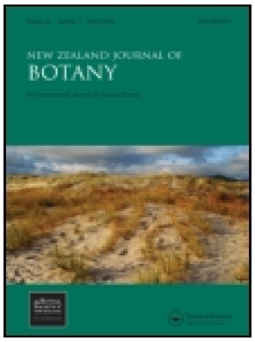

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Observations on some chemical parameters and the phytoplankton of five west coast dune lakes in Northland, New Zealand

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Abstract In a survey at different seasons from April 1976 to September 1977 an analysis of temperature, conductivity, oxygen, ammonia, soluble phosphate, nitrate, and algal taxonomy was carried out in five west coast dune lakes in Northland. Chemical data indicated that the Pouto group lakes (Kanono, Waingata, and Parawanui) did not possess significantly higher nutrient levels than the Kai-iwi group (Taharoa, Waikere). Preserved phytoplankton from Lakes Kanono and Parawanui was mainly diatom-dominated, whereas that from Lakes Waingata, Taharoa, and Waikere consisted almost entirely of desmids and dinoflagellates. Evidence for increasing eutrophication in Lake Kanono came from the presence, though in small quantities, of the diatom *Fragilaria crotonensis* and blue-green algae including *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*. Some of the lesser-known algae are described and illustrated. Several new records have been made for the freshwater algal flora of New Zealand.

Keywords freshwater phytoplankton; desmids; diatoms; dinoflagellates; water chemistry; eutrophication; ecology; taxonomy; dune lakes; Northland, New Zealand

INTRODUCTION

Between April 1976 and September 1977 a survey was made by the Northland Catchment Commission and Regional Water Board of various chemical parameters in five west coast dune lakes in Northland: Kanono, Waingata, Parawanui, Taharoa, and Waikere (Fig. 1), in relation to the algae present. Although Cunningham *et al.* (1953), Cunningham (1957), Fish (1966), Jolly (1968), Stout (1975), and Green (1975a, b; 1976) have all discussed limnological characteristics of these lakes, there has not been a detailed study of their algal populations. Relevant geographic and morphometric data (Table 1) have been compiled by Irwin (1975).

Cunningham *et al.* (1953) did not study the species comprising the phytoplankton algae in the Northland dune lakes, except to note that a trace