.4	21	21.4	13

TABLE 4/20 continued

<i>P. stomatophora</i>	0.2			
<i>P. viridis</i>	0.2			
<i>Stauroneis phoenicenteron</i>	0.2			
Epithemiaceae				
<i>Epithemia sores</i>	0.2			
Nitzschiaceae				
<i>Hantzschia amphioxys</i>	0.2			
<i>Nitzschia acicularis</i>	0.7			
<i>N. palea</i>	0.1			
<i>N. sigmoidea</i>	0.1			
Surirellaceae				
<i>Surirella linearis</i>	0.9			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa elachista</i>	0.1			
<i>A. e. var. conferta</i>	3.0	52=	12.6	19
<i>Chroococcus dispersus</i>	1.1	70=	0.1	64=
<i>C. d. var. minor</i>	22.4	22	0.1	64=
<i>C. limneticus</i>	138.9	7	31.4	10
<i>C. minutus</i>	1.2	68=	0.01	73
<i>C. turgidus</i>	0.8			
<i>Gomphosphaeria lacustris</i>	1.7	60=	13.9	17
<i>Merismopedia minima</i>	67.2	13	0.06	70
<i>M. punctata</i>	1.5	62=	0.007	74
<i>M. tenuissima</i>	6.9	41	0.04	71
<i>Microcystis aeruginosa</i>	402.0	3	26310.5	1
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	136.3	8	54.8	9
<i>A. flos-aquae</i>	11.8	30	7.9	24
<i>A. minutissima</i> ?	0.2			
<i>A. solitaria</i>	8.6	35=	11.7	20
<i>A. spiroides</i> var. <i>tumida</i>	0.4			
<i>A. tenericaulis</i>	332.3	4	98.4	7
Oscillatoriaceae				
<i>Oscillatoria articulata</i>	0.2			
<i>O. guttulata</i>	0.2			
<i>O. mougeotii</i>	0.2			
<i>O. planctonica</i>	0.2			
<i>O. splendida</i>	0.4			
<i>O. subbrevis</i>	0.4			
<i>Spirulina laxa</i>	0.6			
<i>S. major</i>	0.4			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Cyclidiopsis acus</i>	0.4			
<i>Euglena acus</i>	0.3			
<i>E. oxyuris</i>	2.1	57=	88.7	8

TABLE 4/20 continued

<i>S. acutiformis</i>	0.2			
<i>S. denticulatus</i>	0.2			
<i>S. dimorphus</i>	0.2			
<i>S. intermedius</i>	4.2	49	1.7	52=
<i>S. longispina</i>	0.2			
<i>S. opoliensis</i>	3.6	51	3.8	33
<i>S. protuberans</i>	0.2			
<i>S. quadricauda</i>	590.0	2	132.7	6
<i>S. sempervirens</i>	5.0	44=	0.6	54=
Hydrodictyaceae				
<i>Tetrastrum staurogeniaforme</i>	33.3	19	2.2	40=
<i>T. triangulare</i>	43.5	16	1.7	52=
<i>Pediastrum duplex</i>	8.4	38	3.4	35
<i>P. tetras</i>	17.5	24	0.9	51
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	4.5	47	0.6	54=
Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium undulatum</i>	0.2			
Zygophyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	9.7	33	7.8	25
Desmidiaceae				
<i>Closterium aciculare</i>	0.2			
<i>C. acutum</i> var. <i>variabile</i>	117.0	9	7.0	26
<i>C. gracile</i>	8.5	37	4.4	31
<i>C. parvulum</i>	0.2			
<i>C. pronum</i>	3.8	50	5.3	29
<i>Cosmarium laeve</i>	2.0			
<i>Staurastrum avicula</i>	2.0			
<i>S. chaetopus</i> ?	2.7	56	3.2	36
<i>S. leptocladum</i> var. <i>insigne</i>	0.5			
<i>S. muticum</i> var. <i>victoriense</i>	0.2			
<i>S.</i> sp. B	0.6			
<i>S.</i> sp. C	50.1	15	13.4	18
<i>Staurodesmus cuspidatus</i>	0.2			
<i>St. dejectus</i>	0.8			
<i>St. glaber</i> var. <i>limnophilus</i>	0.6			
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufesens</i>	16.0	25	5.9	28
Dinobryaceae				
<i>Dinobryon cylindricum</i>	0.09			
<i>D. divergens</i>	0.09			
Synuraceae				
<i>Mallomonas acaroides</i>	1.3	65=	1.1	49=
<i>M. tonsurata</i>	1.3	65=	1.2	47=
<i>Synura spinosa</i>	1.7	60=	0.4	58=
<i>S. uvella</i>	1.1	70=	0.2	62=
Xanthophyceae				
Mischococcales				

TABLE 4/20 continued

Characiopsidaceae				
<i>Peroniella planctonica</i>	0.2			
Sciadiaceae				
<i>Centrित्रactus belonophorus</i>	2.1	57=	9.8	21
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	67.5	12	23.6	12
<i>A. granulata</i>	0.2			
<i>A. g. var. angustissima</i>	2413.1	1	2823.3	2
<i>Cyclotella meneghiniana</i>	0.9			
<i>C. stelligera</i>	4.6	46	1.1	49=
<i>Melosira varians</i>	0.4			
Rhizosoleniales				
Rhizosoleniaceae				
<i>Rhizosolenia eriensis</i>	0.2			
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	0.9			
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	93.3	10	14.0	16
<i>Fragilaria ulna</i>	2.0	59	9.3	22
<i>F. u. var. acus</i>	0.09			
<i>Meridion circulare var. constricta</i>	0.1			
<i>Tabellaria fenestrata</i>	0.2			
<i>T. flocculosa</i>	7.9	39=	14.4	15
Eunotiales				
Eunotiaceae				
<i>Eunotia curvata</i>	0.1			
<i>E. diodon</i>	0.2			
<i>E. formica</i>	0.4			
<i>E. naegeli</i>	0.2			
<i>E. pectinalis</i>	0.2			
<i>E. p. var. undulata</i>	0.2			
<i>E. p. var. ventricosa</i>	0.2			
<i>E. serpentina</i>	0.09			
Achnanthales				
Achnanthaceae				
<i>Cocconeis placentula</i>	0.4			
<i>Rhoicosphenia curvata</i>	0.2			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	0.2			
<i>Anomoeoneis serians</i>	0.4			
<i>Cymbella aspersa</i>	0.2			
<i>C. minuta</i>	0.2			
<i>Diploneis oblongella</i>	0.4			
<i>Frustulia rhomboides var. saxonica</i>	0.2			
<i>Gomphonema berggrenii</i>	0.2			
<i>G. truncatum</i>	0.7			
<i>Navicula bacillum</i>	0.2			
<i>N. pupula</i>	0.2			
<i>Pinnularia borealis</i>	0.2			
<i>P. divergens</i>	0.2			
<i>P. gibba</i>	0.2			

TABLE 4/20 continued

<i>Phacus acuminatus</i>	0.2			
<i>P. chloroplastes</i>	0.2			
<i>P. helicoides</i>	0.2			
<i>P. polytrophos</i>	1.0	73=	0.1	64=
<i>P. pyrum</i>	0.2			
<i>P. rudicola</i>	0.2			
<i>P. tortus</i>	0.4			
<i>Trachelomonas furcata</i>	0.4			
<i>T. hispida</i>	0.3			
<i>T. h. var. punctata</i>	0.2			
<i>T. planctonica</i>	0.4			
<i>T. p. var. oblonga</i>	0.2			
<i>T. playfairi</i>	1.2	68=	4.3	32
<i>T. volvocina</i>	186.8	5	528.6	4
<i>Strombomonas urceolata</i>	0.4			
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	0.2			
<i>C. marssonii</i>	55.4	14	24.9	11
<i>C. ovata</i>				
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium aciculiferum</i>	0.6			
<i>P. cinctum</i>	22.0	23	863.5	3
<i>P. pusillum</i> tab. <i>conjectum</i>	1.5	62=	6.0	27
Ceratiaceae				
<i>Ceratium hirundinella</i>	0.2			

TABLE 4/21 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Ngaroto, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	51	30.7
Ulothricophyceae	1	0.6
Zygophyceae	16	9.6
CHROMOPHYTA		
Chrysophyceae	7	4.2
Diatomophyceae	42	25.3
Xanthophyceae	2	1.2
CYANOPHYTA		
Cyanophyceae	24	14.4
EUGLENOPHYTA		
Euglenophyceae	16	9.6
PYRRHOPHYTA		
Cryptophyceae	3	1.8
Dinophyceae	4	2.4
TOTAL	<u>166</u>	<u>99.8</u>

TABLE 4/22 Mean distribution of plankton units and biomass amongst the major taxa in Lake Ngaroto, July 1983 to July 1984; mean values < 1 pu ml⁻¹ are excluded from the analyses (n = 21).

Taxon	Pu ml ⁻¹		Biomass	
	Number	Proportion (%)	mg m ³	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	1,241	22.7	552	1.7
Zygophyceae	195	3.5	41	0.1
CHROMOPHYTA				
Chrysophyceae	21	0.4	9	0.03
Diatomophyceae	2,600	47.5	2,886	9.1
Xanthophyceae	2	0.03	10	0.03
CYANOPHYTA				
Cyanophyceae	1,139	20.8	26,541	84.1
EUGLENOPHYTA				
Euglenophyceae	195	3.5	622	2.0
PYRRHOPHYTA				
Cryptophyceae	56	1.0	25	0.08
Dinophyceae	24	0.4	869	2.7
TOTAL	<u>5,473</u>	<u>99.8</u>	<u>31,555</u>	<u>99.8</u>

4.2.5.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 21)

Of the 43 major species, the most abundant was *Aulacosira granulata* var. *angustissima* (44%), followed by *Scenedesmus quadricauda* (11%) and *Microcystis aeruginosa* (7%). Although 24 (56%) of the major species were chlorophytes, only *Scenedesmus quadricauda* was proportionately significant. Abundant cyanophytes were *Anabaena tenericaulis* (6%) and *A. circinalis* (3%), while *Trachelomonas volvocina*, the most abundant euglenophyte, ranked fifth (3%) (Table 4/23).

Microcystis aeruginosa dominated the mean standing crop (83%), in terms of biomass, and proportions of other species were relatively small by comparison. *Aulacosira granulata* var. *angustissima* (9%) and *Peridinium cinctum* (3%) ranked second and third, respectively (Table 4/23).

4.2.5.4. Size Distribution

The majority of phytoplankters (135 species [77%]) were nanoplanktonic; 31% (including the three most important species in terms of biomass) belonged to the 41 to 63 μm fraction. A total of 38 net plankton species (22%) was found, of which the most abundant were diatoms (53%). The 21 to 43 μm fraction contained 33% of all major species. Only one ultraplankton species was recorded (Table 4/24).

4.2.6 Lake Rotokauri

4.2.6.1 Species Composition

The community contained 203 species, belonging to 92 genera (Table 4/25). The Euchlorophyceae (48 species [24%]) and the Zygothryxaceae (46 species [23%]) were the most important classes. The Euglenophyceae (16%), Diatomophyceae (14%) and Cyanophyceae (13%) had relatively similar but lesser proportions; all other classes had low species numbers (Table 4/26).

4.2.6.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 22)

Numerically, the Euchlorophyceae dominated the community (258 pu ml^{-1} [40%]). However, the Chrysophyceae (117 pu ml^{-1} [18%]),

TABLE 4/23 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Ngaroto, July 1983 to July 1984 (n = 21).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Oocystaceae		
<i>Ankistrodesmus bibraianus</i>	0.1	-
<i>A. falcatus</i>	0.4	-
<i>A. fusiformis</i>	0.3	-
<i>A. gracilis</i>	0.3	-
<i>Monoraphidium contortum</i>	3.0	-
<i>M. minutum</i>	0.1	-
<i>Oocystis lacustris</i>	0.2	-
<i>Raphidocelis contorta</i>	1.6	-
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	0.7	1.0
Scenedesmaceae		
<i>Actinastrum hantzschii</i>	0.8	-
<i>Coelastrum microporum</i>	0.2	-
<i>C. reticulatum</i>	0.2	-
<i>Crucigeniella apiculata</i>	0.3	-
<i>C. rectangularis</i>	0.3	-
<i>Scenedesmus acuminatus</i>	0.4	-
<i>S. quadricauda</i>	10.8	0.4
Hydrodictyaceae		
<i>Tetrastrum staurogeniaforme</i>	0.6	-
<i>T. triangulare</i>	0.8	-
<i>Pediastrum duplex</i>	0.1	-
<i>P. tetras</i>	0.3	-
Zygophyceae		
Zygnematales		
Zygnemataceae		
<i>Mougeotia</i> sp. B	0.2	-
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	2.1	-
<i>C. gracile</i>	0.1	-
<i>Staurastrum</i> sp. C	0.9	-
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.3	-
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira distans</i>	1.2	-
<i>A. granulata</i> var. <i>angustissima</i>	44.1	8.9
Diatomales		

TABLE 4/23 continued

<i>Asterionella formosa</i>	1.7	-
<i>Tabellaria flocculosa</i>	0.1	-
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Chroococcus dispersus</i> var. <i>minor</i>	0.4	-
<i>C. limneticus</i>	2.5	-
<i>Merismopedia minima</i>	1.2	-
<i>M. tenuissima</i>	0.1	-
<i>Microcystis aeruginosa</i>	7.3	83.4
Nostocales		
Nostocaceae		
<i>Anabaena circinalis</i>	2.5	0.2
<i>A. flos-aquae</i>	0.2	-
<i>A. solitaria</i>	0.1	-
<i>A. tenericaulis</i>	6.0	0.3
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Euglena oxyuris</i>	-	0.3
<i>Trachelomonas volvocina</i>	3.4	1.7
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas marssonii</i> }		
<i>C. ovata</i> }	1.0	-
Dinophyceae		
Peridinales		
Peridiniaceae		
<i>Peridinium cinctum</i>	0.4	2.7
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

TABLE 4/24 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Ngaroto, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	38	21.8
Nannoplankton	41 - 63	54	31.0
	21 - 40	58	33.3
	11 - 20	20	11.5
	6 - 10	3	1.7
Ultraplankton	≤ 5	1	0.5
Total		<u>174</u>	<u>99.8</u>

TABLE 4/25 Mean density and biomass contributions of the phytoplankton in Lake Rotokauri, July 1983 to July 1984; n = 22. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Volvocaceae				
<i>Eudorina elegans</i>	0.8			
<i>Gonium pectorale</i>	0.04			
<i>Pandorina morum</i>	0.4			
Chlorococcales				
Chlorococcaceae				
<i>Tetraedron minimum</i>	0.09			
Palmellaceae				
<i>Sphaerocystis schroeteri</i>	0.4			
Oocystaceae				
<i>Ankistrodesmus bibraianus</i>	63.0	2	19.5	11
<i>A. falcatus</i>	27.9	6	4.9	26=
<i>A. fusiformis</i>	1.6	47=	0.2	52=
<i>A. gracilis</i>	28.9	5	3.7	29
<i>A. spiralis</i>	6.0	25	0.4	46=
<i>Chlorella</i> sp.	0.4			
<i>Kirchneriella lunaris</i>	9.9	19	2.0	37=
<i>K. obesa</i>	18.9	11	7.0	18
<i>Monoraphidium contortum</i>	26.7	7	0.4	46=
<i>M. griffithii</i>	1.0	61	0.05	59
<i>M. irregulare</i>	0.2			
<i>M. komarkovae</i>	1.5	49=	0.2	52=
<i>M. minutum</i>	1.1	58=	0.2	52=
<i>M. tortile</i>	1.1	58=	0.1	57=
<i>Nephrocytium agardhianum</i>	0.1			
<i>N. limneticum</i>	0.2			
<i>Oocystis lacustris</i>	0.2			
<i>O. solitaria</i>	0.3			
<i>Raphidocelis contorta</i>	0.7			
<i>Treubaria setigera</i>	0.1			
Micractineaceae				
<i>Micractinium pusillum</i>	0.1			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	1.2	56=	13.8	15
<i>Dictyosphaerium ehrenbergianum</i>	0.7			
<i>D. pulchellum</i>	8.4	20	0.2	52=
<i>Dimorphococcus lunatus</i>	11.4	15	0.5	44=
Scenedesmaceae				
<i>Actinastrum hantzschii</i>	1.5	49=	0.3	49=
<i>Coelastrum cambricum</i>	0.1			
<i>C. microporum</i>	4.2	29	2.2	34=
<i>C. reticulatum</i>	1.9	43=	2.9	31=
<i>Crucigenia quadrata</i>	0.4			
<i>Crucigeniella apiculata</i>	2.1	39	0.4	46=

TABLE 4/25 continued

<i>C. rectangularis</i>	1.9	43=	0.2	52=
<i>Scenedesmus acuminatus</i>	0.3			
<i>S. acutiformis</i>	25.2	8	5.7	22
<i>S. obtusus</i>	3.5	32	0.9	42
<i>S. opoliensis</i>	0.03			
<i>S. quadricauda</i>	1.3	54=	0.3	49=
<i>S. sempervirens</i>	0.5			
<i>Tetrastrum triangulare</i>	0.4			
Hydrodictyaceae				
<i>Pediastrum angulosum</i>	0.2			
<i>P. duplex</i>	0.2			
<i>P. tetras</i>	0.7			
<i>Sorastrum spinulosum</i>	0.4			
Ulothricophyceae				
Ulothricales				
Ulothricaceae				
<i>Ulothrix</i> sp.	0.3			
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium undulatum</i>	0.1			
Zygophyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	7.3	22	5.8	21
<i>M.</i> sp. C	0.4			
<i>Spirogyra</i> sp. A	0.2			
<i>S.</i> sp. B	0.4			
Mesotaeniaceae				
<i>Gonatozygon brebissonii</i>	0.03			
<i>G. kinahanii</i>	0.1			
Desmidiaceae				
<i>Actinotaenium globosum</i>	0.07			
<i>A. wollei</i>	0.1			
<i>Closterium acutum</i>	0.4			
<i>C. a.</i> var. <i>variabile</i>	2.0	40=	0.1	57=
<i>C. gracile</i>	0.3			
<i>C. kuetzingii</i>	0.4			
<i>C. leibleinii</i>	0.03			
<i>C. moniliferum</i>	0.09			
<i>C. parvulum</i>	0.2			
<i>C. pronum</i>	0.1			
<i>C. setaceum</i>	0.03			
<i>C. venus</i> var. <i>westii</i>	0.03			
<i>Cosmarium bioculatum</i>	2.8	36	2.2	34=
<i>C. contractum</i>	0.2			
<i>C. laeve</i>	0.4			
<i>C. lapponicum</i>	0.03			
<i>C. lundelli</i>	0.2			
<i>C. reniforme</i>	0.03			
<i>Desmidium baileyi</i>	0.2			
<i>Euastrum denticulatum</i>	0.03			
<i>E. praemorsum</i>	0.1			
<i>Hyalotheca dissiliens</i>	0.1			
<i>Micrasterias decemdentata</i>	0.1			
<i>Phymatodocis nordstedtiana</i>	0.1			
<i>Pleurotaenium trabecula</i>	0.2			
<i>Sphaerososma aubertianum</i>	0.1			
<i>Spondylosium planum</i>	0.9			

TABLE 4/25 continued

<i>Staurastrum arcuatum</i>	0.3			
<i>S. gracile</i> var. <i>bulbosum</i>	0.2			
<i>S. grande</i> var. <i>parvum</i>	0.2			
<i>S. leptocladum</i> var. <i>insigne</i>	0.1			
<i>S. muticum</i> var. <i>victoriense</i>	3.0	35	10.8	17
<i>S. subradians</i> forma	0.6			
<i>S. tohopekaligense</i> var. <i>minus</i>	0.2			
<i>S. sp. C</i>	5.3	27	1.4	40
<i>Staurodesmus convergens</i> var. <i>laportei</i>	0.1			
<i>St. dejectus</i>	6.9	24	4.9	26=
<i>St. glaber</i> var. <i>limnophilus</i>	0.1			
<i>St. leptodermus</i> var. <i>subcorniculatus</i>	0.4			
<i>St. mucronatus</i> var. <i>subtriangularis</i>	0.1			
<i>St. spetsbergensis</i>	0.1			
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	14.6	14	5.6	23
Dinobryaceae				
<i>Dinobryon cylindricum</i>	1.5	49=	0.3	49=
Synuraceae				
<i>Mallomonas acaroides</i>	2.4	37=	2.0	37=
<i>M. akrokomos</i>	73.8	1	70.8	3
<i>M. tonsurata</i>	0.6			
<i>Synura uvella</i>	23.9	9	4.8	28
Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Pseudostaurastrum</i> sp. A	0.07			
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	15.4	13	6.6	20
<i>A. granulata</i>	0.4			
<i>A. g.</i> var. <i>angustissima</i>	1.8	45=	2.1	36
<i>Cyclotella meneghiniana</i>	0.1			
<i>C. stelligera</i>	0.7			
<i>Melosira varians</i>	0.3			
Rhizosoleniales				
Rhizosoleniaceae				
<i>Rhizosolenia eriensis</i>	0.6			
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	22.4	10	17.4	13
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	0.4			
<i>Fragilaria capucina</i>	0.2			
<i>F. ulna</i>	10.6	17	34.0	7
<i>F. u.</i> var. <i>acus</i>	8.3	21	23.6	10
<i>Tabellaria flocculosa</i>	2.0	40=	3.6	30
Eunotiales				
Eunotiaceae				
<i>Eunotia curvata</i>	0.1			
<i>E. exugia</i>	0.1			

TABLE 4/25 continued

<i>E. pectinalis</i>	1.4	52=	1.1	41
Achnanthes				
Achnanthes				
<i>Achnanthes linearis</i>	10.0	18	0.5	44=
<i>Cocconeis placentula</i>	0.1			
<i>Rhoicosphenia curvata</i>	0.03			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	1.1	58=	2.6	33
<i>Anomoeneis serians</i>	0.03			
<i>Cymbella minuta</i>	0.9			
<i>Gomphonema truncatum</i>	17.0	12	56.2	5
<i>Navicula cuspidata</i>	0.2			
<i>N. pupula</i>	0.03			
<i>Pinnularia flexuosa</i>	0.07			
<i>P. gentilis</i>	0.03			
Epithemiaceae				
<i>Epithemia sorex</i>	0.03			
Nitzschiaceae				
<i>Nitzschia acicularis</i>	11.1	16	2.9	31=
<i>N. gracilis</i>	0.2			
Surirellaceae				
<i>Surirella linearis</i>	0.03			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa delicatissima</i>	0.3			
<i>A. elachista</i> var. <i>conferta</i>	0.5			
<i>Chroococcus dispersus</i>	0.07			
<i>C. d.</i> var. <i>minor</i>	3.3	33	0.03	60
<i>C. limneticus</i>	0.2			
<i>C. minor</i>	0.2			
<i>C. minutus</i>	0.6			
<i>C. turgidus</i>	0.5			
<i>Coelosphaerium kuetzingianum</i>	0.5			
<i>Gomphosphaeria lacustris</i>	2.0	40=	16.4	14
<i>G. l.</i> var. <i>compacta</i>	0.07			
<i>Merismopedia glauca</i>	0.4			
<i>M. minima</i>	1.2	56=	0.001	61
<i>M. tenuissima</i>	0.7			
<i>Microcystis aeruginosa</i>	0.4			
<i>Rhabdoderma lineare</i>	0.7			
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	0.03			
<i>A. minutissima</i> ?	4.0	30	0.8	43
<i>A. tenericaulis</i>	0.2			
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.1			
<i>Oscillatoria agardhii</i>	0.07			
<i>O. jasorvensis</i>	0.07			
<i>O. limnetica</i>	0.3			
<i>O. limosa</i>	0.1			
<i>O. planctonica</i>	0.3			
<i>O. splendida</i>	0.5			

TABLE 4/25 continued

<i>O. subbrevis</i>	0.7			
<i>O. tenuis</i>	0.8			
<i>Spirulina laxa</i>	0.1			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Cyclidiopsis acus</i>	0.1			
<i>Euglena acus</i>	4.9	28	24.4	9
<i>E. ehrenbergii</i>	0.1			
<i>E. limnophila</i>	2.4	37=	12.2	16
<i>E. oxyuris</i>	0.07			
<i>E. proxima</i>	0.1			
<i>E. spirogyra</i> var. <i>suprema</i>	0.03			
<i>Lepocinclis marssonii</i>	0.1			
<i>L. ovum</i>	3.9	31	5.3	24
<i>Menoidium gracile</i>	0.3			
<i>M. pellucidum</i>	0.4			
<i>Phacus agilis</i>	0.3			
<i>P. curvicauda</i>	0.4			
<i>P. glaber</i>	0.3			
<i>P. helicoides</i>	1.4	52=	1.9	39
<i>P. inflexus</i>	0.07			
<i>P. longicauda</i>	0.5			
<i>P. pleuronectes</i>	0.9			
<i>P. pyrum</i>	0.1			
<i>P. raciborski</i>	0.1			
<i>P. rudicola</i>	0.03			
<i>P. suecicus</i>	0.3			
<i>P. tortus</i>	0.03			
<i>Trachelomonas armata</i>	0.3			
<i>T. a.</i> var. <i>inevoluta</i>	5.4	26	89.1	1
<i>T. a.</i> var. <i>longispina</i>	0.6			
<i>T. cylindrica</i>	0.03			
<i>T. dangeardiana</i>	0.03			
<i>T. furcata</i>	0.03			
<i>T. hispida</i>	7.0	23	68.7	4
<i>T. lacustris</i>	0.03			
<i>T. mirabilis</i> var. <i>helvetica</i>	0.03			
<i>T. planctonica</i>				
<i>T. playfairi</i>				
<i>T. stokesi</i>	0.2			
<i>T. volvocina</i> (includes <i>T. planctonica</i> and <i>playfairi</i>)	37.6	4	80.6	2
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	1.6	47=	5.2	25
<i>C. marssonii</i> }				
<i>C. ovata</i> }	41.3	3	18.6	12
Dinophyceae				
Peridinales				
Gymnodiniaceae				

TABLE 4/25 continued

<i>Gymnodinium fuscum</i>	1.3	54=	52.1	6
Peridiniaceae				
<i>Peridinium cinctum</i>	0.5			
<i>P. inconspicuum</i>	0.03			
<i>P. pusillum</i> tab. <i>conjunctum</i>	3.2	34	24.9	8
<i>P. umbonatum</i> tab. <i>conjunctum</i> var. <i>inaequale</i>	0.3			
Ceratiaceae				
<i>Ceratium hirundinella</i>	0.1			
Dinococcales				
Phytodiniaceae				
<i>Cystodinium cornifax</i>	0.1			
RAPHIDOPHYTA				
Raphidophyceae				
Raphidomonadales				
Vacuolariaceae				
<i>Vacuolaria</i> sp.	1.8	45=	6.8	19

TABLE 4/26 Number and percentage of
 phytoplankton species within each
 of the major taxonomic groups in
 Lake Rotokauri, July 1983 to July
 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	48	23.6
Ulothricophyceae	2	1.0
Zygophyceae	46	22.7
CHROMOPHYTA		
Chrysophyceae	6	2.9
Diatomophyceae	29	14.3
Xanthophyceae	1	0.5
CYANOPHYTA		
Cyanophyceae	27	13.3
EUGLENOPHYTA		
Euglenophyceae	33	16.2
PYRRHOPHYTA		
Cryptophyceae	3	1.5
Dinophyceae	7	3.4
RAPHIDOPHYTA		
Raphidophyceae	1	0.5
TOTAL	<u>203</u>	<u>99.8</u>

Diatomophyceae (106 pu ml⁻¹ [16%]) and Euglenophyceae (68 pu ml⁻¹ [10%]) were also significant.

The relatively large biovolumes of the most abundant euglenophyte and diatom taxa resulted in these two groups dominating the biomass (282 mg m³ [39%] and 151 mg m³ [21%], respectively). Other important classes were the Dinophyceae (77 mg m³ [11%], Chrysophyceae (83 mg m³ [11%]) and Euchlorophyceae (66 mg m³ [9%]) (Table 4/27).

4.2.6.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 22)

Of the 75 major species (plus 2 varieties) found in this lake, the majority (42%) were euchlorophytes. The most abundant, however, was a chrysophyte, *Mallomonas akrokomos* (11%), followed by *Ankistrodesmus bibraianus* (10%) and *Cryptomonas* spp. (*C. marssonii* and *C. ovata* [6%]). The biomass was dominated by *Trachelomonas* spp.; *T. armata* var. *inevoluta*, *T. hispida*, *T. planctonica*, *T. playfairi* and *T. volvocina* collectively made up 33% of the mean total biomass. Other important species, in terms of biomass, were *Mallomonas akrokomos* (10%) and *Gomphonema truncatum* (8%) (Table 4/28).

4.2.6.4 Size Distribution

The community consisted mainly of relatively large phytoplankters (Table 4/29), with the GALD of 102 (87%) species $\geq 21 \mu\text{m}$. The number of species within each of the three largest size fractions was very similar, and most of these large species were zygophytes (25%), euchlorophytes (21%), or euglenophytes (19%). The GALD of 27 (13%) phytoplankters was $\leq 20 \mu\text{m}$, and of these, only one belonged to the ultraplankton.

4.2.7 Lake Rotomanuka North

4.2.7.1 Species Composition

Table 4/30 lists the 192 species, belonging to 91 genera, found in Lake Rotomanuka North, together with their mean density and biomass contributions. The major class was the Euchlorophyceae (59 species [31%]), but the Diatomophyceae (30 species [16%]), Euglenophyceae (27 species [14%]), Zygophyceae (25 species [13%]) and Cyanophyceae (23

TABLE 4/27 Mean distribution of plankton units and biomass amongst the major taxa in Lake Rotokauri, July 1983 to July 1984; mean values $< 1 \text{ pu ml}^{-1}$ are excluded from the analyses ($n = 22$).

Taxon	Pu ml^{-1}		Biomass	
	Number	Proportion (%)	mg m^3	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	258	39.5	66	9.0
Zygophyceae	35	5.3	25	3.4
CHROMOPHYTA				
Chrysophyceae	117	17.9	83	11.3
Diatomophyceae	106	16.2	151	20.6
CYANOPHYTA				
Cyanophyceae	19	2.9	17	2.3
EUGLENOPHYTA				
Euglenophyceae	68	10.4	282	38.5
PYRRHOPHYTA				
Cryptophyceae	43	6.6	24	3.3
Dinophyceae	5	0.8	77	10.5
RAPHIDOPHYTA				
Raphidophyceae	2	0.3	7	0.9
TOTAL	<u>653</u>	<u>99.9</u>	<u>732</u>	<u>99.8</u>

TABLE 4/28 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Rotokauri, July 1983 to July 1984 (n = 22).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Volvocales		
Volvocaceae		
<i>Eudorina elegans</i>	0.1	-
Chlorococcales		
Oocystaceae		
<i>Ankistrodesmus bibraianus</i>	9.6	2.7
<i>A. falcatus</i>	4.3	0.7
<i>A. fusiformis</i>	0.2	-
<i>A. gracilis</i>	4.4	0.5
<i>Kirchneriella lunaris</i>	1.5	0.3
<i>K. obesa</i>	2.9	0.9
<i>Monoraphidium contortum</i>	4.1	-
<i>M. griffithii</i>	0.1	-
<i>M. komarkovae</i>	0.2	-
<i>M. minutum</i>	0.2	-
<i>M. tortile</i>	0.2	-
<i>Raphidocelis contorta</i>	0.1	-
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	0.2	1.9
<i>Dictyosphaerium pulchellum</i>	1.3	-
<i>Dimorphococcus lunatus</i>	1.7	-
Scenedesmaceae		
<i>Actinastrum hantzschii</i>	0.2	-
<i>Coelastrum microporum</i>	0.6	0.3
<i>C. reticulatum</i>	0.3	0.4
<i>Crucigeniella apiculata</i>	0.3	-
<i>C. rectangularis</i>	0.3	-
<i>Scenedesmus acutiformis</i>	3.8	0.8
<i>S. obtusus</i>	0.5	0.1
<i>S. quadricauda</i>	0.2	-
Hydrodictyaceae		
<i>Pediastrum tetras</i>	0.1	-
Zygophyceae		
Zygnematales		
Zygnemataceae		
<i>Mougeotia</i> sp. B	1.1	0.8
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	0.3	-
<i>Cosmarium bioculatum</i>	0.4	0.3
<i>Staurastrum muticum</i> var. <i>victoriense</i>	0.4	1.5
<i>S. subradians</i> ?	0.1	-
<i>S.</i> sp. C	0.8	0.2
<i>Stauroidesmus dejectus</i>	1.0	0.7
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		

TABLE 4/28 continued

Chrysococcaceae		
<i>Chrysococcus rufescens</i>	2.2	0.8
Dinobryaceae		
<i>Dinobryon cylindricum</i>	0.2	-
Synuraceae		
<i>Mallomonas acaroides</i>	0.4	0.3
<i>M. akrokomos</i>	11.3	9.7
<i>M. tonsurata</i>	0.1	-
<i>Synura uvella</i>	3.7	-
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira distans</i>	2.3	0.9
<i>A. granulata</i> var. <i>angustissima</i>	0.3	0.3
<i>Cyclotella stelligera</i>	0.1	-
Rhizosoleniales		
Rhizosoleniaceae		
<i>Rhizosolenia eriensis</i>	0.1	-
Biddulphiales		
Chaetoceraceae		
<i>Acanthoceras zachariasii</i>	3.4	2.4
Diatomales		
Diatomaceae		
<i>Fragilaria ulna</i>	1.6	4.6
<i>F. u.</i> var. <i>acus</i>	1.3	3.2
<i>Tabellaria flocculosa</i>	0.3	0.5
Eunotiales		
Eunotiaceae		
<i>Eunotia pectinalis</i>	0.2	0.1
Achnanthales		
Achnanthaceae		
<i>Achnanthes linearis</i>	1.5	-
Naviculales		
Naviculaceae		
<i>Amphora</i> sp.	0.2	0.3
<i>Gomphonema truncatum</i>	2.6	7.7
Nitzschiaceae		
<i>Nitzschia acicularis</i>	1.7	0.4
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Chroococcus dispersus</i> var. <i>minor</i>	0.5	-
<i>C. minutus</i>	0.1	-
<i>Gomphosphaeria lacustris</i>	0.3	2.2
<i>Merismopedia minima</i>	0.2	-
<i>M. tenuissima</i>	0.1	-
<i>Rhabdoderma lineare</i>	0.1	-
Nostocales		
Nostocaceae		
<i>Anabaena minutissima</i> ?	0.6	0.1
Oscillatoriaceae		
<i>Oscillatoria subbrevis</i>	0.1	-
<i>O. tenuis</i>	0.1	-

TABLE 4/28 continued

EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Euglena acus</i>	0.7	3.3
<i>E. limnophila</i>	0.4	1.7
<i>Lepocinclis ovum</i>	0.6	0.7
<i>Phacus helicoides</i>	0.2	0.2
<i>P. pleuronectes</i>	0.1	-
<i>Trachelomonas armata</i> var. <i>inevoluta</i>	0.8	12.2
<i>T. a.</i> var. <i>longispina</i>	0.1	-
<i>T. hispida</i>	1.1	9.4
<i>T. planctonica</i>]		
<i>T. playfairi</i>]		
<i>T. volvocina</i>]	5.7	11.0
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas erosa</i>	0.2	0.7
<i>C. marssonii</i>]		
<i>C. ovata</i>]	6.3	2.5
Dinophyceae		
Peridinales		
Gymnodiniaceae		
<i>Gymnodinium fuscum</i>	0.2	7.1
Peridiniaceae		
<i>Peridinium pusillum</i> tab. <i>conjunctum</i>	0.5	3.4
RAPHIDOPHYTA		
Raphidophyceae		
Raphidomonadales		
Vacuolariaceae		
<i>Vacuolaria</i> sp.	0.3	0.9
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

TABLE 4/29 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Rotokauri, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	56	26.7
Nannoplankton	41 - 63	62	29.5
	21 - 40	65	30.9
	11 - 20	21	10.0
	6 - 10	5	2.4
Ultraplankton	≤ 5	1	0.4
Total		<u>210</u>	<u>99.9</u>

TABLE 4/30 Mean density and biomass contributions of the phytoplankton in Lake Rotomanuka North, July 1983 to July 1984; n = 21. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Chlamydomonaceae				
<i>Chlamydomonas</i> sp. A	0.2			
C. sp. B	0.1			
Volvocaceae				
<i>Eudorina elegans</i>	0.04			
<i>Gonium pectorale</i>	0.09			
Chlorococcales				
Chlorococcaceae				
<i>Ankyra judayi</i>	0.04			
<i>Tetraedron minimum</i>	0.3			
Oocystaceae				
<i>Ankistrodesmus bernardii</i>	0.4			
<i>A. bibraianus</i>	0.8			
<i>A. falcatus</i>	0.2			
<i>A. fasciculatus</i>	0.1			
<i>A. fusiformis</i>	0.3			
<i>A. gracilis</i>	0.5			
<i>A. spiralis</i>	0.3			
<i>Kirchneriella lunaris</i>	0.3			
<i>K. obesa</i>	0.6			
<i>Lagerheimia ciliata</i>	0.1			
<i>L. citrifomis</i>	0.3			
<i>Monoraphidium contortum</i>	5.4	12	0.1	23=
<i>M. griffithii</i>	2.0	20=	0.1	23=
<i>M. irregulare</i>	5.7	11	0.2	21=
<i>M. komarkovae</i>	0.1			
<i>M. minutum</i>	1.3	25	0.02	27
<i>M. tortile</i>	3.7	14	0.04	26
<i>Nephrocytium agardhianum</i>	0.08			
<i>N. limneticum</i>	0.04			
<i>Oocystis borgei</i>	0.04			
<i>O. lacustris</i>	0.4			
<i>O. solitaria</i>	0.7			
<i>Quadrigula lacustris</i>	0.08			
<i>Raphidocelis contorta</i>	0.9			
<i>Trochiscia aciculifera</i>	0.08			
Micractiniaceae				
<i>Golenkinia radiata</i>	0.04			
<i>Micractinium pusillum</i>	0.1			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	18.6	4	237.5	2
<i>Dictyosphaerium ehrenbergianum</i>	0.2			
<i>Westella botryoides</i>	0.3			
Scenedesmaceae				
<i>Actinastrum fluviatile</i>	0.1			

TABLE 4/30 continued

<i>A. gracillimum</i>	0.08			
<i>A. hantzschii</i>	0.1			
<i>Coelastrum astroideum</i>	0.04			
<i>C. cambricum</i>	0.04			
<i>C. indicum</i>	0.1			
<i>C. microporum</i>	0.9			
<i>C. reticulatum</i>	0.8			
<i>Crucigenia fenestrata</i>	0.1			
<i>C. quadrata</i>	0.1			
<i>Crucigeniella rectangularis</i>	0.2			
<i>Scenedesmus acuminatus</i>	0.1			
<i>S. a. var. minor</i>	0.08			
<i>S. acutus</i>	0.3			
<i>S. denticulatus</i>	0.1			
<i>S. ecornis</i>	0.8			
<i>S. obtusus</i>	0.6			
<i>S. quadricauda</i>	0.3			
<i>Tetrastrum staurogeniaforme</i>	0.04			
<i>T. triangulare</i>	2.0	20=	0.1	23=
Hydrodictyaceae				
<i>Pediastrum boryanum</i>	0.08			
<i>P. tetras</i>	0.5			
<i>Sorastrum spinulosum</i>	0.04			
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	0.08			
Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Bulbochaete</i> sp.	0.08			
Zygothyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. A	0.04			
<i>M. sp. B</i>	0.5			
Mesotaeniaceae				
<i>Gonatozygon brebissonii</i>	0.1			
<i>Netrium digitus</i>	0.08			
Desmidiaceae				
<i>Closterium acutum</i> var. <i>linea</i>	0.04			
<i>C. a. var. variabile</i>	10.5	7	0.7	18
<i>C. gracile</i>	0.1			
<i>C. parvulum</i>	0.04			
<i>C. pronum</i>	0.3			
<i>Cosmarium amplum</i>	0.04			
<i>Co. botrytis</i>	0.08			
<i>Co. laeve</i>	0.1			
<i>Euastrum verrucosum</i>	0.04			
<i>Micrasterias decemdentata</i>	0.08			
<i>Staurastrum arcuatum</i>	0.04			
<i>S. avicula</i>	0.04			
<i>S. gracile</i> var. <i>bulbosum</i>	0.04			
<i>S. leptocladum</i> var. <i>insigne</i>	0.2			
<i>S. muticum</i> var. <i>victoriense</i>	0.3			
<i>S. subradians</i> forma ?	0.08			
<i>S. tohopekaligense</i> var. <i>minus</i>	0.08			
<i>S. sp. A</i>	0.6			
<i>S. sp. B</i>	0.04			
<i>Staurodesmus dejectus</i>	0.04			

TABLE 4/30 continued

<i>St. glaber</i> var. <i>limnophilus</i>	0.08			
<i>St. mucronatus</i> var. <i>delicatulus</i>	0.04			
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	2.4	17=	1.2	15=
Chrysamoebaceae				
<i>Chrysamoeba radians</i>	0.08			
Dinobryaceae				
<i>Dinobryon bavaricum</i>	3.0	16	0.6	19
<i>D. crenulatum</i>	0.1			
<i>D. cylindricum</i>	139.8	1	25.7	7
<i>D. divergens</i>	0.3			
<i>D. elegantissimum</i> forma <i>gallica</i>	0.1			
Synuraceae				
<i>Chrysosphaerella longispina</i>	4.5	13	0.9	17
<i>Mallomonas akrokomos</i>	0.1			
<i>M. tonsurata</i>	0.08			
<i>Stokesiella epipyxis</i> ?	0.1			
<i>Synura spinosa</i>	0.1			
<i>Synura uvella</i>	8.6	8	1.5	14
Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Pseudostaurastrum</i> sp. B	0.1			
<i>Tetraedriella jovetii</i>	0.08			
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	0.3			
<i>A. granulata</i>	0.2			
<i>A. g.</i> var. <i>angustissima</i>	0.1			
<i>Cyclotella meneghiniana</i>	0.04			
<i>C. stelligera</i>	17.3	6	4.2	10
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	0.04			
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	0.1			
<i>Centronella reichelti</i>	0.08			
<i>Fragilaria capucina</i>	0.1			
<i>F. delicatissima</i>	7.5	10	1.6	13
<i>F. ulna</i>	0.1			
<i>Tabellaria flocculosa</i>	1.2	26	2.2	11
Eunotiales				
Eunotiaceae				
<i>Eunotia diodon</i>	0.04			
<i>E. exugia</i>	0.04			
<i>E. pectinalis</i>	0.8			
<i>E. p.</i> var. <i>undulata</i>	0.04			
Achnanthales				
Achnanthaceae				
<i>Achnanthes linearis</i>	0.8			
<i>Cocconeis placentula</i>	0.08			

TABLE 4/30 continued

<i>C. p. var. euglypta</i>	0.08			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	0.08			
<i>Cymbella aspersa</i>	0.04			
<i>Frustulia rhomboides</i> var. <i>capitata</i>	0.04			
<i>F. r.</i> var. <i>saxonica</i>	0.2			
<i>Gomphonema acuminatum</i>	0.03			
<i>G. truncatum</i>	0.2			
<i>Navicula radiosa</i>	0.04			
<i>N. subtilissima</i>	0.04			
<i>Pinnularia borealis</i>	0.04			
<i>Stauroneis agrestis</i>	0.04			
Nitzschiaceae				
<i>Hantzschia amphioxys</i>	0.04			
<i>Nitzschia acicularis</i>	0.04			
<i>N. gracilis</i>	0.04			
Surirellaceae				
<i>Stenopterobia intermedia</i>	0.08			
<i>Surirella angustata</i>	0.04			
<i>S. linearis</i> var. <i>constricta</i>	0.04			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa delicatissima</i>	0.08			
<i>A. elachista</i> var. <i>conferta</i>	0.08			
<i>Chroococcus dispersus</i>	0.3			
<i>C. limneticus</i>	0.4			
<i>C. minor</i>	0.3			
<i>Merismopedia elegans</i>	0.8			
<i>M. glauca</i>	0.8			
<i>M. minima</i>	0.3			
<i>M. tenuissima</i>	0.6			
<i>Microcystis aeruginosa</i>	3.2	15	78.2	4
<i>Rhabdoderma lineare</i>	0.1			
Nostocales				
Nostocaceae				
<i>Anabaena circinalis</i>	0.2			
<i>A. flos-aquae</i>	0.1			
<i>A. minutissima</i> ?	1.1	27	0.3	20
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.1			
<i>Oscillatoria articulata</i>	0.04			
<i>O. geminata</i>	0.04			
<i>O. limnetica</i>	0.08			
<i>O. planctonica</i>	0.1			
<i>O. splendida</i>	0.1			
<i>O. subbrevis</i>	0.2			
<i>O. tenuis</i>	0.3			
<i>Spirulina laxa</i>	0.1			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				

TABLE 4/30 continued

Euglenaceae				
<i>Astasia harrisii</i>	0.04			
<i>Cyclidiopsis acus</i>	0.04			
<i>Euglena oxyuris</i>	0.04			
<i>Lepocinclis marssonii</i>	1.4	23=	1.2	15=
<i>L. ovum</i>	0.4			
<i>Menoidium gracile</i>	0.4			
<i>Phacus agilis</i>	1.4	23=	0.2	21=
<i>P. glaber</i>	0.2			
<i>P. helicoides</i>	0.2			
<i>P. raciborski</i>	0.4			
<i>P. suecicus</i>	0.4			
<i>P. s. var. oidon</i>	0.2			
<i>P. sesquitortus</i>	0.08			
<i>P. tortus</i>	0.08			
<i>Trachelomonas aculeata</i>	0.04			
<i>T. armata</i>	0.04			
<i>T. a. var. longispina</i>	0.9			
<i>T. cylindrica</i>	0.4			
<i>T. furcata</i>	0.05			
<i>T. hexangulata</i>	0.1			
<i>T. hispida</i>	0.08			
<i>T. h. var. coronata</i>	0.04			
<i>T. lacustris</i>	0.08			
<i>T. lemmermanii</i>	0.04			
<i>T. planctonica</i>	0.04			
<i>T. playfairi</i>	0.04			
<i>T. pulcherrima var. minor</i>	0.08			
<i>T. p. var. ovalis</i>	0.04			
<i>T. sydneyensis</i>	0.1			
<i>T. volvocina</i>	17.9	5	31.6	5
<i>Urceolus sp.</i>	0.04			
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	0.3			
<i>C. marssonii</i>				
<i>C. ovata</i>	46.7	2	22.4	8
Dinophyceae				
Peridinales				
Gymnodiniaceae				
<i>Gymnodinium fuscum</i>	0.08			
Peridiniaceae				
<i>Peridinium aciculiferum</i>	0.1			
<i>P. cinctum</i>	26.4	3	1099.0	1
<i>P. inconspicuum</i>	2.3	19	1.8	12
<i>P. pusillum tab. conjunctum</i>	1.5	22	10.5	9
<i>P. umbonatum tab. conjunctum var. inaequale</i>	0.1			
Ceratiaceae				
<i>Ceratium hirundinella</i>	2.4	17=	149.9	3
Dinococcales				
Phytodiniaceae				
<i>Cystodinium cornifax</i>	0.04			

TABLE 4/30 continued

RAPHIDOPHYTA				
Raphidophyceae				
Raphidomonadales				
Vacuolariaceae				
<i>Vacuolaria</i> sp.	7.9	9	29.8	6

TABLE 4/31 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Rotomanuka North, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	59	30.7
Ulothricophyceae	1	0.5
Zygophyceae	25	13.0
CHROMOPHYTA		
Chrysophyceae	13	6.8
Diatomophyceae	30	15.6
Xanthophyceae	2	1.0
CYANOPHYTA		
Cyanophyceae	23	12.0
EUGLENOPHYTA		
Euglenophyceae	27	14.1
PYRRHOPHYTA		
Cryptophyceae	3	1.5
Dinophyceae	8	4.2
RAPHIDOPHYTA		
Raphidophyceae	1	0.5
TOTAL	<u>192</u>	<u>99.9</u>

species [12%]), were also well represented (Table 4/31).

4.7.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 21)

Numerically, the Chrysophyceae was the most important class (159 pu ml⁻¹ [42%]); the Euchlorophyceae (52 pu ml⁻¹ [14%]) and Cryptophyceae (47 pu ml⁻¹ [12%]) were ranked second and third, respectively, while the remaining classes were relatively insignificant. However, in terms of biomass, the mean standing crop was dominated by the Dinophyceae (1261 mg m³ [74%]) and, with the exception of the Euchlorophyceae (238 mg m³ [14%]), other classes were of minor importance (Table 4/32).

4.2.7.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 21)

There were 28 major species, with the three most abundant (*Dinobryon cylindricum* [37%], *Cryptomonas* spp. [*C. marssonii* and *C. ovata*] [12%] and *Peridinium cinctum* [7%]) making up c. 56% of the mean total number of pu ml⁻¹. Concentration of dominance amongst a few species was even more marked in terms of biomass, with only three species together making up 88% (*Peridinium cinctum* [65%], *Botryococcus braunii* [14%] and *Ceratium hirundinella* [9%]) (Table 4/33).

4.2.7.4 Size Distribution

The GALDs of 83% of all taxa were $\geq 21 \mu\text{m}$. The 21 to 41 μm fraction contained the highest number of species (68 [33%]), but the larger fractions were also well represented. Conversely, a low number of species (24 [17%]) was present in the $\leq 20 \mu\text{m}$ fraction (Table 4/34). The majority of phytoplankters with GALDs $\geq 21 \mu\text{m}$ were euchlorophytes (44 species [26%]) and diatoms (31 species [18%]), in contrast to the group $\leq 20 \mu\text{m}$, which was dominated by euglenophytes (7 species [21%]).

4.2.8 Lake Rotomanuka South

4.2.8.1 Species Composition

118 species, belonging to 65 genera, were identified from Lake Rotomanuka South (Table 4/35). Most were euchlorophytes (35 species

TABLE 4/32 Mean distribution of plankton units and biomass amongst the major taxa in Lake Rotomanuka North, July 1983 to July 1984; mean values $< 1 \text{ pu ml}^{-1}$ are excluded from the analyses (n = 21).

Taxon	Pu ml^{-1}		Biomass	
	Number	Proportion (%)	mg m^3	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	52	13.7	238	14.0
Zygophyceae	14	3.7	-	-
CHROMOPHYTA				
Chrysophyceae	159	42.1	30	1.8
Diatomophyceae	30	7.9	8	0.5
CYANOPHYTA				
Cyanophyceae	9	2.4	78	4.5
EUGLENOPHYTA				
Euglenophyceae	26	6.9	33	1.9
PYRRHOPHYTA				
Cryptophyceae	47	12.4	22	1.3
Dinophyceae	33	8.7	1,261	74.2
RAPHIDOPHYTA				
Raphidophyceae	8	2.1	30	1.8
TOTAL	<u>378</u>	<u>99.9</u>	<u>1,700</u>	<u>100.0</u>

TABLE 4/33 Mean percentage contributions of the major* phytoplankton species to the mean total density and biomass in Lake Rotomanuka North, July 1983 to July 1984 (n = 21).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Oocystaceae		
<i>Ankistrodesmus bernardii</i>	0.1	
<i>A. bibraianus</i>	0.2	
<i>A. gracilis</i>	0.1	
<i>Kirchneriella obesa</i>	0.1	
<i>Monoraphidium contortum</i>	1.4	
<i>M. griffithii</i>	0.5	
<i>M. irregulare</i>	1.5	
<i>M. minutum</i>	0.3	
<i>M. tortile</i>	1.0	
<i>Oocystis lacustris</i>	0.1	
<i>O. solitaria</i>	0.2	
<i>Raphidocelis contorta</i>	0.2	
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	4.9	14.0
<i>Coelastrum microporum</i>	0.2	
<i>C. reticulatum</i>	0.2	
<i>Scenedesmus ecornis</i>	0.2	
<i>S. obtusus</i>	0.1	
<i>Tetrastrum triangulare</i>	0.5	
Hydrodictyaceae		
<i>Pediastrum tetras</i>	0.1	
Zygophyceae		
Zygnematales		
Zygnemataceae		
<i>Mougeotia</i> sp. B	0.1	
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	2.8	
<i>Staurastrum</i> sp. A	0.1	
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.6	
Dinobryaceae		
<i>Dinobryon bavaricum</i>	0.8	
<i>D. cylindricum</i>	37.0	1.5
Synuraceae		
<i>Chrysosphaerella longispina</i>	1.2	
<i>Synura uvella</i>	2.3	
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Cyclotella stelligera</i>	4.5	

TABLE 4/33 continued

Diatomales			
Diatomaceae			
<i>Fragilaria delicatissima</i>	1.2		
<i>Tabellaria flocculosa</i>	0.3		
Eunotiales			
Eunotiaceae			
<i>Eunotia pectinalis</i>	0.2		
Achnanthes			
Achnanthes			
<i>Achnanthes linearis</i>	0.2		
CYANOPHYTA			
Cyanophyceae			
Chroococcales			
Chroococcaceae			
<i>Chroococcus limneticus</i>	0.1		
<i>Merismopedia elegans</i>	0.2		
<i>M. glauca</i>	0.2		
<i>M. tenuissima</i>	0.1		
<i>Microcystis aeruginosa</i>	0.8	4.6	
Nostocales			
Nostocaceae			
<i>Anabaena minutissima</i> ?	0.3		
EUGLENOPHYTA			
Euglenophyceae			
Euglenales			
Euglenaceae			
<i>Lepocinclis marssonii</i>	0.4		
<i>L. ovum</i>	0.1		
<i>Menoidium gracile</i>	0.1		
<i>Phacus agilis</i>	0.4		
<i>P. raciborski</i>	0.1		
<i>P. suecicus</i>	0.1		
<i>Trachelomons armata</i> var. <i>longispina</i>	0.2		
<i>T. cylindrica</i>	0.1		
<i>T. playfairi</i>	0.1		
<i>T. volvocina</i>	4.7	1.8	
PYRRHOPHYTA			
Cryptophyceae			
Cryptomonadales			
Cryptomonadaceae			
<i>Cryptomonas marssonii</i> }			
<i>C. ovata</i> }	12.3	1.3	
Dinophyceae			
Peridinales			
Peridiniaceae			
<i>Peridinium cinctum</i>	7.0	64.6	
<i>P. inconspicuum</i>	0.6	0.1	
<i>P. pusillum</i> tab. <i>conjunctum</i>	0.4	0.6	
Ceratiaceae			
<i>Ceratium hirundinella</i>	0.6	8.8	

TABLE 4/33 continued

RAPHIDOPHYTA		
Raphidophyceae		
Raphidomonadales		
Vacuolariaceae		
<i>Vacuolaria</i> sp.	2.1	1.7
* A major species is defined as one with a mean contribution $\geq 0.1\%$ of either the mean total density or biomass		

TABLE 4/34 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Rotomanuka North, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	44	21.7
Nannoplankton	41 - 63	57	28.1
	21 - 40	68	33.5
	11 - 20	28	13.8
	6 - 10	5	2.4
Ultraplankton	≤ 5	1	0.4
Total		<u>203</u>	<u>100.0</u>

TABLE 4/35 Mean density and biomass contributions of the phytoplankton in Lake Rotomanuka South, October 1983 to July 1984; n = 15. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹.) Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Chlamydomonaceae				
<i>Chlamydomonas</i> sp. A	5.6	28	1.4	31=
<i>C.</i> sp. B	0.3			
Volvocaceae				
<i>Eudorina elegans</i>	0.3			
<i>Gonium pectorale</i>	0.3			
Chlorococcales				
Chlorococcaceae				
<i>Tetraedron minimum</i>	0.3			
Oocystaceae				
<i>Ankistrodesmus bibraianus</i>	5.2	30	1.4	31=
<i>A. falcatus</i>	2.1	39	0.3	42
<i>Kirchneriella obesa</i>	1.1	47=	0.4	38
<i>Monoraphidium contortum</i>	1.6	42=	0.02	51
<i>M. griffithii</i>	1.6	42=	0.2	43=
<i>M. irregulare</i>	0.5			
<i>M. komarkovae</i>	3.9	34	0.4	38=
<i>M. minutum</i>	0.5			
<i>M. tortile</i>	18.9	10	0.2	43=
<i>Nephrocystium agardhianum</i>	0.3			
<i>N. limneticum</i>	0.3			
<i>Oocystis lacustris</i>	6.8	24	1.6	30
<i>O. solitaria</i>	0.5			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	1.0	52	8.2	17
<i>Dictyosphaerium pulchellum</i>	1.1	47=	0.6	47=
Scenedesmaceae				
<i>Actinastrum hantzschii</i>	7.0	22	1.4	31=
<i>Coelastrum indicum</i>	0.8			
<i>C. microporum</i>	0.7			
<i>C. reticulatum</i>	12.0	14	21.7	11
<i>Scenedesmus acuminatus</i>	2.5	38	2.3	27
<i>S. denticulatus</i>	0.3			
<i>S. intermedius</i>	0.3			
<i>S. obtusus</i>	0.5			
<i>S. quadricauda</i>	10.5	17=	2.4	26
<i>Tetrastrum staurogeniaforme</i>	0.5			
<i>T. triangulare</i>	9.3	19	0.4	38=
Hydrodictyaceae				
<i>Pediastrum angulosum</i>	0.8			
<i>P. duplex</i>	1.1	47=	0.4	38=
<i>P. tetras</i>	0.5			
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	4.0	32=	0.06	47=

TABLE 4/35 continued

Zygomycetes				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. B	0.5			
Mesotaeniaceae				
<i>Gonatozygon brebissonii</i>	0.3			
Desmidiaceae				
<i>Closterium aciculare</i>	0.7			
<i>C. acutum</i> var. <i>variabile</i>	1962.4	1	119.7	3
<i>C. gracile</i>	13.0	13	6.7	18
<i>C. pronum</i>	0.5			
<i>Cosmarium contractum</i>	6.1	25	21.3	12
<i>Staurastrum avicula</i>	1.4	44	4.9	22
<i>S. chaetopus</i> ?	0.3			
<i>S. gracile</i> forma	0.3			
<i>S. leptocladum</i> var. <i>insigne</i>	0.3			
<i>S. muticum</i> var. <i>victoriense</i>	0.3			
<i>S. subradians</i> ?	0.3			
<i>S. sp. A</i>	21.6	9	3.7	23
<i>Staurodesmus cuspidatus</i>	4.2	31	22.7	10
<i>St. dejectus</i>	1.3	45=	1.7	29
<i>St. glaber</i> var. <i>limnophilus</i>	8.0	20=	1.2	35
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	22.3	7	8.5	16
Dinobryaceae				
<i>Dinobryon cylindricum</i>	18.4	11	2.5	25
Synuraceae				
<i>Mallomonas acaroides</i>	5.9	26=	5.0	21
<i>M. akrokomos</i>	3.2	36	3.1	24
<i>Synura uvella</i>	50.5	6	11.7	15
Xanthophyceae				
Mischococcales				
Sciadiaceae				
<i>Centritractus belonophorus</i>	0.5			
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	2.6	37	0.9	36
<i>A. granulata</i>	5.9	26=	32.6	6
<i>A. g.</i> var. <i>angustissima</i>	1.8	40	2.1	28
<i>Cyclotella meneghiniana</i>	0.5			
<i>C. stelligera</i>	21.8	8	5.1	20
<i>Melosira varians</i>	0.3			
Rhizosoleniales				
Rhizosoleniaceae				
<i>Rhizosolenia eriensis</i>	1.1	47=	0.9	36=
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	18.1	12	13.3	14

TABLE 4/35 continued

Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	0.5			
<i>Fragilaria ulna</i>	1.3	45=	6.0	19
<i>Tabellaria fenestrata</i>	0.5			
<i>T. flocculosa</i>	11.1	16	20.0	13
Eunotiales				
Eunotiaceae				
<i>Eunotia curvata</i>	0.1			
<i>E. pectinalis</i>	0.9			
<i>E. p. var. undulata</i>	0.3			
<i>E. serpentina</i>	0.5			
Achnanthales				
Achnanthaceae				
<i>Achnanthes linearis</i>	1.1	47=	0.1	45
<i>Cocconeis placentula</i>	0.9			
Naviculales				
Naviculaceae				
<i>Amphora</i> sp.	0.3			
<i>Anomoeoneis serians</i>	0.5			
<i>Cymbella minuta</i>	0.5			
<i>Gomphonema truncatum</i>	0.2			
<i>Gyrosigma acuminatum</i>	0.3			
<i>Navicula radiosa</i>	0.3			
<i>N. subtilissima</i>	0.3			
Nitzschiaceae				
<i>Nitzschia acicularis</i>	5.5	29	1.4	31=
Surirellaceae				
<i>Stenopterobia intermedia</i>	0.1			
<i>Surirella linearis</i> var. <i>constricta</i>	0.1			
CYANOPHYTA				
Cyanophyceae				
Chroococcales				
Chroococcaceae				
<i>Aphanocapsa delicatissima</i>	4.0	32=	0.05	50
<i>A. elachista</i> var. <i>conferta</i>	0.3			
<i>Chroococcus dispersus</i> var. <i>minor</i>	8.0	20=	0.06	47=
<i>Gomphosphaeria lacustris</i>	0.3			
<i>Merismopedia minima</i>	11.7	15	0.01	52
<i>Microcystis aeruginosa</i>	352.0	2	26445.4	1
<i>M. pulverea</i>	0.3			
Nostocales				
Nostocaceae				
<i>Anabaena flos-aquae</i>	0.3			
<i>A. minutissima</i> ?	0.3			
<i>A. tenericaulis</i>	170.4	3	48.0	5
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.1			
<i>Oscillatoria limnetica</i>	0.1			
<i>O. subbrevis</i>	0.3			
<i>Phormidium mucicola</i>	3.7	35	0.07	46
<i>Spirulina laxa</i>	0.3			

TABLE 4/35 continued

EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Euglena acus</i>	0.3			
<i>E. oxyuris</i>	0.3			
<i>Lepocinclis ovum</i>	0.8			
<i>Phacus glaber</i>	0.3			
<i>P. latus</i>	0.3			
<i>P. pleuronectes</i>	0.1			
<i>Trachelomonas armata</i> var.				
<i>longspina</i>	0.3			
<i>T. dubia</i>	0.3			
<i>T. hexangulata</i>	0.3			
<i>T. hispida</i>	0.5			
<i>T. planctonica</i> *				
<i>T. playfairi</i>	0.6			
<i>T. volvocina</i>	108.4	4	306.8	2
<i>T. volzii</i> var. <i>cylindriaceae</i>	0.3			
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	10.5	17	32.0	7
<i>C. ovata</i>	62.1	5	28.6	8
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium cinctum</i>	1.7	41	66.7	4
<i>P. pusillum</i> tab. <i>conjunctum</i>	6.9	23	27.7	9
Ceratiaceae				
<i>Ceratium hirundinella</i>	0.3			
* Included in <i>Trachelomonas volvocina</i> counts				

[30%]) and diatoms (26 species [22%]). Cyanophytes and euglenophytes contributed 13 and 12%, respectively, but other classes contained few species (Table 4/36).

4.2.8.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 15)

Numerically, the community consisted largely of zygothytes (2021 pu ml⁻¹ [66%]); cyanophytes were the second most abundant group (552 pu ml⁻¹ [18%]), while the other seven classes were relatively unimportant. However, in terms of biomass, the community was totally dominated by cyanophytes (26,493 mg m³ [97%]), and the euglenophytes, despite their relatively small mean biomass (307 mg m³ [1%]), were ranked second (Table 4/37).

4.2.8.3 Mean Percentage Contributions of the Major Species to the Mean Total Phytoplankton Density and Biomass (n = 15)

Closterium acutum var. *variabile* made the largest contribution to the mean total density (64%), followed by *Microcystis aeruginosa* (12%) and *Anabaena tenericaulis* (6%). Although 37 (47%) of the major species were chlorophytes, with the exception of *C. a.* var. *variabile*, none of their mean contributions exceeded 1% of the mean total density. Furthermore, all five chrysophytes found in the lake ranked as a major species, the most important being *Synura uvella* (2%). *Trachelomonas volvocina* (4%) and *Cryptomonas ovata* (2%), were the most abundant euglenophyte and cryptomonad, respectively (Table 4/38).

In terms of biomass, *Microcystis aeruginosa* (97%) totally dominated the community. *Trachelomonas* spp. (*T. planctonica* and *T. volvocina*) ranked second, but made up only 1%, while *Closterium acutum* var. *variabile*, despite its numerical importance, contributed only 0.4% (Table 4/38).

4.2.8.4 Size Distribution

The majority of species (77%) were nanoplankton; 33% of these belonged to the 41 to 63 µm size fraction, including the major species in terms of both biomass and abundance. The 21 to 43 µm fraction contained 36 species (30%), most (30%) of which were euglenophytes,

TABLE 4/36 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Rotomanuka South, October 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	35	29.7
Zygophyceae	17	14.4
CHROMOPHYTA		
Chrysophyceae	5	4.2
Diatomophyceae	26	22.0
Xanthophyceae	1	0.8
CYANOPHYTA		
Cyanophyceae	15	12.7
EUGLENOPHYTA		
Euglenophyceae	14	11.9
PYRRHOPHYTA		
Cryptophyceae	2	1.7
Dinophyceae	3	2.5
TOTAL	<u>118</u>	<u>99.9</u>

TABLE 4/37 Mean distribution of plankton units and biomass amongst the major taxa in Lake Rotomanuka South, October 1983 to July 1984; mean values $< 1 \text{ pu ml}^{-1}$ are excluded from the analyses (n = 15).

Taxon	Pu ml^{-1}		Biomass	
	Number	Proportion (%)	mg m^3	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	103	3.4	43	0.1
Zygothyceae	2,021	66.3	182	0.6
CHROMOPHYTA				
Chrysophyceae	100	3.3	31	0.1
Diatomophyceae	77	2.5	82	0.3
CYANOPHYTA				
Cyanophyceae	552	18.1	26,493	97.1
EUGLENOPHYTA				
Euglenophyceae	113	3.7	307	1.1
PYRRHOPHYTA				
Cryptophyceae	73	2.4	61	0.2
Dinophyceae	9	0.3	94	0.3
TOTAL	<u>3,048</u>	<u>100</u>	<u>27,293</u>	<u>99.8</u>

TABLE 4/38 Mean percentage contributions of the major* species to the mean total density and biomass in Lake Rotomanuka South, October 1983 to July 1984 (n = 15).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Volvocales		
<i>Chlamydomonas</i> sp. A	0.2	
Chlorococcales		
Chlorococcaceae		
<i>Ankistrodesmus bibraianus</i>	0.2	
<i>Monoraphidium komarkovae</i>	0.1	
<i>M. tortile</i>	0.6	
<i>Oocystis lacustris</i>	0.2	
Scenedesmaceae		
<i>Actinastrum hantzschii</i>	0.2	
<i>Coelastrum reticulatum</i>	0.4	
<i>Scenedesmus quadricauda</i>	0.3	
<i>Tetrastrum triangulare</i>	0.3	
Coccomyxaceae		
<i>Elakatothrix gelatinosa</i>	0.1	
Zygophyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	64.4	0.4
<i>C. gracile</i>	0.4	
<i>Cosmarium contractum</i>	0.2	
<i>Staurastrum</i> sp. A	0.7	
<i>Staurodesmus glaber</i> var. <i>limnophilus</i>	0.3	
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.7	
Dinobryaceae		
<i>Dinobryon cylindricum</i>	0.6	
Synuraceae		
<i>Mallomonas acaroides</i>	0.2	
<i>M. akrokomos</i>	0.1	
<i>Synura uvella</i>	1.6	
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira granulata</i>	0.2	0.1
<i>Cyclotella stelligera</i>	0.7	
Biddulphiales		
Chaetoceraceae		
<i>Acanthoceras zachariasii</i>	0.6	
Diatomales		
Diatomaceae		
<i>Tabellaria flocculosa</i>	0.4	

TABLE 4/38 continued

Nitzschiaceae		
<i>Nitzschia acicularis</i>	0.2	
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Aphanocapsa delicatissima</i>	0.1	
<i>Chroococcus dispersus</i> var. <i>minor</i>	0.3	
<i>Merismopedia minima</i>	0.4	
<i>Microcystis aeruginosa</i>	11.5	96.9
Nostocales		
Nostocaceae		
<i>Anabaena tenericaulis</i>	5.6	0.2
Oscillatoriaceae		
<i>Phormidium mucicola</i>	0.1	
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Trachelomonas planctonica</i>	3.5	1.1
<i>T. volvocina</i>		
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas erosa</i>	0.3	0.1
<i>C. ovata</i>	2.0	0.1
Dinophyceae		
Peridinales		
Peridiniaceae		
<i>Peridinium cinctum</i>	-	0.2
<i>P. pusillum</i> tab. <i>conjunctum</i>	0.2	0.1
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

while the net plankton (26 species [22%]), was comprised largely of diatoms (38%) (Table 4/39).

4.2.9 Lake Rotoroa

4.2.9.1 Species Composition

Table 4/40 lists the 70 genera, containing 146 species, found in Lake Rotoroa, and their mean density and biomass contributions. The Euchlorophyceae (42 species [29%]) was the major class, but the Diatomophyceae (28 species [19%]) and the Zygothryxaceae (24 species [16%]) were also important. The Cyanophyceae and Euglenophyceae contained fewer species (15 [10%] and 17 [12%], respectively), while numbers within the remaining classes were insignificant (Table 4/41).

4.2.9.2 Mean Distribution of Plankton Units and Biomass Amongst the Major Taxa (n = 22)

In terms of abundance, the community was dominated by the Euchlorophyceae (1105 pu ml⁻¹ [58%]), followed by the Chrysophyceae (417 pu ml⁻¹ [22%]). All other classes were relatively unimportant.

However, despite the comparatively low densities of the Dinophyceae (36 pu ml⁻¹ [5%]), it was the major taxon in terms of biomass (1435 mg m³ [78%]). Three classes, the Chrysophyceae (107 mg m³ [6%]), Euglenophyceae (103 mg m³ [6%]) and Euchlorophyceae (103 mg m³ [6%]), were of similar importance (Table 4/42).

4.2.9.3 Mean Percentage Contributions of the Major Phytoplankton Species to the Mean Total Density and Biomass (n = 22)

Of the 38 major species found in Lake Rotoroa, the euchlorophytes (10 species [26%]) and diatoms (7 species [18%]) were the most common, although all classes were represented. *Tetrastrum triangulare* (55%), *Dinobryon cylindricum* (17%) and *Cyclotella stelligera* (7%) were the most abundant phytoplankters but, because of their relatively small biovolumes, none was dominant in terms of biomass. Instead, *Peridinium* spp. (*P. cinctum* and *P. sp. A*) made up 69% of the mean total biomass. Other important species, in terms of mean biomass, were *Ceratium hirundinella* (8%) and *Trachelomonas* spp. (*T. playfairi* and *T. volvocina* [6%]) (Table 4/43).

TABLE 4/39 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Rotomanuka South, October 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net plankton	≥ 64	26	21.7
Nannoplankton	41 - 63	40	33.3
	21 - 40	36	30.0
	11 - 20	13	10.8
	6 - 10	4	3.3
Ultraplankton	≤ 5	1	0.8
Total		<u>120</u>	<u>99.9</u>

TABLE 4/40 Mean density and biomass contributions of the phytoplankton in Lake Rotoroa, July 1983 to July 1984; n = 22. (Biomass analyses omit species with a mean density < 1 pu ml⁻¹). Rankings are given when a mean contribution ≥ 1 pu ml⁻¹.

Taxon	Density		Biomass	
	pu ml ⁻¹	Rank	mg m ³	Rank
CHLOROPHYTA				
Euchlorophyceae				
Volvocales				
Volvocaceae				
<i>Pandorina morum</i>	0.1			
Chlorococcales				
Chlorococcaceae				
<i>Tetraedron minimum</i>	0.2			
Palmellaceae				
<i>Sphaerocystis schroeteri</i>	0.4			
Oocystaceae				
<i>Ankistrodesmus bibraianus</i>	1.3	37=	0.3	35
<i>A. gracilis</i>	3.3	19	4.4	18
<i>Kirchneriella obesa</i>	1.1	42	0.4	31=
<i>Monoraphidium contortum</i>	3.2	20=	0.05	40
<i>M. irregulare</i>	0.1			
<i>M. komarkovae</i>	0.1			
<i>M. minutum</i>	0.4			
<i>M. tortile</i>	0.4			
<i>Nephrocystium agardhianum</i>	1.3	37=	3.0	23
<i>N. limneticum</i>	0.1			
<i>Oocystis lacustris</i>	16.2	10	4.0	19
<i>O. solitaria</i>	0.5			
<i>Raphidocelis contorta</i>	0.3			
Micractiniaceae				
<i>Golenkinia radiata</i>	0.03			
<i>Micractinium pusillum</i>	0.03			
Dictyosphaeriaceae				
<i>Botryococcus braunii</i>	4.1	16	42.2	5
<i>Dictyosphaerium ehrenbergianum</i>	10.4	13	0.2	36=
<i>D. pulchellum</i>	0.1			
Scenedesmaceae				
<i>Coelastrum cambricum</i>	0.2			
<i>C. microporum</i>	9.7	14	5.9	13=
<i>C. reticulatum</i>	0.6			
<i>Crucigeniella rectangularis</i>	0.2			
<i>Scenedesmus acuminatus</i>	0.1			
<i>S. armatus</i>	0.2			
<i>S. denticulatus</i>	0.04			
<i>S. ecornis</i>	0.1			
<i>S. intermedius</i>	0.2			
<i>S. longispina</i>	0.2			
<i>S. magnus</i>	0.1			
<i>S. quadricauda</i>	2.1	39	0.4	31=
<i>S. sempervirens</i>	0.4			
<i>Tetrastrum heteracanthum</i>	0.2			
<i>T. staurogeniaforme</i>	0.2			

TABLE 4/40 continued

<i>T. triangulare</i>	1042.8	1	41.7	6
Hydrodictyaceae				
<i>Pediastrum angulosum</i>	0.1			
<i>P. boryanum</i>	0.2			
<i>P. duplex</i>	0.4			
<i>P. tetras</i>	0.8			
Coccomyxaceae				
<i>Elakatothrix gelatinosa</i>	2.9	22	0.1	38=
Ulothricophyceae				
Oedogoniales				
Oedogoniaceae				
<i>Oedogonium</i> sp.	0.2			
Zygophyceae				
Zygnematales				
Zygnemataceae				
<i>Mougeotia</i> sp. A	0.2			
<i>M.</i> sp. B	0.4			
<i>M.</i> sp. D	0.5			
<i>Spirogyra</i> sp. A	0.1			
<i>Zygnema</i> sp.	0.2			
Mesotaeniaceae				
<i>Gonatozygon kinahanii</i>	0.2			
Desmidiaceae				
<i>Closterium acutum</i> var. <i>variabile</i>	68.3	4	5.0	16=
<i>C. gracile</i>	1.6	31	0.8	29
<i>C. pronum</i>	0.1			
<i>Penium margaritaceum</i>	0.2			
<i>Pleurotaenium trabecula</i> var. <i>elongatum</i>	0.1			
<i>Staurastrum arcuatum</i>	0.04			
<i>S. brachiatum</i>	0.1			
<i>S. gracile</i> var. <i>bulbosum</i>	0.8			
<i>S. leptocladum</i> var. <i>insigne</i>	1.2	41	0.4	31=
<i>S. muticum</i> var. <i>victoriense</i>	1.4	35=	5.0	16=
<i>S. tohopekaligense</i> var. <i>minus</i>	0.1			
<i>S. subradians</i> forma ?	0.1			
<i>S.</i> sp. A	13.0	12	2.2	24
<i>S.</i> sp. B	0.4			
<i>S.</i> sp. C	0.04			
<i>Staurodesmus cuspidatus</i>	0.5			
<i>St. dejectus</i>	0.1			
<i>St. glaber</i> var. <i>limnophilus</i>	0.04			
CHROMOPHYTA				
Chrysophyceae				
Chromulinales				
Chrysococcaceae				
<i>Chrysococcus rufescens</i>	2.4	24=	0.9	28
Dinobryaceae				
<i>Dinobryon bavaricum</i>	63.4	5	19.3	9
<i>D. crenulatum</i>	0.3			
<i>D. cylindricum</i>	325.0	2	81.5	4
<i>D. divergens</i>	0.6			
<i>D. elegantissium</i> f. <i>gallica</i>	2.4	24=	0.4	31=
Synuraceae				
<i>Mallomonas akrokomos</i>	0.1			
<i>M. tonsurata</i>	0.1			
<i>Synura uvella</i>	22.3	9	5.1	15

TABLE 4/40 continued

Xanthophyceae				
Mischococcales				
Pleurichloridaceae				
<i>Goniochloris pseudogigas</i>	0.1			
Sciadiaceae				
<i>Centritractus belonophorus</i>]				
<i>C. africanus</i>	2.4	24=	10.9	12
Diatomophyceae				
Coscinodiscales				
Coscinodiscaceae				
<i>Aulacosira distans</i>	2.2	27=	0.7	30
<i>A. granulata</i>	0.2			
<i>A. g. var. angustissima</i>	1.5	32=	1.7	25
<i>Cyclotella stelligera</i>	123.7	3	30.9	7
<i>Melosira varians</i>	0.2			
Biddulphiales				
Chaetoceraceae				
<i>Acanthoceras zachariasii</i>	0.7			
Diatomales				
Diatomaceae				
<i>Asterionella formosa</i>	1.4	35=	0.2	36=
<i>Fragilaria brevistriata</i>	1.7	30	3.6	22
<i>F. ulna</i>	0.2			
<i>F. u. var. acus</i>	2.6	23	11.5	11
<i>Tabellaria fenestrata</i>	0.04			
<i>T. flocculosa</i>	3.4	18	5.9	13=
Eunotiales				
Eunotiaceae				
<i>Eunotia flexuosa</i>	0.07			
<i>E. pectinalis</i>	1.5	32=	1.3	26
<i>E. p. var. undulata</i>	0.07			
Achnanthales				
Achnanthaceae				
<i>Achnanthes linearis</i>	2.2	27=	0.1	38=
Naviculales				
Naviculaceae				
<i>Anomoeoneis serians</i>	0.1			
<i>Cymbella minuta</i>	0.2			
<i>Frustulia rhomboides var. saxonica</i>	0.1			
<i>Gomphonema acuminatum</i>	0.1			
<i>Navicula bacillum</i>	0.3			
<i>N. radiosa</i>	0.2			
<i>N. subtilissima</i>	0.3			
<i>Pinnularia gentilis</i>	0.1			
<i>P. gibba</i>	0.3			
<i>Stauroneis anceps</i>	0.1			
<i>S. phoenicenteron</i>	0.04			
Epithemiaceae				
<i>Rhopalodia gibba</i>	0.3			
Nitzschiaceae				
<i>Hantzschia amphioxys</i>	0.2			
<i>Nitzschia acicularis</i>	3.5	17	1.0	27
Surirellaceae				
<i>Surirella linearis</i>	0.07			
CYANOPHYTA				
Cyanophyceae				

TABLE 4/40 continued

Chroococcales				
Chroococcaceae				
<i>Aphanocapsa delicatissima</i>	0.1			
<i>A. elachista</i> var. <i>conferta</i>	0.2			
<i>Chroococcus dispersus</i>	4.2	15	0.05	40=
<i>C. limneticus</i>	15.6	11	3.7	21
<i>C. minutus</i>	1.5	32=	0.02	42
<i>C. turgidus</i>	0.3			
<i>Merismopedia minima</i>	0.9			
<i>M. tenuissima</i>	0.4			
<i>Microcystis aeruginosa</i>	1.3	37=	19.8	8
<i>M. pulverea</i>	0.4			
Nostocales				
Nostocaceae				
<i>Anabaena minutissima</i> ?	0.4			
Oscillatoriaceae				
<i>Lyngbya limnetica</i>	0.5			
<i>Oscillatoria limosa</i>	0.04			
<i>O. tenuis</i>	0.04			
<i>Spirulina laxa</i>	0.4			
EUGLENOPHYTA				
Euglenophyceae				
Euglenales				
Euglenaceae				
<i>Euglena acus</i>	0.1			
<i>E. oxyuris</i>	0.2			
<i>E. proxima</i>	0.04			
<i>Lepocinclis marssonii</i>	0.04			
<i>Phacus glaber</i>	0.1			
<i>P. helicoides</i>	0.1			
<i>P. inflexus</i>	0.04			
<i>P. pleuronectes</i>	0.4			
<i>P. suecicus</i>	0.1			
<i>Trachelomonas bacillifera</i> var. <i>minima</i>	0.07			
<i>T. cylindrica</i>	0.07			
<i>T. hexangulata</i>	0.1			
<i>T. hispida</i>	0.04			
<i>T. h.</i> var. <i>coronata</i>	0.04			
<i>T. playfairi</i> (included in <i>T. volvocina</i>)				
<i>T. pulcherrima</i> var. <i>ovalis</i>	0.2			
<i>T. sydneyensis</i>	0.1			
<i>T. volvocina</i>	28.7	8	103.1	3
PYRRHOPHYTA				
Cryptophyceae				
Cryptomonadales				
Cryptomonadaceae				
<i>Cryptomonas erosa</i>	1.3	37=	3.9	20
<i>C. marssonii</i>				
<i>C. ovata</i>	56.6	6	17.3	10
Dinophyceae				
Peridinales				
Peridiniaceae				
<i>Peridinium cinctum</i>	32.6	7	1279.5	1
<i>P. inconspicuum</i>	0.4			

TABLE 4/40 continued

<i>P. sp. A.</i> (included in <i>P. cinctum</i>)				
Ceratiaceae				
<i>Ceratium hirundinella</i>	3.2	20=	155.2	2
<i>C. h. fa. furcoides</i>	0.1			

TABLE 4/41 Number and percentage of phytoplankton species within each of the major taxonomic groups in Lake Rotoroa, July 1983 to July 1984.

Taxon	Species	
	No.	%
CHLOROPHYTA		
Euchlorophyceae	42	28.6
Ulothricophyceae	1	0.6
Zygophyceae	24	16.4
CHROMOPHYTA		
Chrysophyceae	9	6.2
Diatomophyceae	28	19.2
Xanthophyceae	3	2.0
CYANOPHYTA		
Cyanophyceae	15	10.3
EUGLENOPHYTA		
Euglenophyceae	17	11.6
PYRRHOPHYTA		
Cryptophyceae	3	2.0
Dinophyceae	4	2.7
TOTAL	<u>146</u>	<u>99.8</u>

TABLE 4/42 Mean distribution of plankton units and biomass amongst the major taxa in Lake Rotoroa, July 1983 to July 1984; mean values < 1 pu ml⁻¹ are excluded from the analyses (n = 22).

Taxon	Pu ml ⁻¹		Biomass	
	Number	Proportion (%)	mg m ³	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	1,105	57.7	103	5.6
Zygophyceae	90	4.7	13	0.7
CHROMOPHYTA				
Chrysophyceae	417	21.8	107	5.8
Diatomophyceae	148	7.7	26	1.4
Xanthophyceae	2	0.1	11	0.6
CYANOPHYTA				
Cyanophyceae	26	1.3	24	1.3
EUGLENOPHYTA				
Euglenophyceae	30	1.5	103	5.6
PYRRHOPHYTA				
Cryptophyceae	58	3.0	21	1.1
Dinophyceae	36	1.9	1,435	77.9
TOTAL	<u>1,912</u>	<u>99.7</u>	<u>1,843</u>	<u>100.0</u>

TABLE 4/43 Mean percentage contributions of the major* species to the mean total density and biomass in Lake Rotoroa, July 1983 to July 1984 (n = 22).

Taxon	Density (%)	Biomass (%)
CHLOROPHYTA		
Euchlorophyceae		
Chlorococcales		
Oocystaceae		
<i>Ankistrodesmus gracilis</i>	-	0.2
<i>Monoraphidium contortum</i>	0.1	-
<i>Nephrocytium agardhianum</i>	-	0.2
<i>Oocystis lacustris</i>	0.8	0.2
Dictyosphaeriaceae		
<i>Botryococcus braunii</i>	0.2	2.3
<i>Dictyosphaerium ehrenbergianum</i>	0.5	-
Scenedesmaceae		
<i>Coelastrum microporum</i>	0.5	0.3
<i>Scenedesmus quadricauda</i>	0.1	-
<i>Tetrastrum triangulare</i>	54.5	2.3
Coccomyxaceae		
<i>Elakatothrix gelatinosa</i>	0.1	-
Zygophyceae		
Zygnematales		
Desmidiaceae		
<i>Closterium acutum</i> var. <i>variabile</i>	3.6	0.3
<i>Staurostrum muticum</i> var. <i>victoriense</i>	-	0.3
<i>S. sp. A</i>	0.7	0.1
CHROMOPHYTA		
Chrysophyceae		
Chromulinales		
Chrysococcaceae		
<i>Chrysococcus rufescens</i>	0.1	-
Dinobryaceae		
<i>Dinobryon bavaricum</i>	3.3	1.0
<i>D. cylindricum</i>	17.0	4.4
<i>D. elegantissimum</i> fa. <i>gallica</i>	0.1	-
Synuraceae		
<i>Synura uvella</i>	1.2	0.2
Xanthophyceae		
Mischococcales		
Sciadiaceae		
<i>Centritractus africanus</i>]		
<i>C. belonophorus</i>]	0.1	0.6
Diatomophyceae		
Coscinodiscales		
Coscinodiscaceae		
<i>Aulacosira distans</i>	0.1	-
<i>Cyclotella stelligera</i>	6.5	1.5
Diatomales		
Diatomaceae		
<i>Fragilaria brevistriata</i>	-	0.2

TABLE 4/43 continued

<i>F. ulna</i> var. <i>acus</i>	0.1	0.6
<i>Tabellaria flocculosa</i>	0.2	0.3
Achnanthes		
Achnanthes		
<i>Achnanthes linearis</i>	0.1	-
Naviculales		
Nitzschiaceae		
<i>Nitzschia acicularis</i>	0.2	-
CYANOPHYTA		
Cyanophyceae		
Chroococcales		
Chroococcaceae		
<i>Chroococcus dispersus</i>	0.2	-
<i>C. limneticus</i>	0.8	0.2
<i>Microcystis aeruginosa</i>	-	1.1
EUGLENOPHYTA		
Euglenophyceae		
Euglenales		
Euglenaceae		
<i>Trachelomonas playfairi</i>	1.5	5.6
<i>T. volvocina</i>		
PYRRHOPHYTA		
Cryptophyceae		
Cryptomonadales		
Cryptomonadaceae		
<i>Cryptomonas erosa</i>	-	0.2
<i>C. marssonii</i>	2.9	0.9
<i>C. ovata</i>		
Dinophyceae		
Peridinales		
Peridiniaceae		
<i>Peridinium cinctum</i>	1.7	69.4
<i>P. sp. A</i>		
Ceratiaceae		
<i>Ceratium hirundinella</i>	0.2	8.4
* A major species is defined as one with a mean contribution ≥ 0.1% of either the mean total density or biomass		

4.2.9.4 Size Distribution

Large phytoplankters dominated the flora, with the three largest fractions containing relatively similar numbers of species, and together totalling 129 (85%). The remaining fractions contained 22 species, and included one member of the ultraplankton (Table 4/44).

TABLE 4/44 Number and percentage of phytoplankton species (plus varieties) within the various size fractions in Lake Rotoroa, July 1983 to July 1984.

	Size Fraction GALD (μm)	Number	Proportion (%)
Net Plankton	≥ 64	41	27.1
Nannoplankton	41 - 63	47	31.1
	21 - 40	41	27.1
	11 - 20	18	11.9
	6 - 10	3	2.0
Ultraplankton	≤ 5	1	0.6
Total		<u>151</u>	<u>99.8</u>

CHAPTER FIVE

COMPARATIVE ANALYSES OF THE STRUCTURE OF THE NINE PHYTOPLANKTON COMMUNITIES

5.1 COMPOSITION

5.1.1 α Diversity and Distribution of Taxa Within the Major Classes

402 species (including varieties), representing 135 genera, were found in the nine phytoplankton communities (Appendix VII). Of these, 59 species are new records for New Zealand (Appendix VIII). The new cyanophyte records are described in Etheredge & Pridmore (1984).

The most important classes were the Euchlorophyceae (92 species [23%]) and the Diatomophyceae (79 species [20%]), with the Zygothryxaceae, Euglenophyceae and Cyanophyceae containing 74 (18%), 63 (16%) and 45 (11%) species, respectively. Other classes were not represented by substantial numbers (Table 5/0).

The relative abundance of species (including varieties), within the major taxonomic groups differed markedly amongst the study lakes (Table 5/1). Generally, Lakes Rotomanuka North or Rotokauri contained the highest relative numbers; for example, 81% of chrysophytes, 64% of euchlorophytes and 53% of dinoflagellates occurred in Lake Rotomanuka North, and the highest relative numbers of both zygothryxaceae, cyanophytes and euglenophytes (62, 60 and 52%, respectively), were recorded in Lake Rotokauri. However, Lakes Ngaroto and Mangakaware had the highest relative number of diatom species (53 and 48%, respectively). In comparison, the flora of Lake Kainui appeared depauperate, and relatively few diatoms (23%), chrysophytes (19%), euglenophytes (13%) and xanthophytes (10%) were found. Group I lakes (Maratoto and Mangahia) also contained relatively few numbers of species in some classes. At the class-level, only the Cryptophyceae showed marked similarity between the lakes, all three species occurring in eight of the nine lakes. The habitat preferences of the major phytoplankton groups in relation to the physico-chemical regimes of these particular lakes are discussed in Chapter 6.4.

The study lakes also differed markedly in terms of total numbers of genera and species. The sequence for the total number of genera (L. Rotokauri > L. Rotomanuka North > L. Mangakaware > L. Ngaroto > L. Rotoroa > L. Mangahia > L. Maratoto > L. Rotomanuka South > L. Kainui) closely paralleled that of total species (including varieties)

TABLE 5/0 Total number and percentage of phytoplankton genera and species (plus varieties) within each of the major taxonomic groups present in the nine study lakes, July 1983 to July 1984.

Taxon	Genera		Species (plus varieties)	
	Number	Proportion (%)	Number	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	40	29.6	92	22.9
Ulothricophyceae	3	2.2	4	1.0
Zygophyceae	19	14.1	74	18.4
CHROMOPHYTA				
Chrysophyceae	8	5.9	16	4.0
Diatomophyceae	30	22.2	79	19.6
Xanthophyceae	5	3.7	10	2.5
CYANOPHYTA				
Cyanophyceae	14	10.4	45	11.2
EUGLENOPHYTA				
Euglenophyceae	9	6.7	63	15.7
PYRRHOPHYTA				
Cryptophyceae	1	0.7	3	0.7
Dinophyceae	5	3.7	15	3.7
RAPHIDOPHYTA				
Raphidophyceae	1	0.7	1	0.2
TOTAL	<u>135</u>	<u>99.9</u>	<u>402</u>	<u>99.9</u>

TABLE 5/1 Relative abundance (%) of species (including varieties) from all study lakes, within each of the major taxonomic groups, July 1983 to July 1984.

Taxon	Total Number Present in all Lakes	Relative abundance (%)								
		KA*	MH	MK	MA	NG	RK	RMN	RMS	RR
CHLOROPHYTA										
Euchlorophyceae	92	35.9	40.2	50.0	28.3	55.4	52.2	64.1	38.0	45.6
Ulothricophyceae	4	25.0	50.0	75.0	25.0	25.0	50.0	25.0	0.0	25.0
Zygophyceae	74	25.7	21.7	31.1	23.0	21.6	62.2	33.8	23.0	32.4
CHROMOPHYTA										
Chrysophyceae	16	18.7	50.0	37.5	31.2	43.7	37.5	81.2	31.2	56.2
Diatomophyceae	79	22.8	26.6	48.1	45.6	53.2	36.7	38.0	32.9	35.4
Xanthophyceae	10	10.0	30.0	40.0	30.0	20.0	10.0	20.0	10.0	30.0
CYANOPHYTA										
Cyanophyceae	45	37.8	26.7	33.3	28.9	53.3	60.0	51.1	33.3	33.3
EUGLENOPHYTA										
Euglenophyceae	63	12.7	30.1	30.1	19.0	25.4	52.4	42.8	22.2	27.0

PYRRHOPHYTA

Cryptophyceae	3	100	100	100	100	100	100	100	66.7	100
Dinophyceae	15	26.7	26.7	46.7	40.0	26.7	46.7	53.3	20.0	26.7

RAPHIDOPHYTA

Raphidophyceae	1	100	0	100	100	0	100	100	0	0
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TOTAL 402

* Key: KA = Lake Kainui; MH = Lake Mangahia; MK = Lake Mangakaware; MA = Lake Maratoto;
 NG = Lake Ngaroto; RK = Lake Rotokauri; RMN & RMS = Lake Rotomanuka North and South;
 RR = Lake Rotoroa

diversity (L. Rotokauri > L. Rotomanuka North > L. Ngaroto, L. Mangakaware > L. Rotoroa > L. Maratoto > L. Mangahia, > L. Rotomanuka South > L. Kainui) (Chapter 4; Fig. 5/0).

There was no significant correlation between total number of either species or genera and median surface pH. However, when the Group IV, yellow-brown lakes (Ngaroto and Rotomanuka South) were excluded (because of the influence of *Microcystis aeruginosa* blooms on pH [Chapter 3.4]), the mean number of species per sample per lake and median surface pH were significantly correlated ($r = 0.809$; $p < 0.05$; $n = 7$).

Lakes which developed the most stable summer stratification also had high α diversity (Rotokauri, 210 species including varieties; Rotomanuka North, 203 species including varieties), in marked contrast to the low species numbers present in Lakes Kainui, Mangahia and Maratoto (113, 130 and 128, respectively).

Median surface pH was also significantly correlated with the mean density of euchlorophytes ($r = -0.791$; $p < 0.05$; $n = 7$), and the mean relative proportion of cyanophytes ($r = 0.723$; $p < 0.05$; $n = 7$). Also, if analyses were limited to the brown and brown-green coloured lakes, both the mean number of species per sample and α diversity were significantly correlated with Secchi disc transparency ($r = 0.771$; $p < 0.05$; $n = 7$, and $r = 0.830$; $p < 0.05$; $n = 7$, respectively).

5.1.2 Mean Number of Species per Genus

Within the major taxa, the mean number of species per genus ranged from one (Raphidophyceae) to seven (Euglenophyceae) (Table 5/2). The two largest euglenophyte genera, *Trachelomonas* and *Phacus*, were represented by 28 and 19 species, respectively. Relatively high numbers were also found in the Zygothryxaceae (3.9) and the Cyanophyceae (3.2). The largest genera from these two classes were *Staurastrum* (17 species) and *Oscillatoria* (13 species), respectively. Despite high species representation within the Euchlorophyceae and the Diatomophyceae, mean numbers of species per genus were relatively low. However, both were represented by one relatively large genus (*Scenedesmus* [15 species] and *Eunotia* [13 species], respectively [Table 5/2]). Sixty-six genera were represented by one species. The distribution of these genera amongst the classes was uneven, but they were most common in the Dinophyceae (3 genera [60%]), Euchlorophyceae

Fig. 5/0 Numbers of species (including varieties) and genera found in each of the nine study lakes, July 1983 to July 1984.

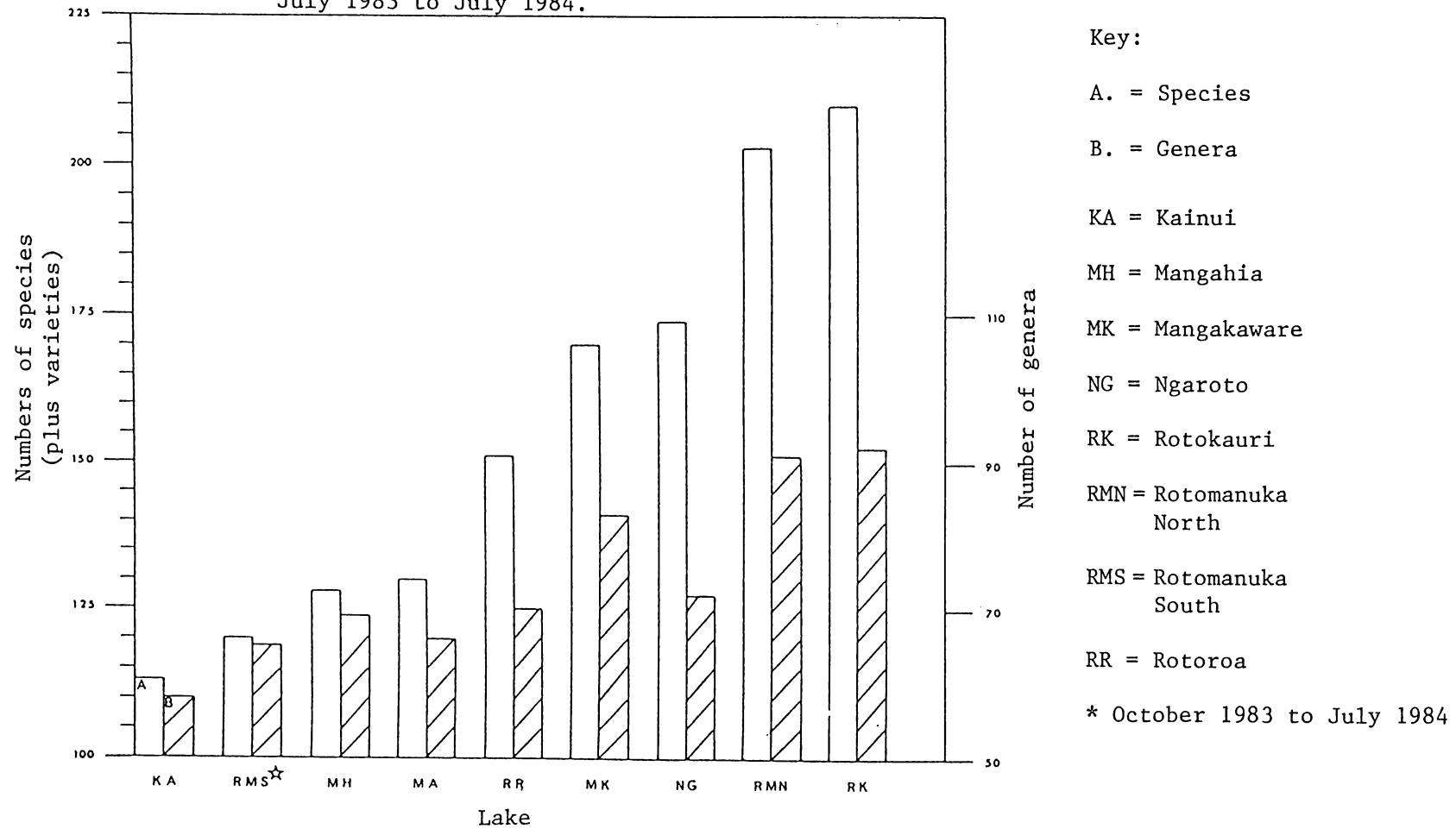


TABLE 5/2 Mean number of species (plus varieties) per genus (and range), together with the genera represented by ≥ 5 species within each of the major taxonomic groups present in the nine study lakes, July 1983 to July 1984; numbers of genera represented by only one species are given after the range.

Taxon	Mean Number of Species per Genus	Range & Number of Genera Represented by only 1 Species	Genera Represented by ≥ 5 Species
CHLOROPHYTA			
Euchlorophyceae	2.3	1 - 15; 23	<i>Scenedesmus</i> (15 spp.) <i>Ankistrodesmus</i> (7 spp.) <i>Monoraphidium</i> (6 spp.) <i>Coelastrum</i> (5 spp.)
Ulothricophyceae	1.3	1 - 2; 2	-
Zygothryxaceae	3.9	1 - 17; 8	<i>Staurastrum</i> (17 spp.) <i>Closterium</i> (13 spp.) <i>Cosmarium</i> (9 spp.) <i>Staurodesmus</i> (9 spp.)
CHROMOPHYTA			
Chrysophyceae	2.0	1 - 6; 5	<i>Dinobryon</i> (6 spp.)
Diatomophyceae	2.6	1 - 13; 14	<i>Eunotia</i> (13 spp.) <i>Pinnularia</i> (12 spp.) <i>Fragilaria</i> (5 spp.) <i>Navicula</i> (5 spp.)
Xanthophyceae	2.0	1 - 3; 1	-
CYANOPHYTA			
Cyanophyceae	3.2	1 - 13; 6	<i>Oscillatoria</i> (13 spp.) <i>Anabaena</i> (6 spp.) <i>Chroococcus</i> (6 spp.) <i>Merismopedia</i> (5 spp.)
EUGLENOPHYTA			
Euglenophyceae	7.0	1 - 28; 4	<i>Trachelomonas</i> (28 spp.) <i>Phacus</i> (19 spp.) <i>Euglena</i> (8 spp.)
PYRRHOPHYTA			
Cryptophyceae	3.0	-	-
Dinophyceae	3.0	1 - 10; 3	<i>Peridinium</i> (10 spp.)

TABLE 5/2 continued

RAPHIDOPHYTA			
Raphidophyceae	1.0	-	-
GRAND MEAN	2.8		

(23 genera [57%]) and Diatomophyceae (14 genera [47%]).

5.1.3 Compositional Overlap

There was a highly significant negative correlation ($r = -0.898$; $p < 0.01$; $n = 9$) between total number of genera per lake and percentage number of genera shared; the latter, however, was not significantly correlated with median surface pH. Lakes Rotomanuka South and Kainui had the highest mean generic overlaps (49 [76%]) and (44 [76%]), respectively; and Lake Rotokauri, the lowest (56 [57%]) (Table 5/3). The grand mean generic overlap was 50 species ($69 \pm 7\%$) (Table 5/7).

Because 46% of the total number of genera recorded were chlorophytes (Table 5/0), their compositional overlap was also calculated (Table 5/4). The mean chlorophyte overlap was remarkably similar to total generic overlap, ranging from 22 (51%) (Lake Rotokauri) to 18 (78%) (Lake Rotomanuka South). The grand mean chlorophyte overlap was 20 species ($67 \pm 10\%$) (Table 5/7). Particularly high overlap occurred in certain instances; for example, all chlorophyte genera (25) present in Lake Mangahia were also recorded in Lake Rotokauri, and 22 (96%) of those found in Lake Rotomanuka South also occurred in Lake Mangakaware. However, there was no significant correlation between mean chlorophyte generic overlap and median surface pH ($p = > 0.05$).

At the specific level, compositional overlap varied considerably (Table 5/5). Differences between Lakes Rotomanuka North and South were particularly marked because, although they shared 92 species, this translates into an overlap of 78% (the highest of the series) for Rotomanuka South, compared to 45% for Rotomanuka North. Compositional overlap at the intra-group level, however, was quite similar in some instances (e.g., Lakes Maratoto and Mangahia [Group I] shared 51 and 52% of their species, respectively), although it was seldom high; the mean overlap per study lake ranged from 47 (Rotokauri and Rotomanuka North) to 67% (Rotomanuka South), while the grand mean specific overlap was $56 \pm 7\%$ (Table 5/7).

There was a significant negative correlation between total number of species (including varieties) per lake and the percentage number of species shared, ($r = -0.901$; $p < 0.001$; $n = 7$). Although there was no significant correlation between the percentage number of species

TABLE 5/3 Generic compositional overlap in the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing number of genera.

Lake:	RK	RMN	MK	NG	RR	MH	MA	RMS	KA
RK* (92)	-	63	62	58	55	53	54	56	46
RMN (91)		-	58	59	53	48	45	54	47
MK (83)			-	57	57	47	53	54	49
NG (72)				-	55	47	52	55	43
RR (70)					-	39	47	47	44
MH (69)						-	43	42	40
MA (66)							-	48	43
RMS† (65)								-	39
KA (58)									-

* Key: RK = L. Rotokauri ; RMN = L. Rotomanuka North;
MK = L. Mangakaware; NG = L. Ngaroto;
RR = L. Rotoroa; MH = L. Manghia; MA = L. Maratoto;
RMS = L. Rotomanuka South; KA = L. Kainui.

† October 1983 to July 1984

TABLE 5/4 Chlorophyte generic compositional overlap in the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing number of genera.

Lake:	RK	RMN	MK	RR	NG	MH	KA	MA	RMS
RK* (43)	-	25	27	21	22	25	20	18	19
RMN (37)		-	25	21	25	21	19	16	19
MK (36)			-	24	22	22	23	20	22
RR (29)				-	21	17	20	16	17
NG (27)					-	20	17	17	19
MH (25)						-	17	17	15
KA (25)							-	18	16
MA (25)								-	16
RMS [†] (23)									-

* Key: RK = L. Rotokauri ; RMN = L. Rotomanuka North;
 MK = L. Mangakaware; NG = L. Ngaroto;
 RR = L. Rotoroa; MH = L. Mangahia; MA = L. Maratoto;
 RMS = L. Rotomanuka South; KA = L. Kainui.

[†] October 1983 to July 1984

TABLE 5/5 Specific (plus varietal) compositional overlap in the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing species number.

Lake:	RK	RMN	NG	MK	RR	MA	MH	RMS	KA
RK* (210)	-	122	107	109	102	88	89	90	80
RMN (203)		-	105	105	102	75	76	92	79
NG (174)			-	99	93	84	84	91	76
MK (170)				-	95	87	82	89	74
RR (151)					-	75	68	79	70
MA (130)						-	67	69	61
MH (128)							-	68	63
RMS† (120)								-	62
KA (113)									-

* Key: RK = L. Rotokauri ; RMN = L. Rotomanuka North;
MK = L. Mangakaware; NG = L. Ngaroto;
RR = L. Rotoroa; MH = L. Mangahia; MA = L. Maratoto;
RMS = L. Rotomanuka South; KA = L. Kainui.

† October 1983 to July 1984

shared and median surface pH, it is noteworthy that Lake Rotomanuka North (Group III) shared only 75 species (36%) with Lake Maratoto (Group I), the lowest overlap scored in the series.

The overlap of chlorophyte species (Table 5/6) was similar to total specific overlap and, once more, the lowest (43%) and highest (69%) overlaps were recorded in Lakes Rotokauri and Rotomanuka South, respectively. The grand mean chlorophyte overlap for the nine lakes was $57.1 \pm 7.8\%$ (Table 5/7). Once more, there were compositional differences between Lakes Rotomanuka North and South. They shared 44 chlorophytes (Table 5/6), equivalent to an 86% overlap for Lake Rotomanuka South and 51% for Lake Rotomanuka North.

In general, compositional overlap of the ten most abundant species (including varieties) in each lake, was also low (Table 5/8) (grand mean for the nine lakes $29 \pm 13\%$). Lakes Maratoto and Mangahia (Group I) both shared only one of their ten most abundant species (*Trachelomonas volvocina*) with Lake Rotomanuka North (Group III). The highest overlap (70%) occurred between two Group III lakes (Rotomanuka North and Rotoroa), and included no representatives of either the Euchlorophyceae or the Cyanophyceae. The seven dominant taxa these lakes shared were *Closterium acutum* var. *variabile*, *Cryptomonas* spp., *Cyclotella stelligera*, *Dinobryon cylindricum*, *Peridinium cinctum*, *Synura uvella* and *Trachelomonas volvocina*.

However, high intra-group overlap such as that between the two Group III lakes, was the exception; for example, both Lakes Maratoto and Mangahia (Group I), and Lakes Ngaroto and Rotomanuka South (Group IV), shared only four of their ten most abundant species, while Lakes Rotokauri and Rotomanuka North (Group III) shared two. In addition, overlap did not increase markedly when a further ten species (i.e. the twenty most abundant species) were included in the analysis (Table 5/9). The grand mean percentage overlap increased to $32.5 \pm 11.2\%$ i.e. a minimum increase (4%). No pattern was discernible, and both intra- and inter-group variation was considerable. Again, Lakes Rotomanuka North and Rotoroa (Group III) shared the highest number of important species (55%), but Lake Rotokauri, the third Group III lake shared only 15% with the other two.

Only 24 species (including varieties) (6%) were found in all nine lakes (Table 5/10), thus providing further evidence of their overall compositional dissimilarity. Of these, the majority were

TABLE 5/6 Chlorophyte species (plus varietal) compositional overlap in the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing species number.

Lake:	RK	RMN	MK	NG	RR	KA	MH	RMS	MA
RK* (97)	-	50	49	46	45	39	39	37	30
RMN (87)		-	46	49	47	36	30	44	28
MK (72)			-	45	44	36	34	41	33
NG (69)				-	44	35	36	41	30
RR (67)					-	37	30	37	27
KA (55)						-	28	29	26
MH (54)							-	26	23
RMS [†] (51)								-	26
MA (44)									-

* Key: RK = L. Rotokauri ; RMN = L. Rotomanuka North;
MK = L. Mangakaware; NG = L. Ngaroto;
RR = L. Rotoroa; MH = L. Mangahia; MA = L. Maratoto;
RMS = L. Rotomanuka South; KA = L. Kainui.

[†] October 1983 to July 1984

TABLE 5/7 Mean number and percentage, ± 1 SD, of total genera, chlorophyte genera, total species and chlorophyte species shared by each of the nine study lakes, July 1983 to July 1984 (n = 8). The lakes are listed in decreasing order of species abundance.

Lake	Mean No. of Genera		Mean No. of Chlorophyte Genera		Mean No. of Species		Mean No. of Chlorophyte Species	
	Shared	Shared (%)	Shared	Shared (%)	Shared	Shared (%)	Shared	Shared (%)
Rotokauri	55.9 \pm 5.4	57.0 \pm 13.2	22.1 \pm 3.2	51.4 \pm 7.5	105.9 \pm 28.1	46.8 \pm 6.6	41.6 \pm 7.3	43.1 \pm 7.0
Rotomanuka N.	53.4 \pm 6.4	58.6 \pm 7.0	21.6 \pm 3.2	57.7 \pm 9.2	94.5 \pm 16.9	46.5 \pm 8.3	41.2 \pm 8.7	47.4 \pm 10.0
Ngaroto	53.2 \pm 5.6	73.0 \pm 7.8	21.6 \pm 3.2	75.5 \pm 10.1	99.9 \pm 28.6	53.4 \pm 6.8	40.5 \pm 6.7	59.1 \pm 9.4
Mangakaware	54.6 \pm 4.9	65.8 \pm 6.0	23.1 \pm 2.2	55.6 \pm 6.0	92.5 \pm 11.8	54.4 \pm 6.9	41.1 \pm 6.1	56.9 \pm 8.3
Rotoroa	49.6 \pm 6.3	74.4 \pm 6.8	19.6 \pm 2.7	67.7 \pm 9.4	81.5 \pm 16.1	56.6 \pm 9.3	39.0 \pm 7.5	57.8 \pm 11.4
Maratoto	48.1 \pm 4.4	72.9 \pm 6.7	17.2 \pm 1.4	69.0 \pm 5.5	75.7 \pm 9.9	58.3 \pm 7.6	27.6 \pm 2.9	63.4 \pm 7.0
Mangahia	44.9 \pm 4.7	65.2 \pm 6.6	19.2 \pm 3.3	77.0 \pm 13.3	74.6 \pm 9.5	58.3 \pm 7.4	30.7 \pm 5.3	56.9 \pm 9.8
Rotomanuka S.*	49.4 \pm 6.4	75.9 \pm 9.9	18.1 \pm 2.5	77.7 \pm 9.9	78.1 \pm 11.3	66.7 \pm 10.1	35.6 \pm 6.5	68.9 \pm 14.0
Kainui	43.9 \pm 3.4	75.8 \pm 5.7	30.6 \pm 7.1	75.0 \pm 9.0	70.6 \pm 7.8	62.5 \pm 6.9	33.2 \pm 4.8	60.4 \pm 8.8
Grand Mean	50.3 \pm 4.2	68.8 \pm 7.4	20.1 \pm 2.0	67.4 \pm 10.1	85.9 \pm 12.5	55.9 \pm 6.6	36.7 \pm 5.2	57.1 \pm 7.8

* October 1983 to July 1984

TABLE 5/8 Percentage composition overlap of the ten most abundant species (plus varieties) in each of the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing species number.

Lake:	RK	RMN	NG	MK	RR	MA	MH	RMS	KA
RK*	100	20	20	30	20	10	10	20	30
RMN		100	20	20	70	40	30	50	20
NG			100	40	20	20	40	40	20
MK				100	30	30	30	20	10
RR					100	20	30	50	20
MA						100	40	40	30
MH							100	40	30
RMS [†]								100	20
KA									100

* Key: RK = L. Rotokauri; RMN = L. Rotomanuka North;
MK = L. Mangakaware; NG = L. Ngaroto;
RR = L. Rotoroa; MH = L. Mangahia; MA = L. Maratoto;
RMS = L. Rotomanuka South; KA = L. Kainui.

[†] October 1983 to July 1984

TABLE 5/9 Percentage composition overlap of the twenty most abundant species (plus varieties) in each of the nine study lakes, July 1983 to July 1984; lakes are arranged in order of decreasing species number.

Lake:	RK	RMN	NG	MK	RR	MA	MH	RMS	KA
RK*	100	15	15	30	15	15	15	15	25
RMN		100	30	35	55	40	40	45	25
NG			100	35	30	30	50	40	30
MK				100	40	20	35	40	15
RR					100	40	35	40	30
MA						100	35	40	40
MH							100	50	40
RMS†								100	40
KA									100

* Key: RK = L. Rotokauri; RMN = L. Rotomanuka North;
 NG = L. Ngaroto; MK = L. Mangakaware;
 RR = L. Rotoroa; MA = L. Maratoto;
 MH = L. Mangahia; RMS = L. Rotomanuka South;
 KA = L. Kainui.

† October 1983 to July 1984

TABLE 5/10 List of twenty-four phytoplankton species found in all nine study lakes on at least one occasion, July 1983 to July 1984.

Taxon
CHLOROPHYTA
Euchlorophyceae
<i>Botryococcus braunii</i>
<i>Coelastrum microporum</i>
<i>C. reticulatum</i>
<i>Monoraphidium contortum</i>
<i>M. tortile</i>
<i>Oocystis lacustris</i>
<i>Pediastrum tetras</i>
<i>Scenedesmus quadricauda</i>
Zygoephyceae
<i>Closterium acutum</i> var. <i>variabile</i>
<i>C. gracile</i>
<i>Mougeotia</i> sp. B
<i>Staurodesmus dejectus</i>
CHROMOPHYTA
Chrysophyceae
<i>Dinobryon cylindricum</i>
Diatomophyceae
<i>Aulacosira distans</i>
<i>A. granulata</i>
<i>A. g.</i> var. <i>angustissima</i>
<i>Cyclotella stelligera</i>
<i>Eunotia pectinalis</i>
<i>Tabellaria flocculosa</i>
EUGLENOPHYTA
Euglenophyceae
<i>Euglena oxyuris</i>
<i>Trachelomonas volvocina</i>
PYRRHOPHYTA
Cryptophyceae
<i>Cryptomonas erosa</i>
<i>C. ovata</i>
Dinophyceae
<i>Peridinium cinctum</i>

euchlorophytes (33%) and diatoms (25%); the Ulothricophyceae, Xanthophyceae, Cyanophyceae and Raphidophyceae were not represented. An additional 24 species (including varieties) were recorded in eight of the nine study lakes (Table 5/11). Again, most of these taxa were euchlorophytes and diatoms (38 and 25%, respectively), and neither the Xanthophyceae nor the Raphidophyceae was present in this category. However, this group contained three cyanophytes (*Anabaena minutissima?*, *Lyngbya limnetica* and *Microcystis aeruginosa*). Conversely, 130 taxa (32%) were found in only one study lake (Table 5/12). These 'rare' taxa were irregularly distributed amongst the classes; the majority were zygothales (26%), but euchlorophytes and euglenophytes were also well represented (21 and 20%, respectively) (Table 5/13). At the generic level, the highest number of these 'rare' taxa belonged to *Trachelomonas* (12 species), and *Euglena* and *Cosmarium* (7 species each). 'Rare' taxa were not evenly distributed amongst the nine lakes. The neutral, brown-green coloured lakes (Group III), contained the highest number (e.g., 28 [22%] were present in both Lakes Rotokauri and Rotomanuka North and 23 [18%] in Lake Rotoroa), and numbers generally declined towards either end of the pH scale (Table 5/14). Because the sampling programme ran for only nine months in Lake Rotomanuka South, (cf. twelve in other study lakes), and as the number of 'rare' taxa found increases with sampling time, the number recorded in Lake Rotomanuka South may be an underestimate.

5.1.4 Important Species Index

ISIs for the major species of each study lake are listed in Appendix IX. ISIs of the ten highest scoring phytoplankters per study lake (Table 5/15), show four features of varying significance: (1) 75 and 50% of the most important desmid taxa occurred in Lakes Kainui and Maratoto, respectively; (2) *Microcystis aeruginosa* and *Anabaena tenebricaulis* were dominant in Group IV lakes (Ngaroto and Rotomanuka South), and all four of the most important cyanophyte species were present in Lake Ngaroto; (3) dinoflagellates were dominant in Group III lakes (Rotomanuka North and Rotoroa); (4) *Closterium gracile* was a dominant species in Group I lakes (Mangahia and Maratoto) only. The significance of these features in terms of habitat preferences of particular taxa is discussed in Chapters 6 and 7. The absence of zygothales with high ISIs from Lake Rotokauri remains anomalous

TABLE 5/11 List of twenty-four phytoplankton
species found in eight of the nine
study lakes, July 1983 to July 1984.

CHLOROPHYTA

Euchlorophyceae

Dictyosphaerium pulchellum
Kirchneriella obesa
Micractinium pusillum
Monoraphidium irregulare
M. komarkovae
M. minutum
Pediastrum duplex
Raphidocelis contorta
Tetrastrum triangulare

Zygophyceae

Staurodesmus glaber var. *limnophilus*

CHROMOPHYTA

Chrysophyceae

Chrysococcus rufescens
Synura uvella

Diatomophyceae

Acanthoceras zachariasii
Asterionella formosa
Cocconeis placentula
Eunotia pectinalis var. *undulata*
Fragilaria ulna
Gomphonema truncatum

CYANOPHYTA

Cyanophyceae

Anabaena minutissima ?
Lyngbya limnetica
Microcystis aeruginosa

EUGLENOPHYTA

Euglenophyceae

Trachelomonas planctonica
T. playfairi

PYRRHOPHYTA

Cryptophyceae

Cryptomonas marssonii

TABLE 5/12 List of 130 phytoplankton species
found in only one of the nine study
lakes, July 1983 to July 1986.

CHLOROPHYTA

Euchlorophyceae

Volvocales

Chlamydomonadaceae

Chlamydomonas sp. C

Volvocaceae

Volvox aureus

Spondylomoraceae

Spondylomorom quarternarium

Chlorococcales

Chlorococcaceae

Ankyra judayi

Characium ornithocephalum

Schroederia setigera

Hormotilaceae

Palmodictyon viride

Oocystaceae

Ankistrodesmus bernardii

A. fasciculatus

Lagerheimia citrifomis

Oocystis borgei

Pachycladella umbrina

Quadriluga lacustris

Rhombocystis complanata

Treubaria planctonica

Trochiscia aciculifera

Micractiniaceae

Micractinium bornhemiense

Dictyosphaeriaceae

Westella botryoides

Scenedesmaceae

Actinastrum aciculare

A. gracillimum

Coelastrum astroideum

Crucigeniella truncata

Scenedesmus acuminatus var. *minor*

S. armatus

S. dimorphus

S. magnus

S. protuberans

Zygothyceae

Zygnematales

Zygnemataceae

Mougeotia sp. C

Spirogyra sp. B

Zygnema sp.

Mesotaeniaceae

Netrium digitus

TABLE 5/12 continued

Desmidiaceae

- Actinotaenium globosum*
- Closterium acutum* var. *linea*
- C. diane* var. *pseudodiane*
- C. kuetzingii*
- C. leibleinii*
- C. venus* var. *westii*
- Cosmarium amplum*
- Co. bioculatum*
- Co. botrytis*
- Co. lapponicum*
- Co. lundelli*
- Co. l.* var. *ellipticum*
- Co. reniforme*
- Desmidium baileyi*
- Euastrum denticulatum*
- E. praemorsum*
- E. verrucosum*
- Hyalotheca dissiliens*
- Penium margaritaceum*
- Pleurotaenium minutum*
- Sphaerososma aubertianum*
- Spondylosium planum*
- S. pulchellum*
- Stauroastrum cingulum* var. *obesum*
- St. grande* var. *parvum*
- St. inflexum*
- St. pinque*
- Staurodesmus convergens* var. *laportei*
- Sta. mammillatus*
- Sta. mucronatus* var. *delicatulus*

CHROMOPHYTA

Chrysophyceae

Chromulinales

Chrysococcaceae

- Bicosoeca petiolata*

Dinobryaceae

- Dinobryon sociale*

Synuraceae

- Stokesiella epipyxis* ?

Xanthophyceae

Mischococcales

Pleurichloridaceae

- Goniochloris pseudogigas*
- G. smithii*
- Pseudostauroastrum hastatum*
- P.* sp. B
- Tetraedriella jovetii*
- T. regularis*

Diatomophyceae

Diatomales

TABLE 5/12 continued

Diatomaceae	
	<i>Centronella reichelti</i>
	<i>Fragilaria brevistriata</i>
	<i>Meridion circulare</i> var. <i>constricta</i>
Eunotiales	
Eunotiaceae	
	<i>Eunotia pectinalis</i> var. <i>ventricosa</i>
	<i>E. tenella</i>
Achnanthales	
Achnanthaceae	
	<i>Cocconeis placentula</i> var. <i>euglypta</i>
Naviculales	
Naviculaceae	
	<i>Cymbella palustris</i>
	<i>Gomphonema berggrenii</i>
	<i>Navicula cuspidata</i>
	<i>Pinnularia abaugensis</i> var. <i>linearis</i>
	<i>P. flexuosa</i>
	<i>P. stomatophora</i>
	<i>Stauroneis anceps</i>
Epithemiaceae	
	<i>Epithemia argus</i>
Nitzschiaceae	
	<i>Nitzschia palea</i>
	<i>N. sigmoidea</i>
Surirellaceae	
	<i>Surirella angustata</i>
CYANOPHYTA	
Cyanophyceae	
Chroococcales	
Chroococcaceae	
	<i>Aphanothece nidulans</i>
	<i>Gomposphaeria lacustris</i> var. <i>compacta</i>
	<i>Merismopedia punctata</i>
Nostocales	
Nostocaceae	
	<i>Anabaena solitaria</i>
	<i>Cylindrospermum minutissimum</i>
	<i>Oscillatoria curviceps</i>
	<i>O. guttulata</i>
	<i>O. jasorvensis</i>
	<i>O. mougeotii</i>
	<i>Phormidium mucicola</i>
	<i>Spirulina major</i>
EUGLENOPHYTA	
Euglenophyceae	
Euglenales	
Euglenaceae	
	<i>Euglena ehrenbergii</i>
	<i>E. limnophila</i>

TABLE 5/12 continued

E. sanguinea
E. spirogyra var. *suprema*
E. tripteris
Phacus acuminatus
P. chloroplastes
P. curvicauda
P. hamatus
P. latus
P. polytrophos
P. sesquitortus
Trachelomonas aculeata
T. bacillifera var. *minima*
T. dybowskii
T. globularis var. *punctata*
T. hispida var. *punctata*
T. lemmermanii
T. mirabilis var. *helvetica*
T. m. var. *obesa*
T. planctonica var. *oblonga*
T. pulcherrima var. *minor*
T. stokesi
T. volzii var. *cylindraceae*
Strombomonas urceolata
Urceolus sp.

PYRRHOPHYTA

Dinophyceae

Peridinales

Peridiniaceae

Peridinium centenniale

P. polonicum

P. sp. A

P. sp. B

Ceratiaceae

Ceratium hirundinella var. *furcoides*

Dinococcales

Phytodiniaceae

Tetradinium intermedium

TABLE 5/13 Distribution of species found in only one of the nine study lakes amongst the major taxa, and the lakes in which those species were substantially represented, July 1983 to July 1984.

Taxon	Number of species	Proportion (%)	Lake	Proportion (%)
CHLOROPHYTA				
Euchlorophyceae	27	21	Rotomanuka North	38
			Ngaroto	21
Zygophyceae	34	26	Rotokauri	47
			Rotomanuka North	14
CHROMOPHYTA				
Chrysophyceae	3	2		
Diatomophyceae	17	13	Ngaroto	33
			Rotomanuka North	22
Xanthophyceae	6	5		
CYANOPHYTA				
Cyanophyceae	11	8	Ngaroto	45
EUGLENOPHYTA				
Euglenophyceae	26	20	Rotokauri	15
			Rotomanuka North	12
PYRRHOPHYTA				
Dinophyceae	6	5		
TOTAL	<u>130</u>	<u>100</u>		

TABLE 5/14 Distribution of species (plus varieties) that were found in only one of the nine study lakes according to surface pH values, July 1983 to July 1984.

Lake	Minimum Surface pH Value	Taxa found in only 1 of the 9 Study Lakes		
		Number of Taxa	Proportion of Total Number of Rare Species (%)	Proportion of Total Number of Species (%)
Maratoto	5.1	9	6.9	6.9
Mangahia	5.8	9	6.9	7.0
Kainui	6.1	8	6.1	7.1
Mangakaware	6.5	12	9.2	7.0
Rotomanuka North	6.8	28	21.5	13.8
Rotokauri	7.0	28	21.5	13.3
Rotoroa	7.3	23	17.7	13.2
Ngaroto	8.2	10	7.7	6.6
Rotomanuka South	8.4	3	2.3	2.5
TOTAL		<u>130</u>	<u>99.8</u>	

TABLE 5/15 List of ISIs* for the ten highest scoring phytoplankters in each of the nine study lakes, July 1983 to July 1984.

Taxon	Lake								
	KA**	MH	MK	MA	NG	RK	RMN	RMS***	RR
CHLOROPHYTA									
Euchlorophyceae									
Volvocales									
Chlamydomonadaceae									
† <i>Chlamydomonas</i> sp. C				377.0					
Chlorococcales									
Oocystaceae									
<i>Ankistrodesmus bibraianus</i>	31.5					610.6			
<i>A. falcatus</i>						332.4			
<i>Chlorella</i> sp.		372.3							
<i>Monoraphidium contortum</i>			2288.2		300.0	354.2	73.4		
<i>M. tortile</i>		59.0	214.5	72.0					
<i>Oocystis lacustris</i>									61.8
<i>Raphidocelis contorta</i>		50.0			121.9				
Dictyosphaeriaceae									
<i>Botryococcus braunii</i>				4113.0			490.0		
Scenedesmaceae									
<i>Scenedesmus acutiformis</i>						310.8			
<i>S. quadricauda</i>	357.0	154.5			1080.0				
<i>Tetrastrum triangulare</i>			164.2						4700.2
Zygophyceae									
Zygnematales									
Desmidiaceae									

<i>Closterium acutum</i> var. <i>variabile</i>	680.0	2390.0	570.0	693.0	280.0	4720.5	
<i>C. gracile</i>		224.2		33.0			
<i>Staurastrum arcuatum</i>	90.0						
<i>S. brachiatum</i>	316.0						
<i>S. chaetopus</i> ?	152.0						
<i>S. inflexum</i>				25.5			
<i>S. sp. A</i>						46.7	57.3
<i>S. sp. B</i>				38.0			
<i>S. sp. C</i>	2091.0						
<i>Staurodesmus</i> spp.	4460.0						

CHROMOPHYTA

Chrysophyceae							
Chromulinales							
Chrysococcaceae							
† <i>Chrysococcus rufescens</i>						37.3	
Dinobryaceae							
† <i>Dinobryon bavaricum</i>							74.9
† <i>D. cylindricum</i>			342.9		2290.3		1700.0
Synuraceae							
† <i>Mallomonas akrokomos</i>					205.7		
† <i>Synura uvella</i>			133.3		151.3	42.7	
Diatomophyceae							
Coscinodiscales							
Coscinodiscaceae							
<i>Aulacosira distans</i>		3610.0					
<i>A. granulata</i> var. <i>angustissima</i>		524.7		4410.0			
<i>Cyclotella stelligera</i>			171.4			450.0	51.3 650.0
Biddulphiales							
Chaetoceraceae							
<i>Acanthoceras zachariasii</i>			560.7			40.0	
Diatomales							
Diatomaceae							

† <i>Peridinium cinctum</i>	700.0	162.2
Ceratiaceae		
† <i>Ceratium hirundinella</i>	57.1	

RAPHIDOPHYTA

Raphidophyceae		
Raphidomonadales		
Vacuolariaceae		
† <i>Vacuolaria</i> sp.	178.0	

KEY:

- * ISI = Important Species Index
- ** KA = Lake Kainui
- MH = Lake Mangahia
- MK = Lake Mangakaware
- MA = Lake Maratoto
- NG = Lake Ngaroto
- RK = Lake Rotokauri
- RMN & RMS = Lakes Rotomanuka North and South
- RR = Lake Rotoroa

*** October 1983 to July 1984

† Flagellate

considering the remarkably high number of zygophytes (46 species) found in the lake.

Generally, the study lakes varied considerably in terms of their ten most important species. For example, of the 44 taxa in this category, only one (*Trachelomonas volvocina*) qualified as important in all nine lakes and 22 (50%) scored in only one lake. Five taxa (*Botryococcus braunii*, *Tetrastrum triangulare*, *Closterium acutum* var. *variabile*, *Staurodesmus* spp. [*S. cuspidatus*, *S. dejectus*, *S. mammillatus*], and *Aulacosira granulata* var. *angustissima*) attained exceptionally high ISIs (> 4000; Appendix IX) in specific lakes, but none was consistently high across the series (Table 5/15).

The mean ISIs of the ten highest scoring phytoplankters from each lake varied considerably (range 2.8 [*Staurastrum inflexum*] to 1037 [*Closterium acutum* var. *variabile*]) (Table 5/16), and is further evidence of the major compositional differences that existed between the study lakes. *A. g.* var. *angustissima* and *Tetrastrum triangulare* ranked second (548) and third (540), respectively.

It is noteworthy that of the 24 taxa (6%) present in all nine study lakes (Chapter 5.2; Table 5/10), 16 (68%) also ranked among one of the ten most important species in at least one lake (Table 5/16).

5.2 MORPHOLOGICAL DIVERSITY

The majority of phytoplankters (252 species [63%]) were unicellular. Colonial and filamentous forms were represented by 26 and 11%, respectively. Group I lakes (Mangahia and Maratoto) had marginally higher, relative mean proportions of unicells (63%) than other groups, and conversely exhibited the lowest mean relative percentages (25%) of colonial forms. The relative numbers of filamentous forms were similar (range 11 to 13%) throughout the four groups (Table 5/17).

When the ten most important species per lake (Table 5/15) were categorised according to their morphology, three features were apparent: (1) filamentous important species were restricted to the three shallowest lakes (Mangahia, Ngaroto and Rotomanuka South); (2) the mean occurrence of unicellular important species in the Group IV lakes was 40%, and thus markedly lower than any other group, each of

TABLE 5/16 Mean and coefficient of variation (C.V.) of the ISIs* of the ten highest scoring phytoplankters from each study lake, together with the number of lakes in which the phytoplankter ranked as an important species, and the total number of study lakes in which it occurred, July 1983 to July 1984.

Taxon	Mean ISI	C.V.	Number of Lakes in which Phytoplankter occurred	Number of Lakes in which Phytoplankter occurred as an Important Species
<i>Closterium acutum</i> var. <i>variabile</i>	1037.0	1.5	9	6
<i>Aulacosira granulata</i> var. <i>angustissima</i>	548.3	2.7	9	2
<i>Tetrastrum triangulare</i>	540.5	2.9	9	2
<i>Botryococcus braunii</i>	511.4	2.6	9	2
<i>Stasurodesmus cuspidatus</i>	495.5	3.0	5	1
<i>S. dejectus</i>			9	
<i>S. mammillatus</i>			1	
<i>Cryptomonas marssonii</i>	401.6	1.2	8	7
<i>C. ovata</i>			9	
<i>Aulacosira distans</i>	401.1	3.0	9	1
<i>Trachelomonas playfairi</i>	340.8	0.7	8	9
<i>T. planctonica</i>			8	
<i>T. volvocina</i>			9	
<i>Monoraphidium contortum</i>	335.1	2.2	9	4
<i>Staurastrum</i> sp. C	232.3	3.0	5	1
<i>Microcystis aeruginosa</i>	208.9	2.1	8	2
<i>Scenedesmus quadricauda</i>	176.8	2.0	9	3
<i>Cyclotella stelligera</i>	147.0	1.6	9	4
<i>Peridinium cinctum</i>	95.8	2.4	9	2
<i>Anabaena tenericaulis</i>	84.9	2.0	3	2
<i>Ankistrodesmus bibraianus</i>	71.3	2.8	6	2
<i>Acanthoceras zachariasii</i>	66.7	2.8	8	2
<i>Asterionella formosa</i>	57.7	2.3	8	2
<i>Dinobryon cylindricum</i>	48.1	1.8	9	3
<i>Chlamydomonas</i> sp. C	41.9	3.0	1	1

<i>Chlorella</i> sp.	41.1	3.0	1	1
<i>Monoraphidium tortile</i>	38.4	1.9	9	3
<i>Ankistrodesmus falcatus</i>	36.9	3.0	6	1
<i>Synura uvella</i>	36.4	1.7	8	3
<i>Staurastrum brachiatum</i>	35.1	3.0	2	1
<i>Scenedesmus acutus</i>	34.5	3.0	2	1
<i>Closterium gracile</i>	28.6	2.6	9	2
<i>Mallomonas akrokomos</i>	22.8	3.0	7	1
<i>Vacuolaria</i> sp.	19.8	3.0	5	1
<i>Raphidocelis contorta</i>	19.1	2.2	8	2
<i>Gomphonema truncatum</i>	17.0	3.0	8	1
<i>Staurastrum chaetopus</i> ?	16.9	3.0	6	1
<i>Anabaena circinalis</i>	14.6	3.0	6	1
<i>Fragilaria ulna</i>	14.5	3.0	8	1
<i>Chroococcus limneticus</i>	13.4	2.4	6	2
<i>Tabellaria flocculosa</i>	13.3	3.0	9	1
<i>Staurastrum</i> sp. A	11.5	2.0	5	2
<i>S. arcuatum</i>	10.0	3.0	5	1
<i>Dinobryon bavaricum</i>	8.3	3.0	2	1
<i>Oocystis lacustris</i>	6.9	3.0	9	1
<i>Ceratium hirundinella</i>	6.3	3.0	7	1
<i>Staurastrum</i> sp. B	4.2	3.0	6	1
<i>Chrysococcus rufescens</i>	4.1	3.0	8	1
<i>Staurastrum inflexum</i>	2.8	3.0	1	1

*ISI = Important Species Index (Chapter 2.4.4)

TABLE 5/17 Relative percentage contributions of morphological forms (unicellular, colonial and filamentous) and flagellates within each of the four lake groups*, July 1983 to July 1984.

Lake	<u>Percentage Contribution</u>			
	<u>Morphological Form</u>			<u>Flagellates</u>
	Unicells	Colonies	Filaments	
Group I:				
Mangahia	58.6	27.3	12.5	26.6
Maratoto	66.9	22.3	10.0	22.3
Group II:				
Kainui	53.1	31.8	14.2	18.6
Mangakaware	60.0	27.1	11.8	24.7
Group III:				
Rotokauri	60.9	26.2	13.3	26.2
Rotomanuka North	57.6	32.0	8.9	28.6
Rotoroa	56.9	33.1	9.9	23.2
Group IV:				
Ngaroto	57.5	32.2	11.5	18.4
Rotomanuka South**	59.2	27.5	10.8	22.5

* Table 3/10

** October 1983 to July 1984

which had a mean of 60%; (3) the mean occurrence of colonial important species increased from Group I to Group III (15, 30 and 37%, respectively).

Of the 402 taxa found in the study lakes (Appendix VII), 104 (26%) were flagellates. Their relative numbers ranged from 18% (Lake Ngaroto) to 29% (Lake Rotomanuka North). The mean percentages of flagellates within the Group I to III lakes, were similar (24, 22 and 26%, respectively), and markedly higher than that of the Group IV lakes (14%) (Table 5/17). Their prominence amongst the important species within each lake varied greatly (Table 5/15); for example, the mean number recorded within the Group III lakes was 75%, compared to 25% in each of the other three groups.

5.3 SIZE FRACTIONS

The GALDs of 89% of taxa found in the study lakes were $\geq 21 \mu\text{m}$. The highest number of species (33%) fell in the 21 to 40 μm fraction, but there were also reasonable numbers in both the 41 to 63 μm and $\geq 64 \mu\text{m}$ fractions (26 and 29%, respectively). The GALDs of 46 species (11%) were $\leq 20 \mu\text{m}$, and while only one ultraplanktonic species (*Tetrastrum triangulare*) was found (Fig. 5/1), it ranked as an important species (Table 5/16) in two lakes (Mangakaware and Rotoroa).

Most important species (ISI) belonged to the 41 to 63 and 11 to 20 μm fractions (32 and 31%, respectively), while the 21 to 40 μm fraction contained 21%. The only representatives of the 6 to 10 μm fraction were found in the Group I lakes (Mangahia and Maratoto). The implications of the distribution of the various size fractions are discussed in the context of the trophic status of individual lakes in Chapter 7.2.

5.4 DISTRIBUTION OF MEAN STANDING CROP

In terms of abundance, there was considerable variation in the number of species that comprised 90% of the mean standing crop (range 5 [Lake Kainui] to 45 [Lake Rotokauri]). Dominance was extremely concentrated in Group I lakes (Mangahia [Fig. 5/2] and Maratoto [Fig. 5/3]), and Kainui (Group II [Fig. 5/4]). Conversely, it was most broadly distributed in two of the Group III lakes (Rotomanuka North [Fig. 5/5]; Rotokauri [Fig. 5/6]). A similar trend was also apparent in terms of mean annual densities; for example, the highest mean

Fig. 5/1 Number and percentage of species (including varieties) in the various size fractions in the nine study lakes, July 1983 to July 1984

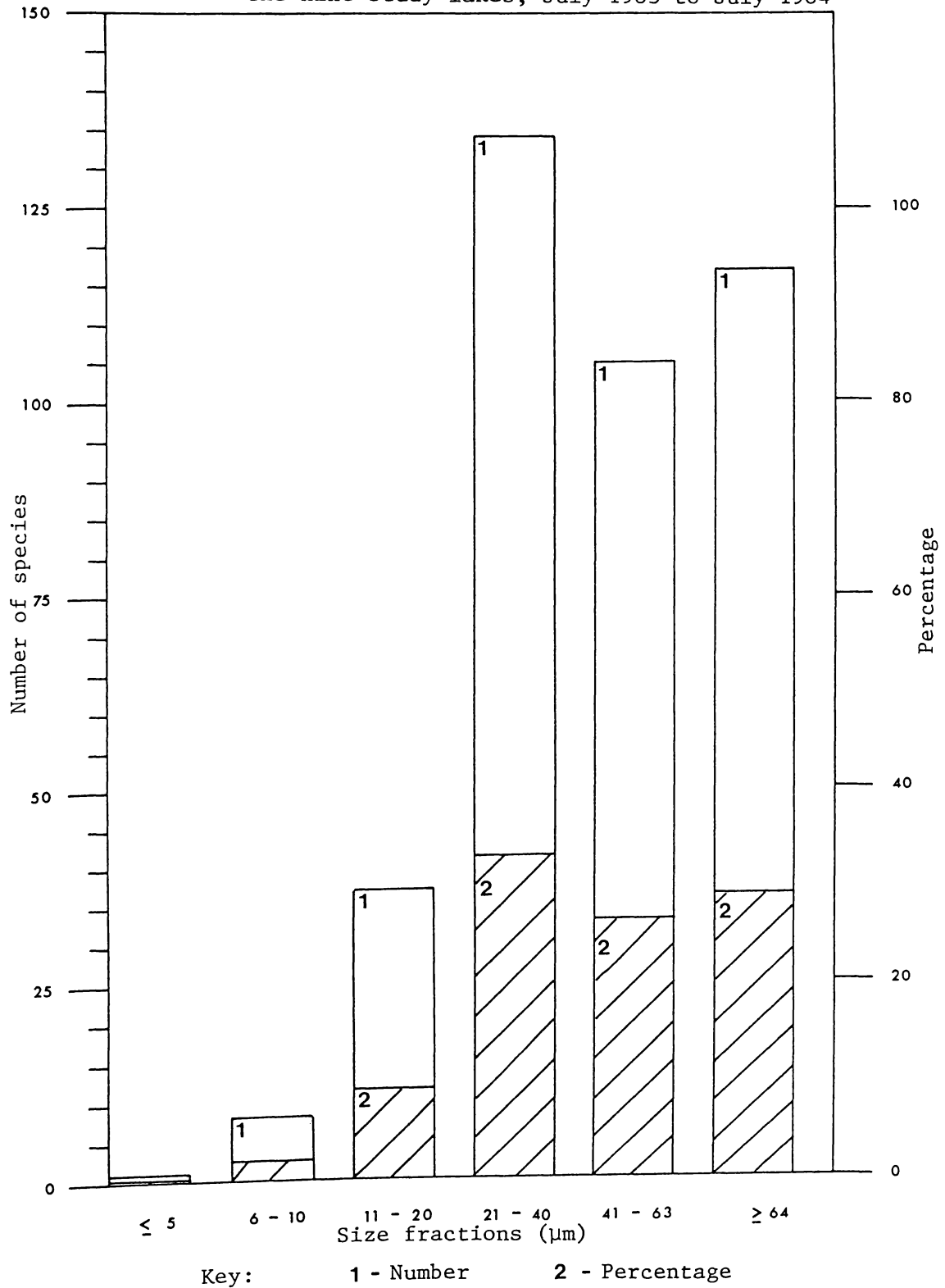


Fig. 5.2 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Mangahia, July 1983 to July 1984. Data are drawn from the means of those species that contributed $\geq 0.1\%$ to the mean total biomass and density. The identity of individual species can be obtained from Table 4/5.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/2

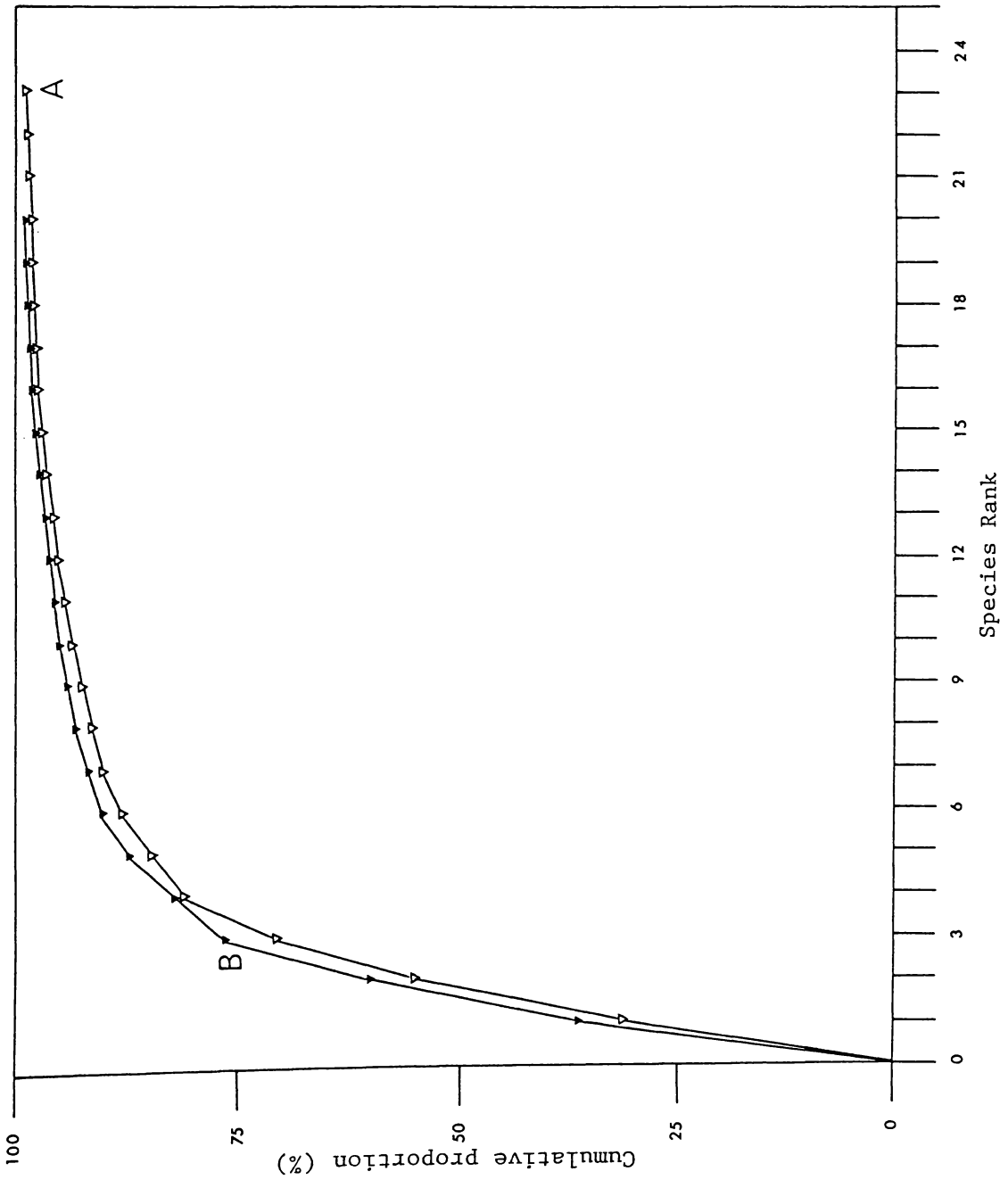
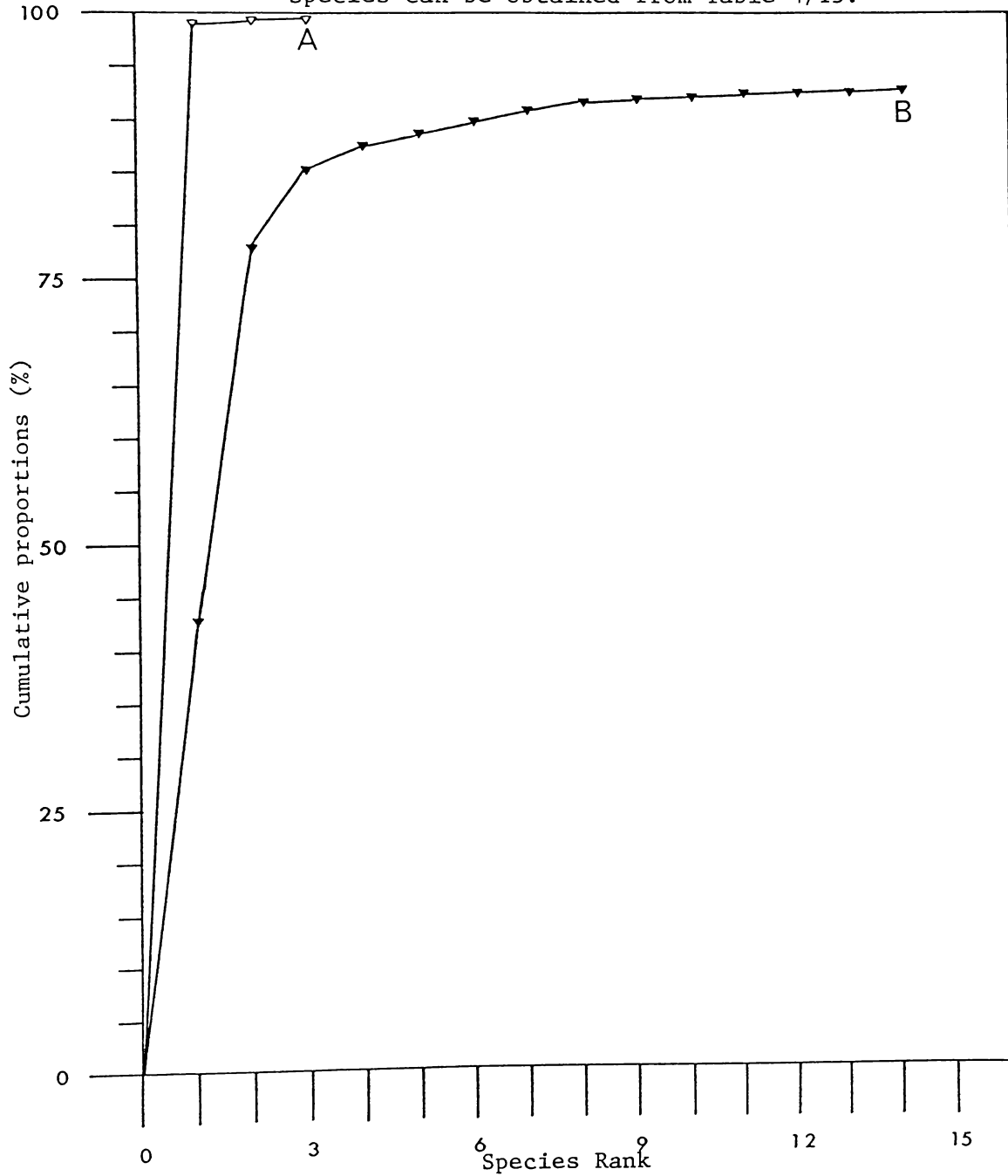


Fig. 5/3 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Maratoto, July 1983 to July 1984. Data are drawn from the means of those species that contributed >0.1% to the mean total biomass and density; The identities of individual species can be obtained from Table 4/15.



Key:

A = biomass
B = pu ml⁻¹

Fig. 5.4 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Kainui, July 1983 to July 1984. Data are drawn from the means of those species that contributed ≥0.1% to the mean total biomass and density. The identity of individual species can be obtained from Table 4/0.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/4

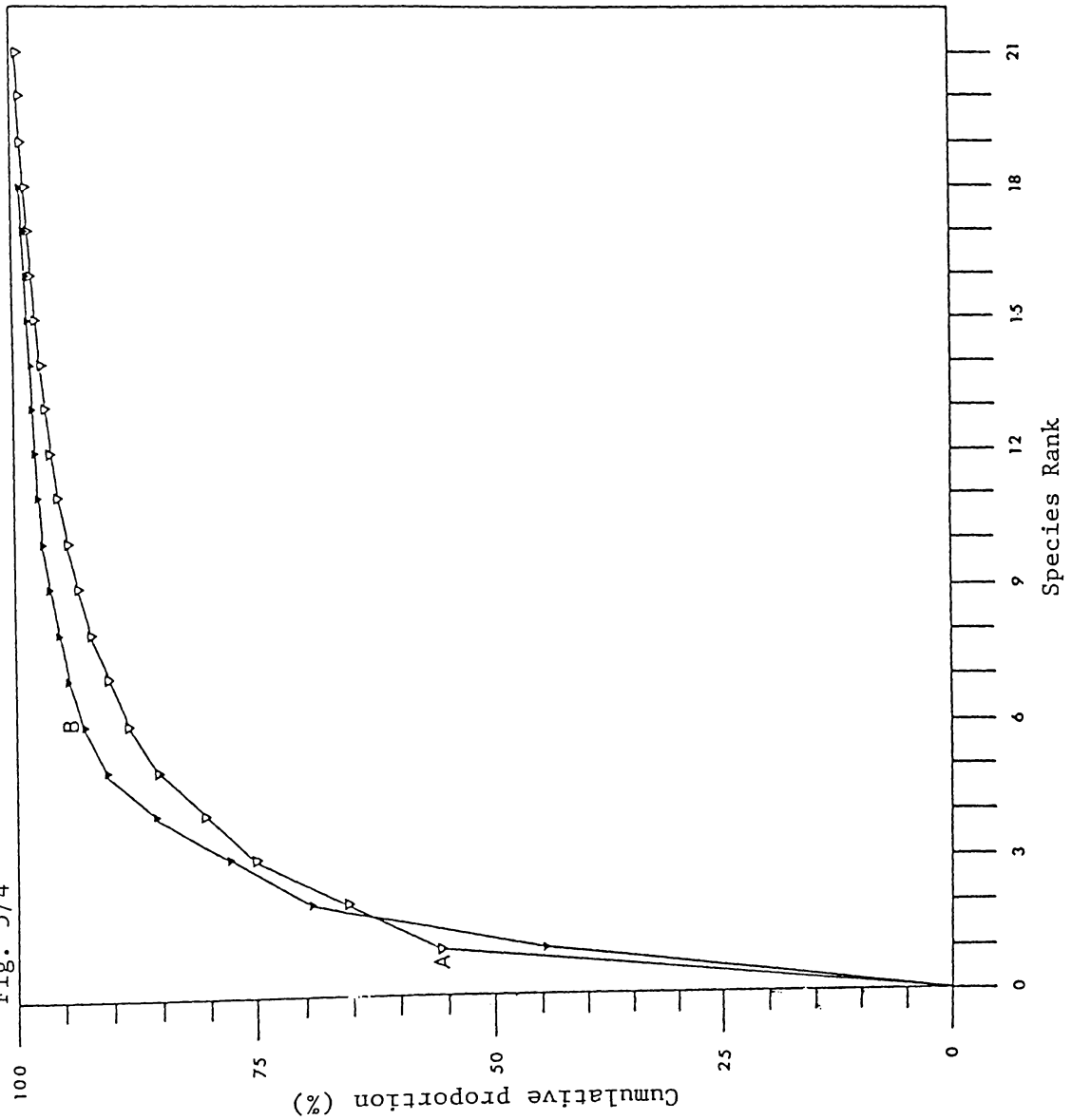


Fig. 5.5 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Rotomanuka North, July 1983 to July 1984. Data are drawn from the means of those species that contributed $\geq 0.1\%$ to the mean total biomass and density. The identity of individual species can be obtained from Table 4/30.

Key:

A. = biomass

B. = pu ml⁻¹

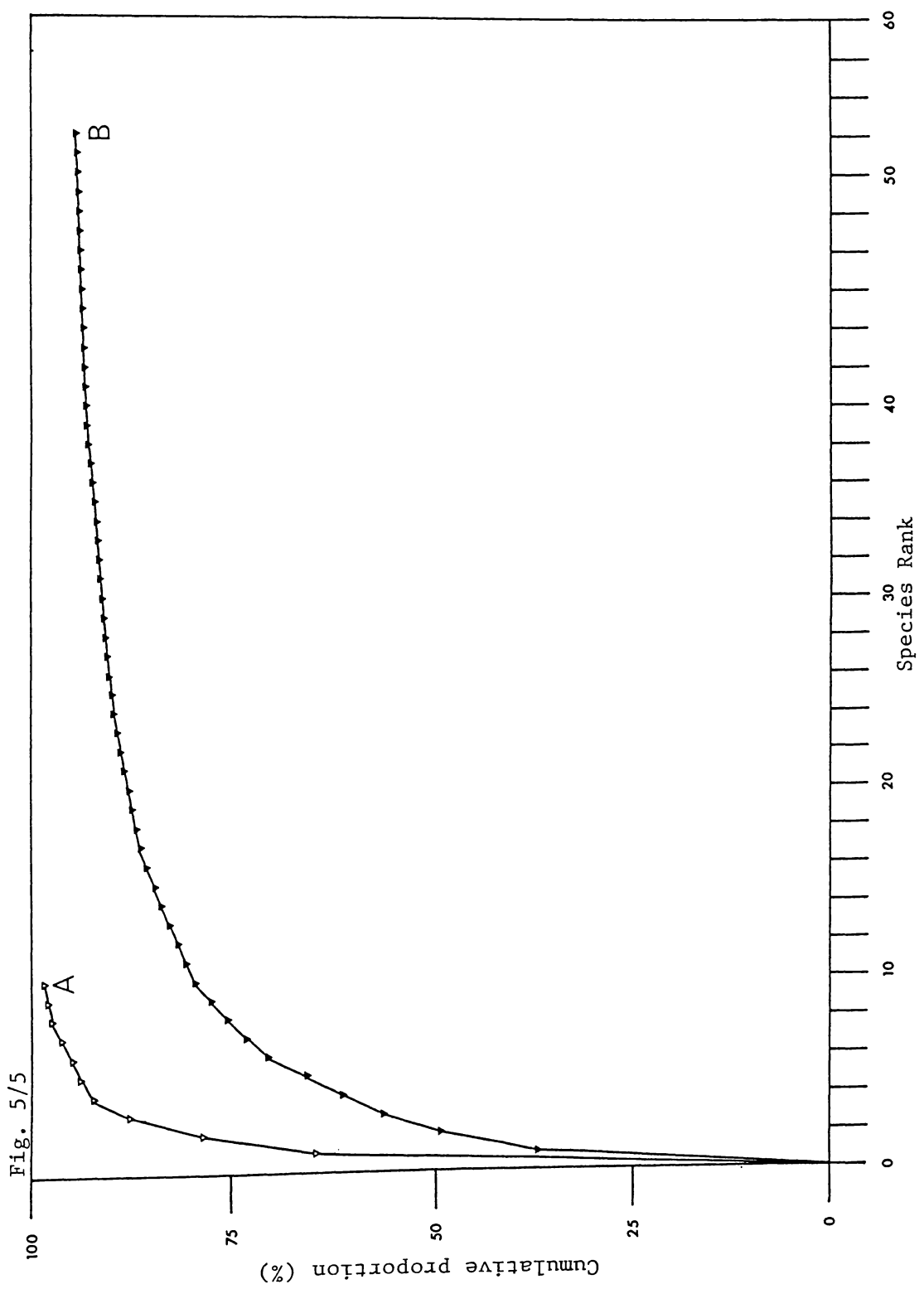


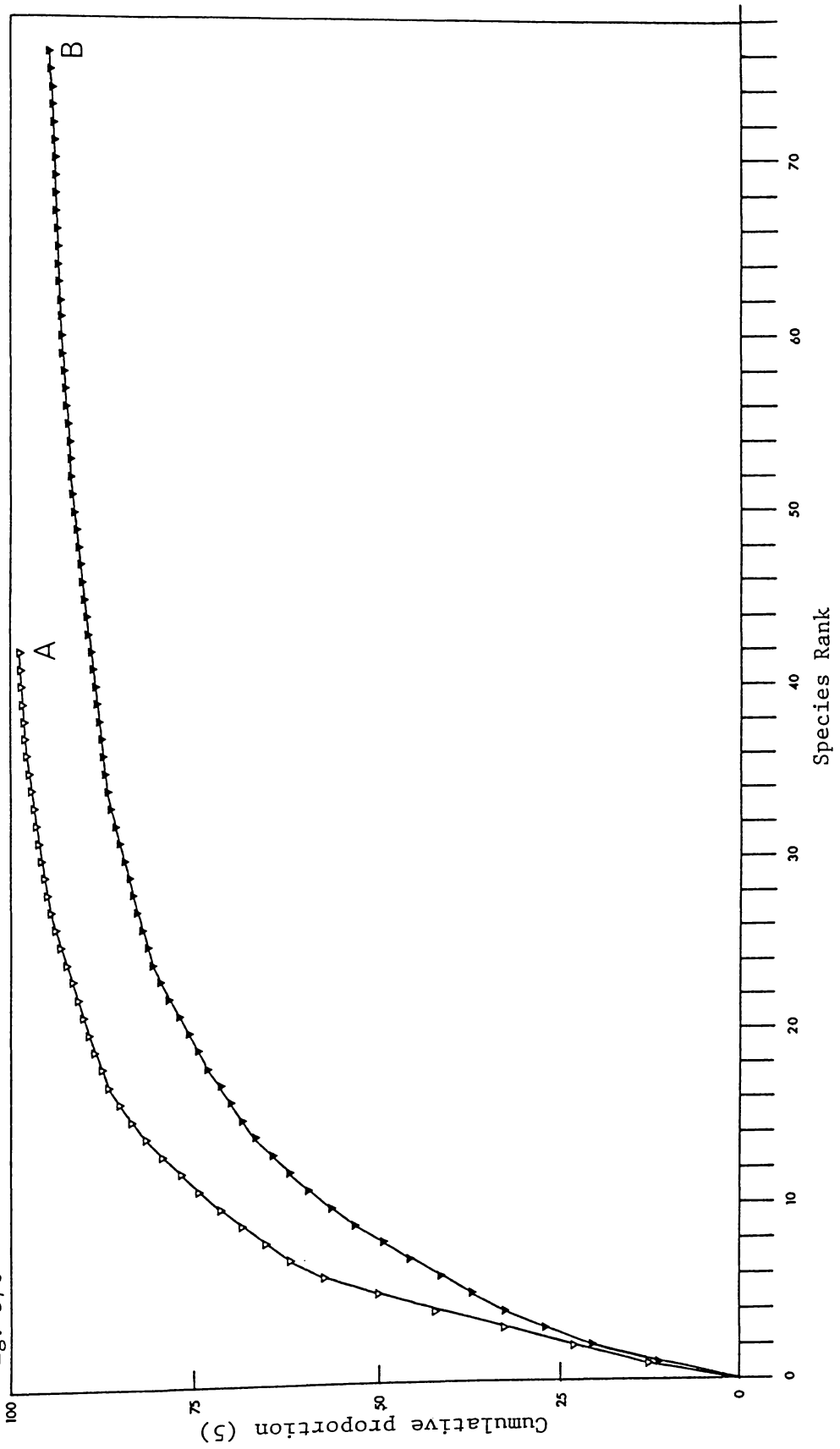
Fig. 5.6 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Rotokauri, July 1983 to July 1984. Data are drawn from the means of those species that contributed ≥0.1% to the mean total biomass and density. The identity of individual species can be obtained from Table 4/25.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/6



numbers of $\mu\text{m l}^{-1}$ were recorded in Lakes Kainui, Maratoto and Mangahia (11,640, 6677 and 6320, respectively), while the two lowest (653 and 378 $\mu\text{m l}^{-1}$) occurred in Lakes Rotokauri and Rotomanuka North, respectively (Table 7/1).

The numbers of species making up 90% of the mean annual biomass ranged from 1 (Lakes Maratoto and Rotomanuka South) to 42 (Lake Rotokauri). Lakes Maratoto (Fig. 5/3), Ngaroto (Fig. 5/7) and Rotomanuka South (Fig. 5/8), each of which had an extremely high concentration of dominance (one or two species contributing 90% of the mean standing crop), also had the highest mean annual biomasses (72, 31 and 27 g m^3 , respectively). Conversely, the mean annual biomass of Lake Rotokauri was 0.7 g m^3 (Table 7/1). However, Lake Mangakaware was an exception to this trend, because although its dominance was broadly spread (40 species [Fig. 5/9]), its mean annual biomass (3.5 g m^3 [Table 7/1]), was considerably higher than that of Lake Rotokauri, but this was due mainly to the large biovolumes of taxa such as *Peridinium* spp. and *Acanthoceras zachariasii* (Table 4/13).

Lakes Rotomanuka North and Rotoroa, despite their low mean annual biomasses (1.7 and 1.8 g m^3 , respectively [Table 7/1]), both showed relatively high concentrations of dominance (4 species [Fig. 5/5] and 5 species [Fig. 5/10], respectively), again a result of high proportions of dinoflagellate with large biovolumes (Tables 4/30 and 4/40).

Dominance-diversity curves (based on mean densities of species with mean contributions $\geq 0.1\%$) (Figs. 5/11 to 5/14) also indicate that Group I lakes (Mangahia and Maratoto), together with Lake Kainui, had high concentrations of dominance amongst a comparatively small number of major species (20, 14 and 18, respectively). In Lake Mangakaware and Group III lakes (Rotoroa, Rotomanuka North and Rotokauri), there were many more major species (36, 27, 54 and 76, respectively). Although Lakes Rotomanuka South and Ngaroto (Group IV) contained similar numbers of major species (36 and 41, respectively), and thus in this respect were not unlike Lake Mangakaware (36 species), there were major differences in the mean proportions of their highest ranking species (64, 44, and 27%, respectively).

Fig. 5.7 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Ngaroto, July 1983 to July 1984. Data are drawn from the means of those species that contributed $\geq 0.1\%$ to the mean total biomass and density. The identity of individual species can be obtained from Table 4/20.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/7

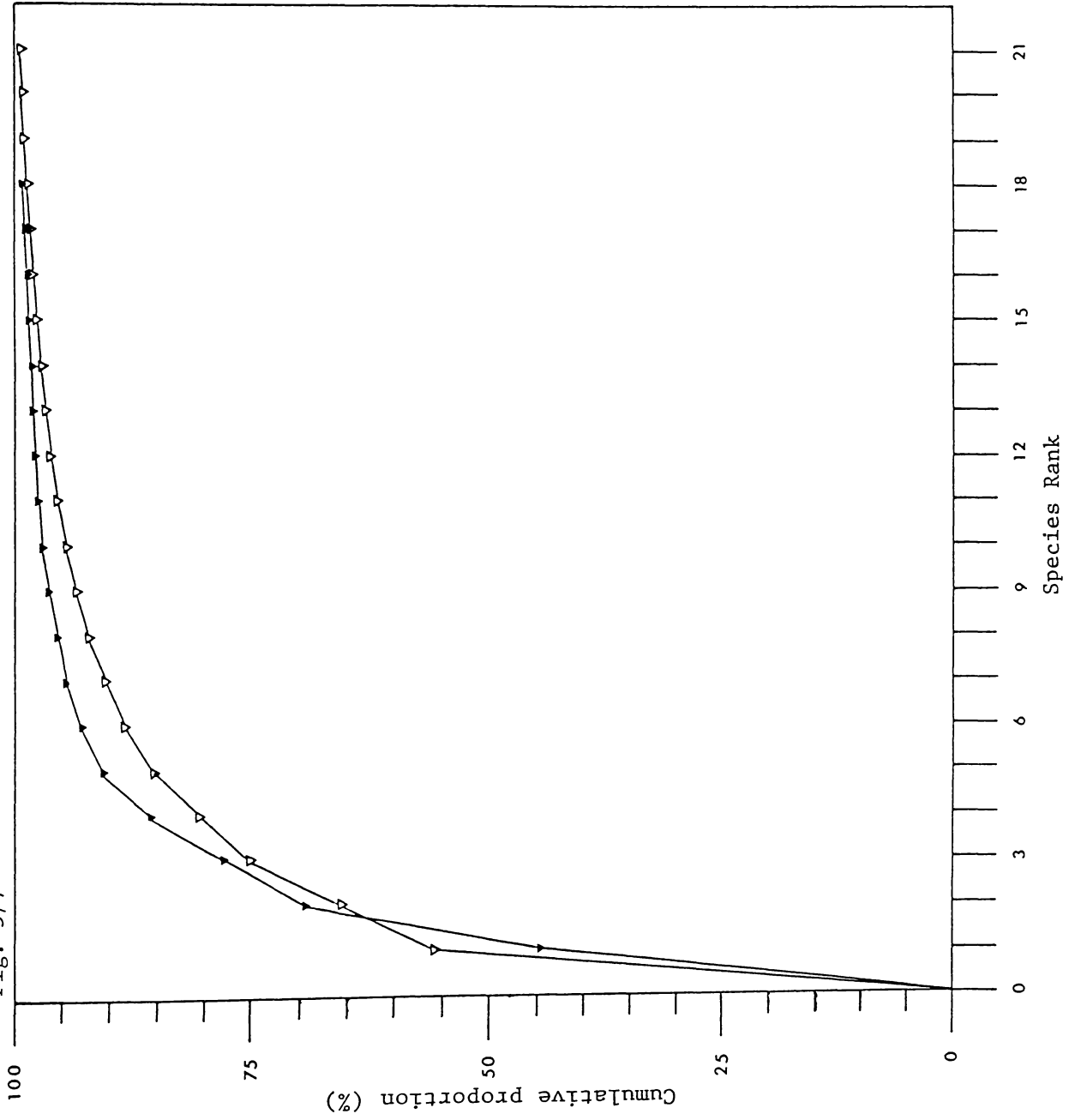


Fig. 5.8 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Rotomanuka South, October 1983 to July 1984. Data are drawn from the means of those species that contributed $\geq 0.1\%$ to the mean total biomass and density. The identity of individual species can be obtained from Table 4/35.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/8

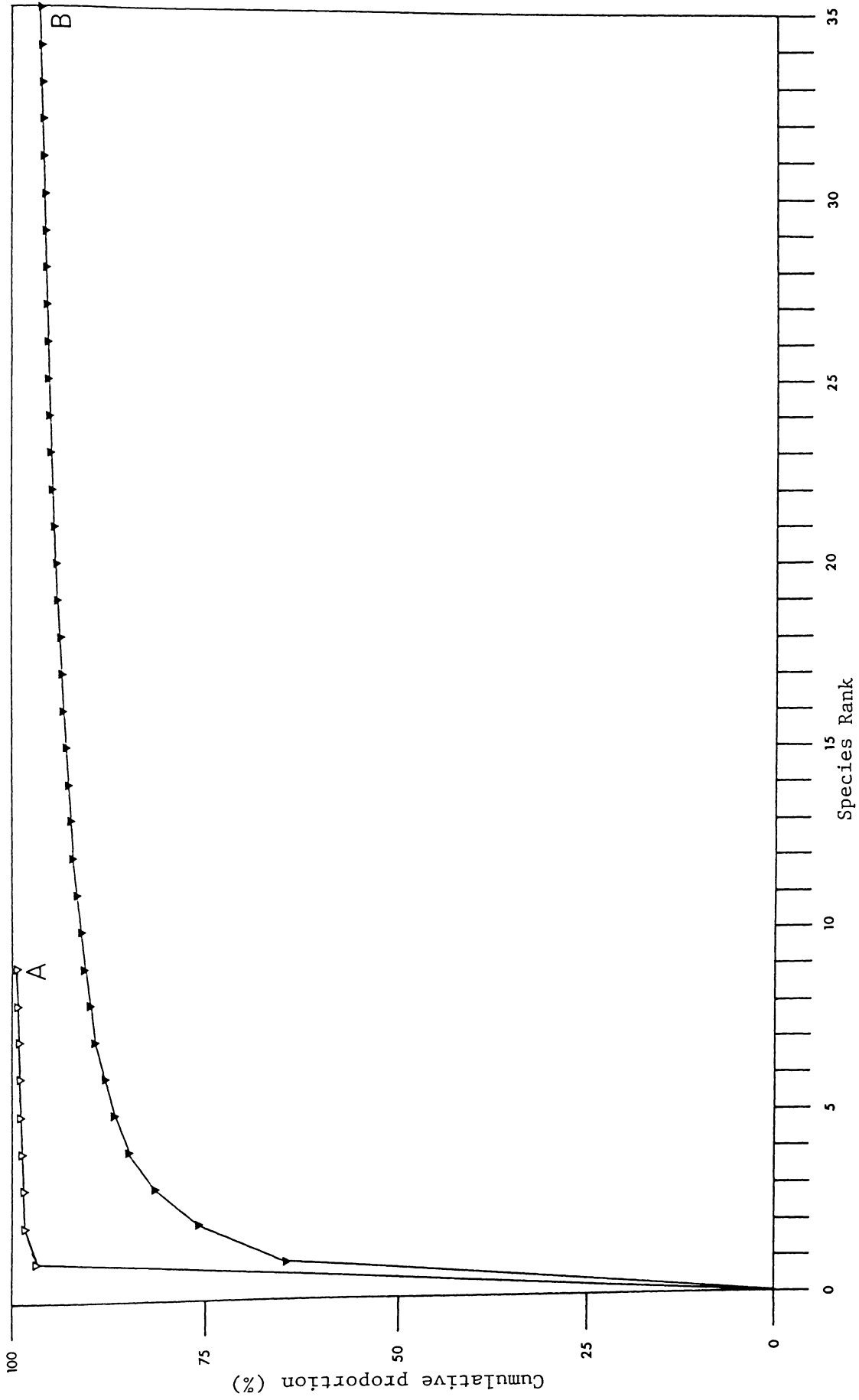


Fig. 5.9 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Mangakaware, July 1983 to July 1984. Data are drawn from the means of those species that contributed ≥0.1% to the mean total biomass and density. The identity of individual species can be obtained from Table 4/10.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/9

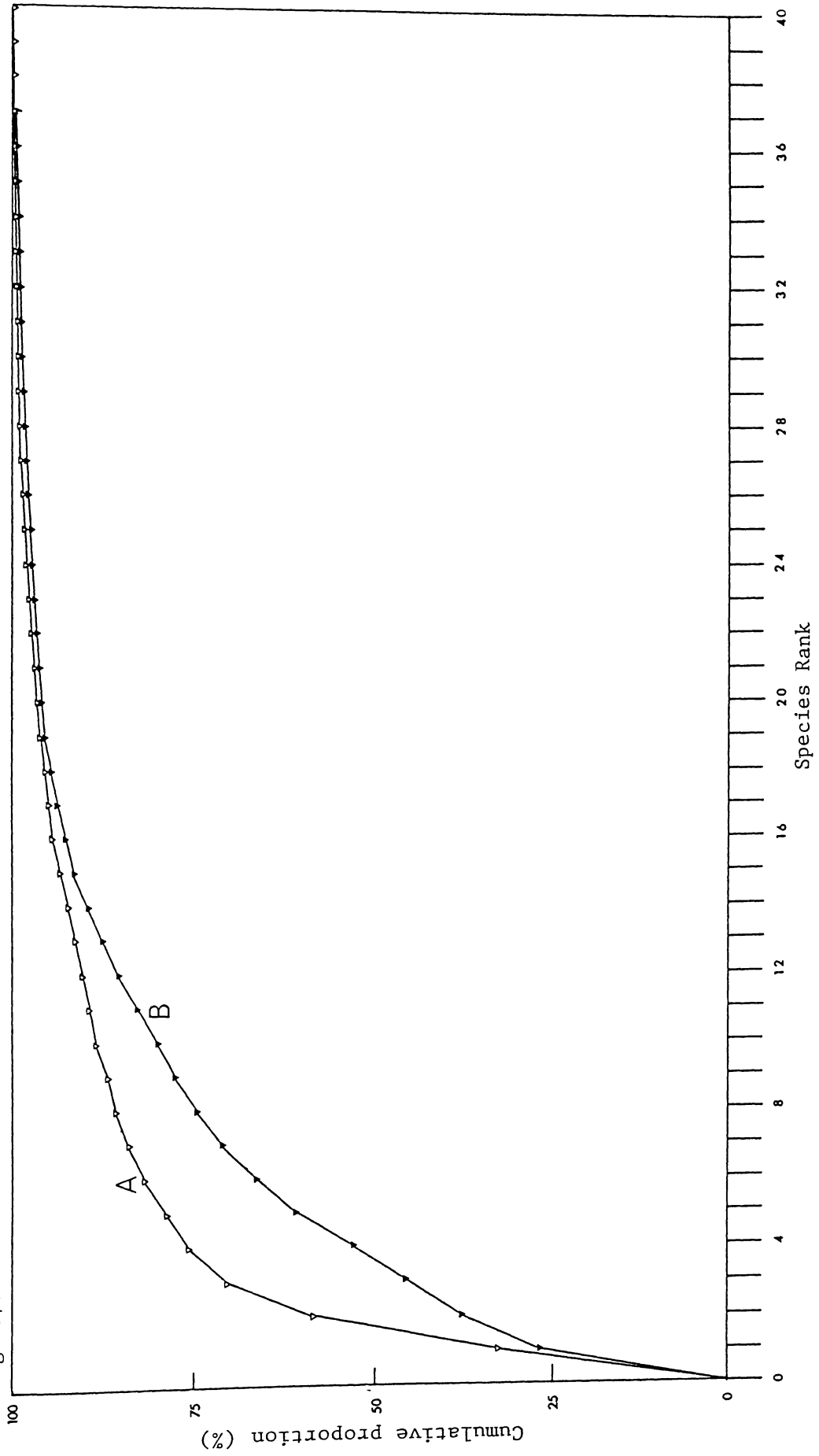


Fig. 5.10 Cumulative proportions of biomass and numbers of pu ml⁻¹ accounted for by successive species ranked in order from the largest to the smallest contributor in Lake Rotoroa, July 1983 to July 1984. Data are drawn from the means of those species that contributed $\geq 0.1\%$ to the mean total biomass and density. The identity of individual species can be obtained from Table 4/40.

Key:

A. = biomass

B. = pu ml⁻¹

Fig. 5/10

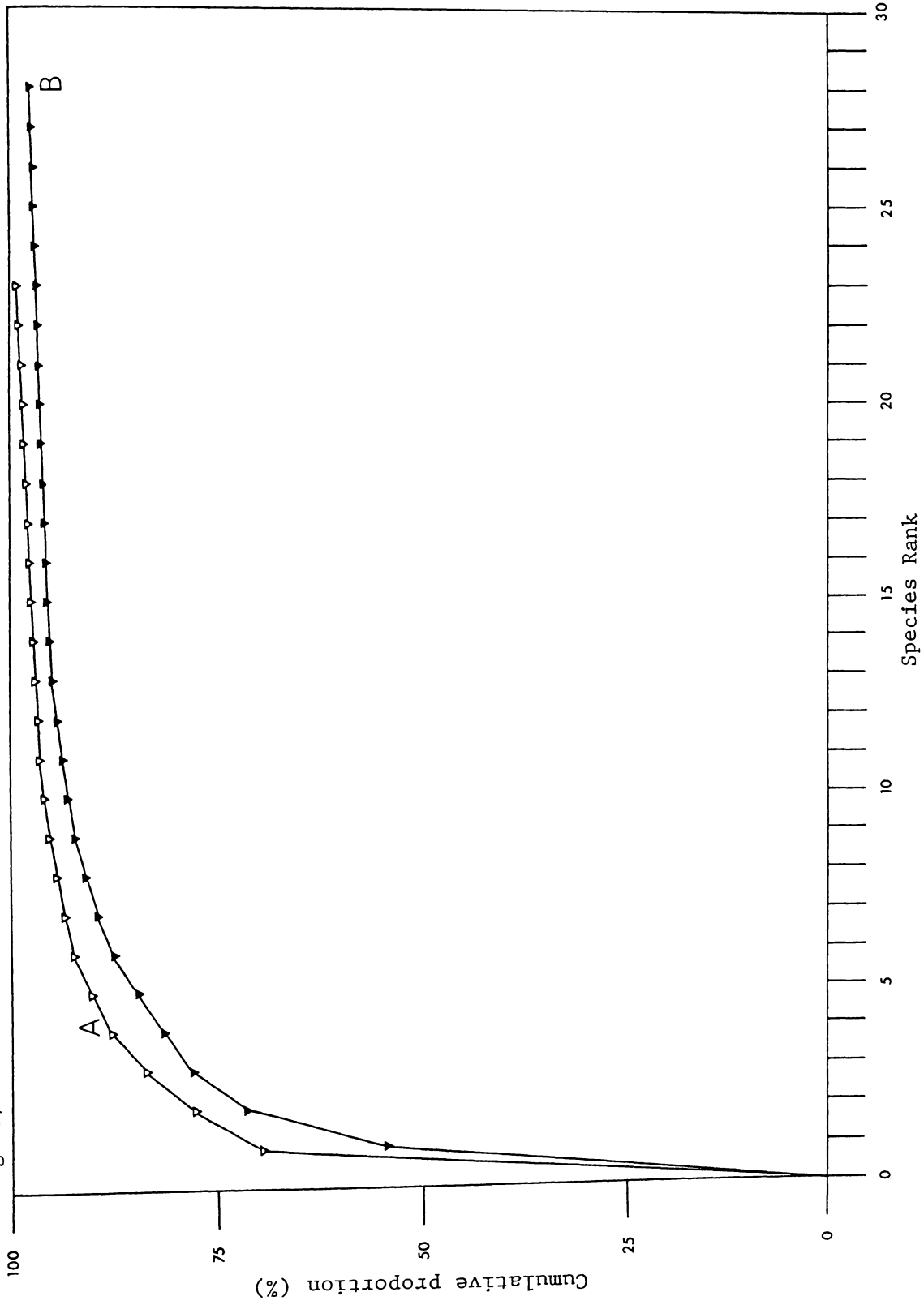


Fig. 5.11 Dominance - diversity curves (based on relative mean density of phytoplankton species with a mean contribution of $\geq 0.1\%$) for Lakes Mangahia and Maratoto (Group I), July 1983 to July 1984. Species are ranked from the most to the least abundant. The identity of individual species can be obtained from Tables 4/5 and 4/15, respectively.

Fig. 5/11

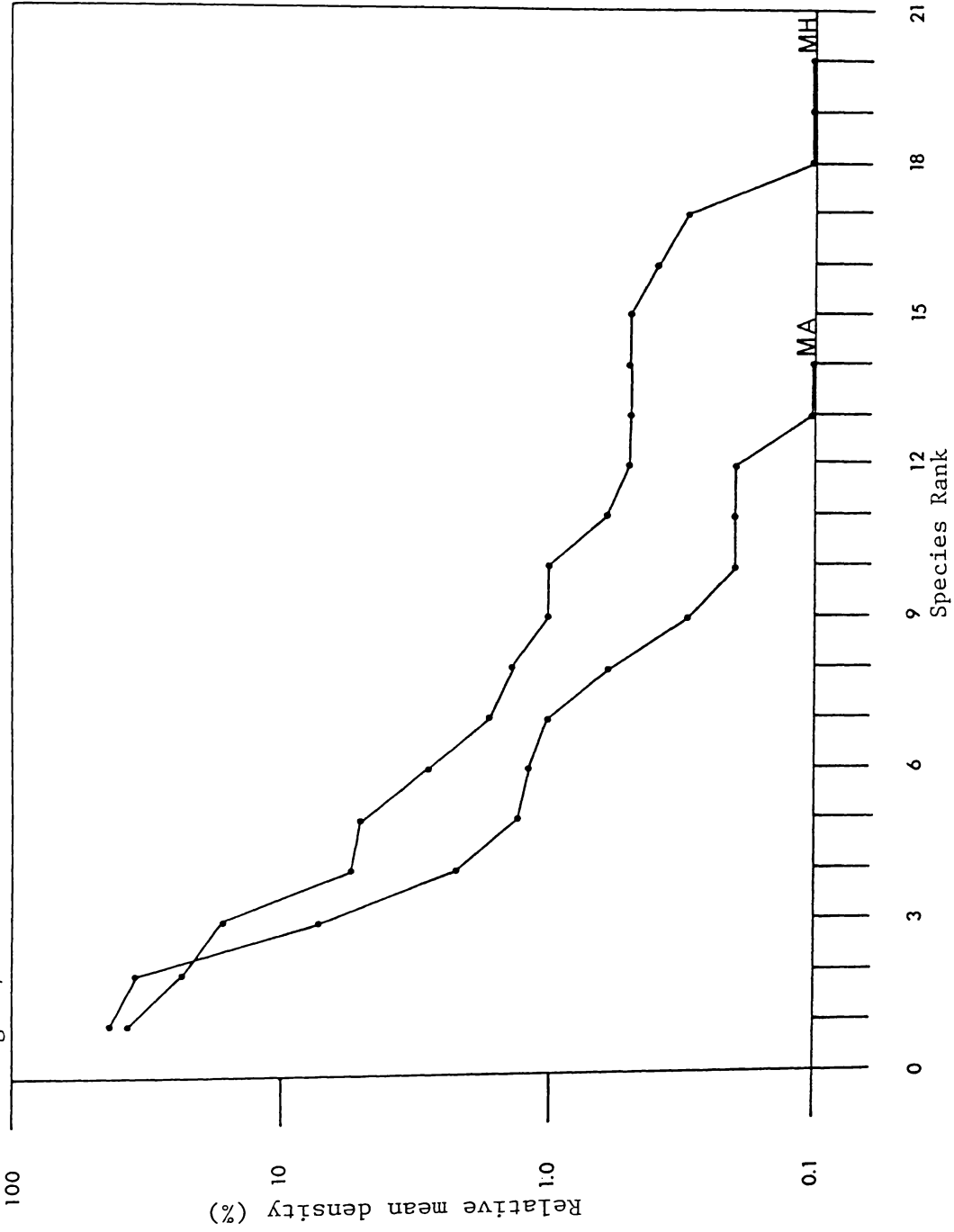


Fig. 5.12 Dominance - diversity curves (based on relative mean density of phytoplankton species with a mean contribution of $\geq 0.1\%$) for Lakes Kainui and Mangakaware (Group II), July 1983 to July 1984. Species are ranked from the most to the least abundant. The identity of individual species can be obtained from Tables 4/0 and 4/10, respectively.

Fig. 5/12

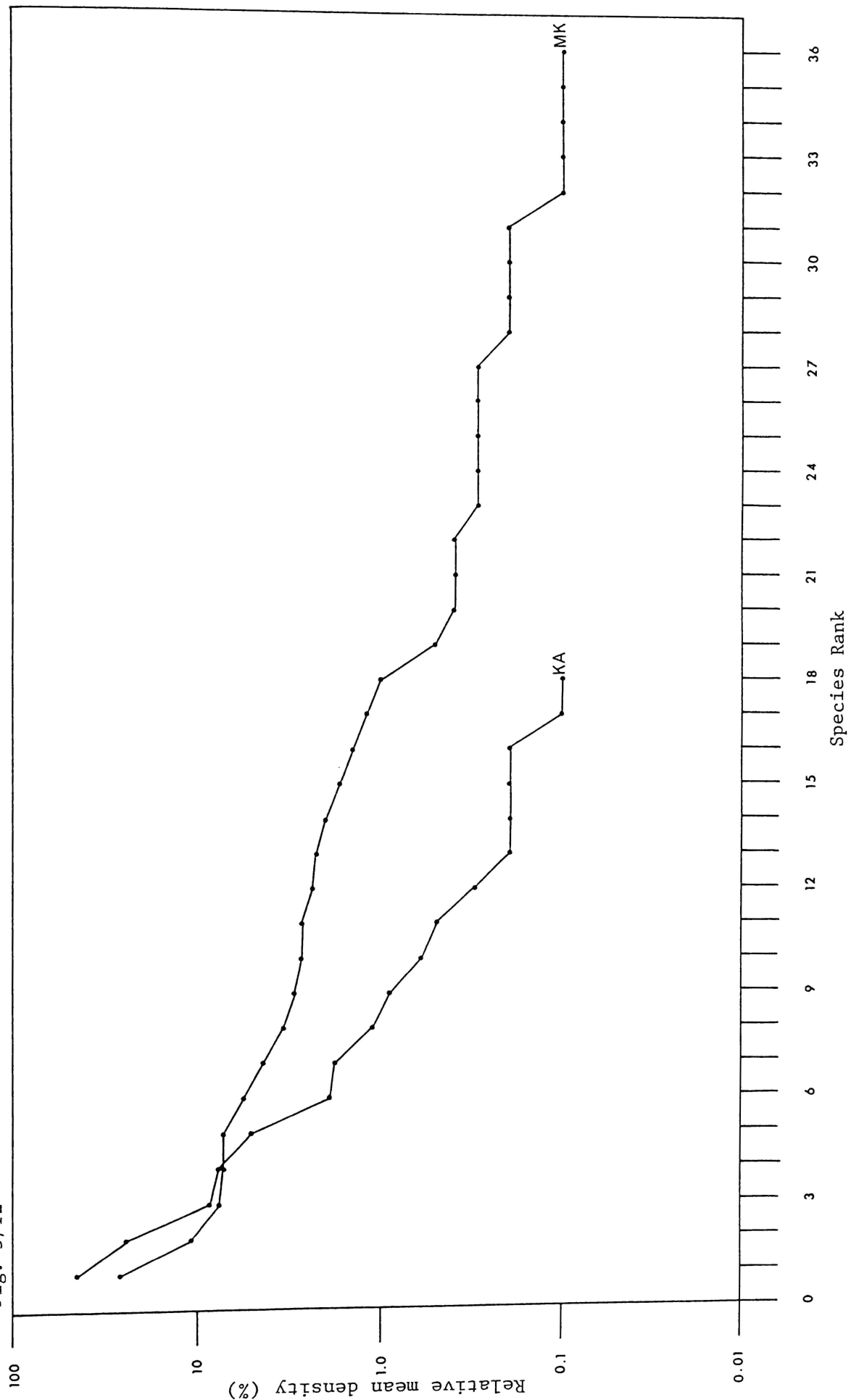


Fig. 5.13 Dominance - diversity curves (based on relative mean density of phytoplankton species with a mean contribution of $\geq 0.1\%$) for Lakes Rotokauri, Rotomanuka North and Rotoroa (Group III), July 1983 to July 1984. Species are ranked from the most to the least abundant. The identity of individual species can be obtained from Tables 4/25, 4/30 and 4/40, respectively.

Fig. 5/13

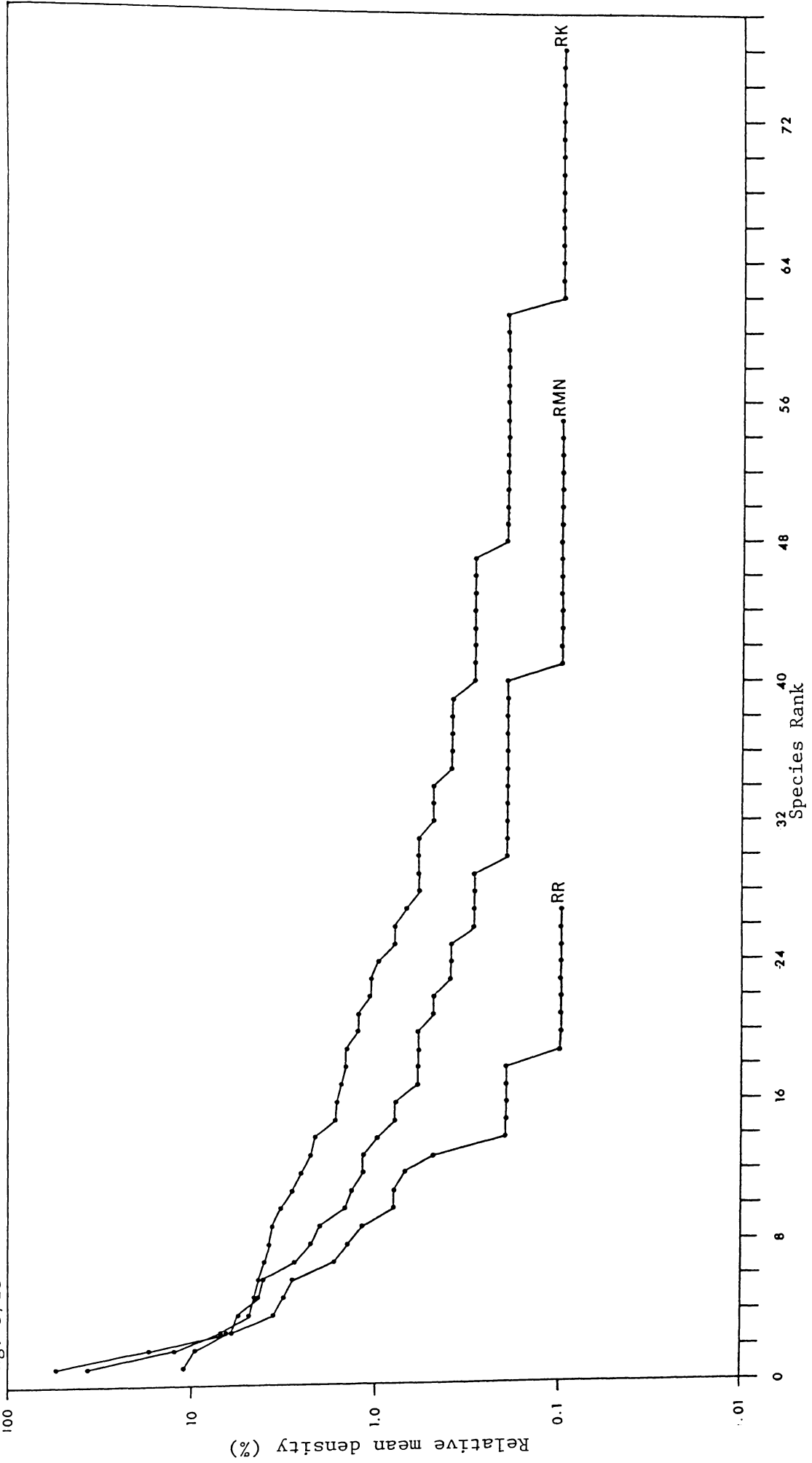
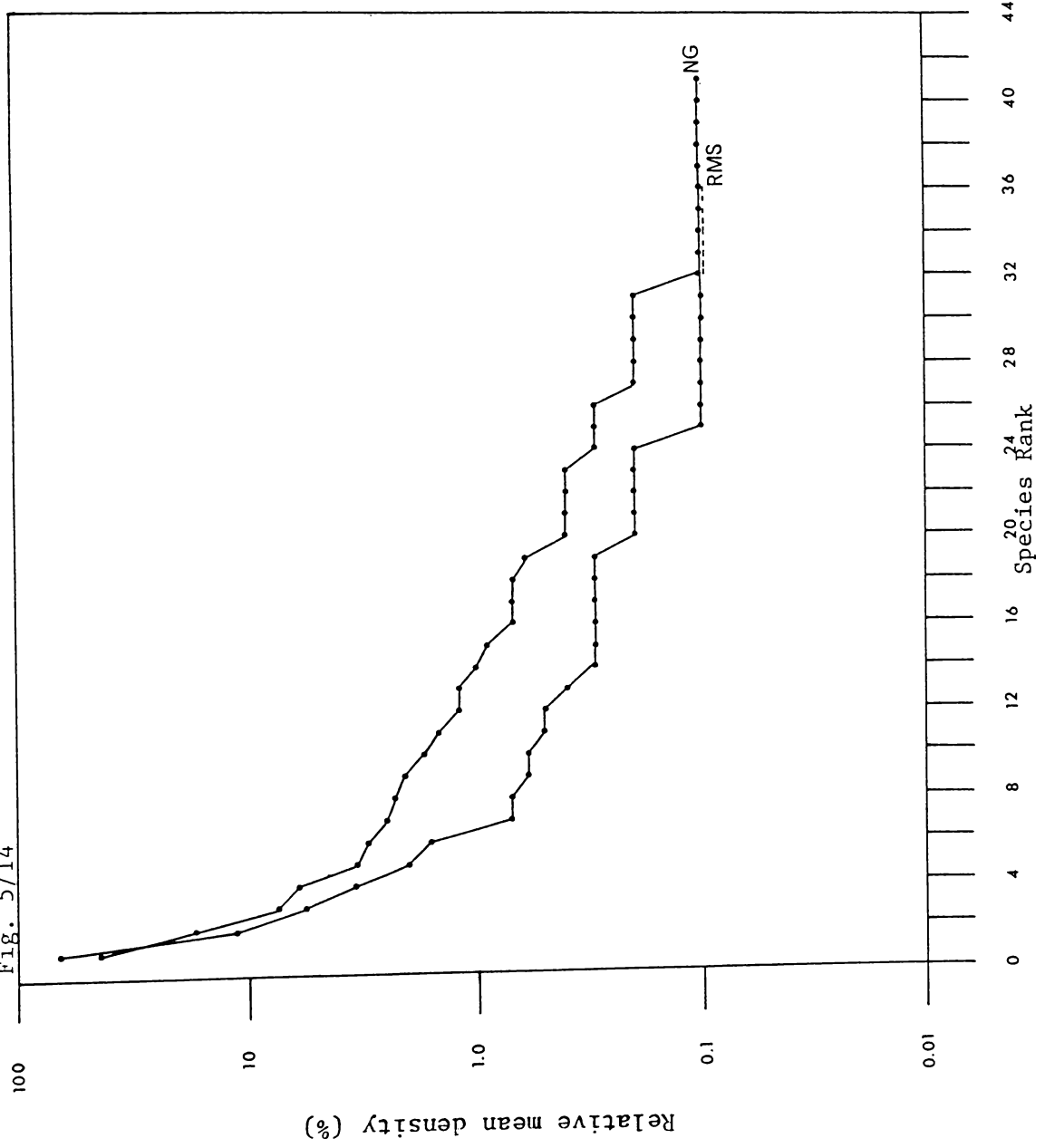


Fig. 5.14 Dominance - diversity curves (based on relative mean density of phytoplankton species with a mean contribution of $\geq 0.1\%$) for Lakes Ngaroto and Rotomanuka South (Group IV), July 1983 to July 1984 and October 1983 to July 1984, respectively. Species are ranked from the most to the least abundant. The identity of individual species can be obtained from Tables 4/20 and 4/35, respectively.

Fig. 5/14



5.5 DISCUSSION

The wide range of environmental parameters present in the study lakes (Chapter 3), was matched by an equally broad variation in community composition, species morphology and concentration of dominance.

Although many factors combine to determine phytoplankton diversity, the precise influence of any one is usually difficult to assess. Dystrophy is an exception because of the particularly distinctive stamp which it gives to a flora, and in the study lakes the affects of differing amounts of DHM are clearly evident. For example, the positive correlations between pH and both numbers of euechlorophytes and contributions of cyanophytes are similar to those reported from groups of European humic lakes (e.g., Ilmavirta 1983, 1984; Ilmavirta *et al.*, 1984). The diatom flora of Lake Maratoto was also typical of that found in other lakes with low pHs and calcium concentrations; for example, *Tabellaria flocculosa*, the most abundant species, is often common in such waters (Patrick 1945, 1948), and species of *Eunotia*, *Frustulia*, *Stenopterobia* and *Pinnularia*, which are classified as calciophobes (Patrick, 1977), were also present. Hustedt (1956) classified diatoms according to their pH preferences as follows:

- alkalibiontic - prefer pH > 7;
- alkaliphilus - occurring at pH about 7;
- indifferent - occurring over a wide range of pH;
- acidophilic - prefer pH < 7;
- acidobiontic - prefer pH ≤ 5;

and in terms of the ecological preferences of the species given by Patrick & Reimer (1966, 1975). Meriläinen (1967) and Chohnoky (1968), 72 and 71% of the Lake Maratoto and Lake Mangahia diatom floras respectively, were acidophilic, acidobiontic, or indifferent. Such preferences were not apparent in other study lakes.

Similarly, the relatively low α diversity of the Group I lakes, and the positive correlations between the mean number of species per sample per lake and both pH and Secchi disc transparency, are in agreement with the accepted link between dystrophy and low species

diversity (Nygaard, 1949; Järnefelt, 1958; Kristiansen, 1959). The number of species found in the Group I lakes and Lake Kainui were similar to those recorded in many European humic lakes (Ilmavirta 1984), but markedly higher than those reported from other brown-stained New Zealand lakes. Flint (1975), for example, identified only five species in Lake Gault, from net samples obtained during spring 1969 and summer 1970. A slightly higher, but still low α diversity (33 species), was reported from Lake Matheson from occasional samples taken in 1933, and 1965 to 1975 (Flint, 1979). Also, Paerl *et al.*, (1979) reported only 42 species (plus several unknown taxa) from nine darkly-stained Westland lakes sampled during March 1976, despite their approximately neutral pHs. Differences in either trophic status and/or amounts of DHM may be partially responsible for this variation in diversity, but probably different sampling intervals and techniques are a major causal factor; for example, water samples obtained with an integrated tube sampler (Chapter 2.3.1) from the centre of Lake Gault on 17.5.84, contained 36 taxa (Appendix X), and this number would undoubtedly increase if the lake was sampled as frequently as in the present study.

Comparisons of total species diversity recorded in Lake Maratoto during 1979 by Etheredge (1983) with values obtained during the present study, provide further evidence of the close relationship between low pH and meagre floras in dystrophic lakes, because there is evidence of a marked increase in surface pH during this time, and with it some significant floristic changes.

During a preliminary survey of the lake in summer 1979, the pH was 4.6, and almost no change was recorded with depth (Chapman & Boubée, 1977). The results of a long-term sampling programme (Boubée, 1983) also gave values ≤ 4.6 ; for example, between 16.12.77 and 10.4.80, pH ranged from 4.1 to 5.5. However, McCabe's (1985) study, which involved regular monitoring between 24.11.81 and 7.7.83, showed a range of 4.6 to 6.1. Finally, during the present study, pH ranged from 5.1 to 6.8 (median 5.5) (Chapter 3).

Throughout this period, changes in floristic composition also occurred. First, total species diversity increased by c. 100% (61 to 130 species); secondly, cyanophytes increased from 3 to 13 (4.9 to 10.6%); thirdly, diatoms increased from 30 to 36, but proportions declined from 49 to 29%; and fourthly, chorophytes, particularly euchlorophytes, increased in abundance (25 to 36%). Furthermore, *Synura sphagnicola*, a key member of European acid, brown-water floras

(Nygaard, 1949; Fott & Ludvík, 1957; Kristiansen, 1975), and also considered to be 'dominant' and 'rather common' in Lakes Gault and Matheson, two dystrophic South Island lakes (Flint, 1977), was an important taxon in 1979, but not during the present study.

As the Lake Rotomanuka North phytoplankton community was also sampled during 1979 (see Etheredge, 1983), and a similar comparative analysis with data from the present study revealed no major floristic changes (α diversities were 193 and 203, respectively), it cannot be argued that the Lake Maratoto floristic changes are simply a result of further sampling. Also it should be noted that cyanophytes are uncommon in waters of low pH (Brock, 1973), thus their increased proportion is further evidence of a link between pH and community structure.

The relative paucity of species in Lake Rotomanuka South may be due to its hyper-eutrophic condition (Chapter 7.3), because of the general trend of reduced species diversity with increasing eutrophy (Willén & Willén, 1978; Westlake, 1980). However, no one factor is considered responsible for the depauperate flora of Lake Kainui, but its low relative abundances of both chrysophytes and diatoms (Table 5/1) may result from a combination of both its relatively low silica concentrations (Table 6/36) and nitrate to phosphate ratios (Table 3/9) (see Chapter 6/4).

Lake Rotoroa, which did not stratify permanently during summer (Fig. 3/24), had a lower α diversity than other Group III lakes (Rotokauri and Rotomanuka North). This suggests that a long period of summer stratification, by allowing the development of marked, vertical niche differentiation (Lund, 1964; Reynolds 1976, 1978; Harris, 1980) was a key causal factor in high species diversity. This suggestion is supported by the observation that cryptomonads, some dinoflagellates and euglenophytes, which aggregate in large numbers within or below the metalimnion in Lake Rotomanuka North (Etheredge, 1983), were markedly higher in number in Lakes Rotomanuka North and Rotokauri which had the most stable summer stratification, than in Lake Rotoroa (Tables 4/36, 4/31 and 4/41, respectively). However, it is also likely that adulteration of the pelagic communities by facultative plankters, particularly desmids, from the extensive littoral macrophyte beds (Chapter 1.4.2), and the lower trophic status (Chapter 7.3), also contributed to the high species diversity in these two lakes.

Total α diversity of the study lakes appears markedly higher than that of any other intensively studied group of New Zealand lakes. For example, the entire flora of the Waitaki lakes (Benmore, Ohau, Pukaki and Tekapo) consisted of about 90 taxa (Duthie & Stout, 1986); 84 species (excluding varieties) were identified from five Northland dune lakes (Kanono, Parawanui, Taharoa, Waikere and Waingata) (Cassie & Freeman, 1980); only c. 100 phytoplankters were found during a survey of three lakes from the Rotorua Lake district (Rotoehu, Rotoiti, and Rotoma) (Cassie, 1978); and 57 species were recorded from Lakes Hayes and Johnson (Burns & Mitchell, 1974).

Although the accuracy of species counts is influenced to some degree by sampling and counting methods, plus the level of expertise and zeal of the taxonomist, the comparatively high total species diversity in the study lakes, is probably mainly due to the broad range of morphometric, physico-chemical and biological parameters within the group (Chapters 1 and 3). Comparisons at the generic level (to minimise differences in taxonomic rigour and accuracy) between mean numbers found in the study lakes and those recorded in other groups of New Zealand, tropical and temperate lakes (Table 5/18), confirm this remarkably high diversity, despite the hyper-eutrophic status suggested for six of them (Chapter 7.3).

A notable feature of the study lakes was the relatively high numbers of euglenophytes compared to those found in other groups of New Zealand lakes that have been the focus of detailed investigations (Table 5/19). Because euglenophyte floras are generally very sparse in oligotrophic waters (Nygaard, 1949; Round, 1957), their absence from both Northland and Waitaki lakes is not surprising. However, numbers found in Lakes Hayes and Johnson, and also the eutrophic Rotorua lakes, excluding Rotoehu, are surprisingly low.

There have been few ecological studies of the Euglenophyceae, but their facultative heterotrophy, and use of ammonia and organic nitrogen as major nitrogen sources, are well-documented (e.g., Wetzel, 1975). In the present study, particularly high numbers were recorded in the two lakes with the most stable thermal regimes (Rotomanuka North and Rotokauri). In both these lakes, high densities (with one exception), coincided with periods of marked stratification, as was the case in Lake Rotomanuka North during 1979 (Etheredge, 1983), when *Phacus agilis*, in particular, displayed distinct preferences for the hypolimnion and metalimnion during oxic and anoxic periods,

TABLE 5/18 Comparisons between the mean number of genera found in the nine study lakes (July 1983 to July 1984) and other New Zealand, tropical and temperate lakes.

Region	Mean number of Genera \pm 1 SD	Number of lakes	Reference/s
New Zealand			
Waikato	74 \pm 12	9	Present study
Northland ¹	18 \pm 5	5	Cassie & Freeman (1980)
Rotorua ²	39 \pm 10	11	Cassie (1969, 1978); Forsyth & McColl (1975); Flint (1977); Etheredge (unpublished data)
Westland ³	16 \pm 4	8	Paerl <i>et al.</i> , (1979)
South Westland ⁴	30 \pm 9	3	Flint (1979)
Waitaki ⁵	54 (total number)	4	Duthie & Stout (1986)
Central Otago ⁶	31 \pm 1	2	Burns & Mitchell (1974)
Tropical	21 \pm 5	10	Lewis (1978b)
Temperate	36 \pm 16	10	Lewis (1978b)

¹ Includes Lakes Kanono, Parawanui, Taharoa, Waikere, Waingata.

² Includes Lakes Ngahewa, Ngapouri, Okareka, Okaro, Okataina, Rotokakahi, Rotoehu, Rotoiti, Rotoma, Rotorua, Tararewa.

³ Includes Lakes Ahaura, Brunner, Haupiri, Hochstetter, Kangaroo, Kaniere, Lady, Poerua.

⁴ Includes Lakes Mapourika, Matheson, Wombat.

⁵ Includes Lakes Benmore, Ohau, Pukaki, Tekapo.

⁶ Includes Lakes Hayes, Johnson.

TABLE 5/19 Numbers of euglenophytes (including varieties) found in the study lakes, and other New Zealand groups of lakes which have been the focus of detailed investigations.

Area	Lake	<u>Euglenophyta Taxa (including varieties)</u>				Reference
		Group Total		Group Total		
		No.	%	No.	%	
Waikato	Kainui*	8	7.4			Present study
	Mangahia*	19	15.2			
	Mangakaware*	19	11.5			
	Maratoto*	12	9.8			
	Ngaroto*	16	9.6			
	Rotokauri	33	16.2			
	Rotomanuka North*	27	14.1			
	Rotomanuka South*	14	11.9			
	Rotoroa*	17	11.6			
				63	16	
Northland	Kanono	0	0			Cassie & Freeman (1980)
	Parawanui	0	0			
	Taharoa	0	0			
	Waignata	2	5.9			
	Waikere	0	0			
				2	2.3	
Rotorua Lakes District	Rotoiti	3	3.4			Cassie (1974)
	Rotorua*	3	2.0			
				3	2.6	

Rotorua	Rotoehu*	3	6.5			Cassie (1978)
Lakes	Rotoiti*	1	1.6			
District +	Rotoma	1	2.4			
Lake	Waikaremoana	0	0			
Waikaremoana				3	3.3	
Rotorua	Ngapouri*	3	5.3			Flint (1977)
Lakes	Okareka	2	4.3			
District	Okaro*	3	5.8			
	Okataina	1	2.0			
	Rotokakahi	3	5.8			
	Rotoma	2	3.8			
	Tikitapu	2	4.5	3	2.7	
Waitaki	Benmore	0	0			Duthie & Stout
Lakes	Ohau	0	0			(1986)
	Pukaki	0	0			
	Tekapo	0	0	0	0	
Central	Hayes*	1	2.5			Burns & Mitchell
Otago	Johnson*	1	2.5			(1974)
				2	3.5	

* Classified as eutrophic at time of investigation.

respectively. However, thermal stability cannot have been responsible for high euglenoid diversity in other study lakes. It is possible that the frequent mixing episodes, so characteristic of these lakes (Chapter 3), resulted in an almost continuous resuspension of these species from the organic-rich, bottom sediments, which are regarded as their preferred habitat (Round, 1957).

The low mean compositional overlap of the phytoplankton communities (even within lake groups categorised by similar pH, water colour and Secchi disc transparency) (Tables 5/3 to 5/9) and the considerable range in mean ISIs (Table 5/16), are probably also attributable to this mosaic of potential habitats. However, although only 24 species were found in all nine study lakes (Table 5/10), 16 ranked as important species in at least one lake suggesting that the study lakes contain a small core of ecologically very versatile species. The most ubiquitous of these were *Trachelomonas volvocina*, *Cryptomonas ovata* (including *C. marssonii*) and *Closterium acutum* var. *variabile*. (ranked as important in nine, seven and six lakes, respectively), followed by *Monoraphidium contortum* and *Cyclotella stelligera*, both of which were important taxa in four lakes.

Except for *Monoraphidium contortum*, the ecological preferences of these taxa are especially well known, and match the conditions in the study lakes. *Trachelomonas* is a tolerant genus, but shows a definite preference for habitats with a high organic content (Järnefelt, 1952; Rao, 1955; Weik & Mohlenbrock, 1963); *T. volvocina* is regarded as a eutrophic indicator, and is common in the floras of moderate and rich humic lakes (Rosén, 1981). *Cryptomonas* spp. are also abundant in a wide variety of lake types (Rosén, 1981; Stewart & Wetzel, 1986), and are often dominant at various stages of the annual phytoplankton cycle in dystrophic lakes (Stockner & Shortreed, 1975; Ramberg, 1976; Ilmavirta *et al.*, 1977; DeNoyelles & O'Brien, 1978). *Closterium acutum* var. *variabile*, while present in many New Zealand lakes of varying trophic status (Croasdale & Flint, 1986), often occurs at high densities in eutrophic waters (Rosén, 1981). It is regarded as a strong, eutrophic indicator by both Teiling (1955) and Coesel (1975, 1983). In the present study, exceptionally high densities were recorded in Lakes Rotomanuka South, Mangahia and Kainui (19,300,

13,900 and 11,000 pu ml⁻¹, respectively) (Chapter 6). The maximum recorded in Lake Rotomanuka South, is comparable to that recorded in Lake Johnson (20,300 cells ml⁻¹), a eutrophic, South Island lake (Burns & Mitchell, 1974). *Cyclotella* is included in the classical, oligotrophic diatom association of Hutchinson (1967). However, some workers (e.g., Rawson [1956] and Stoermer [1978]), consider that an abundance of this genus is not necessarily indicative of oligotrophy. In New Zealand, *Cyclotella stelligera* is the most commonly occurring member of the genus. It is present in many lakes (Cassie, 1984a) and is a species of major importance in lakes of varying trophic status; for example, eutrophic Lake Rotorua (Cassie, 1975), several mesotrophic, South Island high country lakes (Horseshoe, Ida and Pearson) (Flint, 1975), and oligotrophic lakes such as Ototoa (Green, 1976a) and Haupiri, a heavily-stained, Westland lake (Paerl *et al.*, 1979). *Monoraphidium contortum* has been recorded on three previous occasions in New Zealand: Lake Ellesmere (Lineham, 1983); Templeton oxidation pond as *Raphidium contortum* (Thuret) Legnerová (Flint, 1966); and Lake Okareka, as *Ankistrodesmus contortus* Thuret (Thomasson, 1974a). Lake Ellesmere is large, brackish and eutrophic (Lineham, 1983), and differs markedly from Lake Okareka, which is oligo-mesotrophic and of volcanic origin (Chapman *et al.*, 1985). Thus it appears that *Monoraphidium contortum* has a broader ecological amplitude than stated by Huber-Pestalozzi *et al.*, (1983), and is equally as tolerant as the other four major species.

However, densities of species may increase (and decline) exceedingly rapidly when ecological changes occur and several examples of this strategy were noted during the study period. The two most spectacular cases occurred in Group I lakes, when *Chlamydomonas* sp. C (Lake Maratoto) (Chapter 6.1.4.5) and *Chlorella* sp. (Lake Mangahia) (Chapter 6.1.2.5) made brief appearances in their communities, but in that time achieved extremely high densities. Similarly, *Dinobryon bavaricum* achieved sudden prominence in Lake Rotorua (although the increase was not as pronounced as those in the Group I lakes), and reappeared, albeit at low densities, on two further occasions (Chapter 6.1.9.5).

The nine lakes contained a large 'hidden' flora. Of all species identified during the present study, 33% were found in only one of the

nine study lakes (Table 5/12), and a further 70 species were recorded in two lakes only (Appendix VII). Thus 50% of all taxa were restricted in their distribution. Of these, very few (3%) were categorised as important species and, not unexpectedly, the greater number were found in Lakes Rotokauri and Rotomanuka North (Table 5/13), where neutral pH, moderately clear water, stable stratification patterns and moderate nutrient levels presumably provided a less stressful habitat than was present in the other seven lakes (Chapter 3).

Two alternative hypotheses are proposed to explain the large 'hidden' flora: (1) that narrow ecological amplitudes restricted these phytoplankters to one or two lakes; (2) that a 14 day sampling interval did not give an accurate representation of the flora of individual lakes; or conversely, a more intensive sampling programme would have reduced the size of the 'hidden' flora. Undoubtedly, some species would have shown a wider distribution within the nine lakes, had the sampling programme been either longer or more intensive; however, as discussed previously, a comparative analysis of the floristic composition of Lake Rotomanuka North during 1979 (Etheredge, 1983) and the present study, suggests that such changes would be minor. Although detailed ecological profiles are not available in the literature for the majority of the rare taxa (Table 5/12), the specific preferences of some are well-documented, and indicate that many of these species must have been nearing their tolerance limits. In particular, several of the desmids (*Closterium leibleinii*, *Euastrum praemorsum* and *Penium margaritaceum*) are associated with oligotrophic waters (Croasdale & Flint, 1986), as is *Dinobryon elegantissimum* (Rosén, 1981). Many of the euglenoids (*Euglena ehrenbergii*, *E. sanguinea*, *E. spirogyra* var. *suprema* and *E. tripteris*) are usually found in shallow water, ponds or ditches, and both *Palmodictyon* and *Tetradinium* are considered tychoplankters, normally inhabiting shallow, vegetated areas (Prescott, 1962).

The study lakes also had low numbers of flagellated species (Table 5/17), especially chrysophytes and cryptophytes. This contrasts markedly with their high numbers in some Northern Hemisphere humic lakes; for example, Ilmavirta *et al.*, (1984) identified 45 chrysophycean taxa from a group of Finnish, polyhumic lakes. As the majority of the study lakes are polymictic, especially the more

darkly-stained lakes, motility is not necessarily a prerequisite for a successful existence, in contrast to the situation in monomictic lakes; and in this connection, it is interesting to note that the mean proportions of flagellates in the Group I to III lakes were similar (Table 5/17), but considerably more flagellates were ranked as important taxa in the Group III lakes (Table 5/15). The reverse trend occurs in Finnish humic lakes, where the most darkly-stained waters contain the highest numbers of flagellated species (Ilmavirta *et al.*, 1984). Another notable feature of community composition was the absence of genera such as *Uroglena* and *Chromulina* (Chrysophyceae), and *Chroomonas* and *Katablepharia* (Cryptophyceae), which play key roles in the community dynamics of Finnish lakes (Ilmavirta *et al.*, 1984).

After a study of 32 humic lakes in southern Finland, Ilmavirta (1983) concluded that water colour or transparency, and the depth of the trophogenic layer, were the major determinants of phytoplankton composition in brown-water lakes, and suggested that nutrient concentrations played a minor role. However, the present study suggests that while DHM influenced both α diversity and community composition at various taxonomic levels, other factors such as nutrient concentrations and morphometry were equally important in determining the structure of the phytoplankton communities. For example, there were definite relationships in some lakes between nutrient concentrations and some well known indicator species. *Mallomonas akrokomos*, one of the most common species in a large number of oligotrophic, humic, Finnish lakes (Ilmavirta 1980, 1982; Ilmavirta *et al.*, 1984), ranked as an important species only in a Group III lake (Rotokauri); and *Dinobryon* spp. (oligotrophic indicators [Rosén, 1981]), which also are typical components of the phytoplankton associations in certain humic, Finnish lakes (Ilmavirta 1980, 1982), also occurred, with one exception, as important species in Group III lakes only (Rotomanuka North and Rotoroa). As Group III lakes had consistently lower total phosphorus concentrations than those of Groups I and II (Table 3/9), and were the least productive (Table 7/1), it suggests that in this instance, relatively low nutrient levels rather than brown water colour and decreased transparency, were the major controlling factor. Similarly, if the distribution and abundance of *Aulacosira distans*, a well-documented acidophilous

species (Meriläinen 1967, 1969; Foged, 1979; Dixit & Dickman, 1986), was regulated by water colour or transparency in the study lakes, then it could be expected to rank as an important species in both Group I lakes, and not just Lake Mangahia (Table 5/15). It is highly probable that morphometric differences (in particular the shallow nature of Lake Mangahia [Table 1/0] which permits more extensive mixing and therefore resuspension of diatoms) were responsible. Phosphorus was not considered a regulatory factor because the proportion of *Aulacosira distans* in a community is known to decrease with increasing phosphorus concentrations (Meriläinen *et al.*, 1982), and concentrations were lower in Lake Maratoto than in Lake Mangahia (Table 3/9). Silica concentrations were not minimal (Table 6/36). Undoubtedly, morphometry also was a major determinant in the distribution and abundance of the second important filamentous diatom species, *Aulacosira granulata* var. *angustissima*, which was important in the two shallowest lakes only (Mangahia and Ngaroto).

The study lakes also varied considerably in the degree to which dominance was concentrated amongst the major species. In terms of biomass, the most dystrophic (Maratoto [Chapter 3.5]) and/or hyper-eutrophic (Ngaroto and Rotomanuka South [Chapter 7.3]) lakes, had the strongest concentrations of dominance (Figs. 5/3, 5/7 and 5/8, respectively). No comparative New Zealand data are available except for those given in Etheredge (1983) for Lakes Maratoto and Rotomanuka North during 1979. In the former, three and four species constituted 95% of the mean standing crop, in terms of biomass and abundance, respectively; and in Lake Rotomanuka North, the equivalent numbers of species were nine and thirty-two. A strong concentration of dominance amongst a few species has also been documented in some Finnish lakes, where generally six or seven species have been responsible for 70% of total biomass and 90% of the total number of individuals (Ilmavirta, 1984b). In tropical Lake Lanao (annual average wet biomass 23,745 mg m²) Lewis (1978b) recorded 13 species, in terms of biomass, as comprising 90% of the standing crop.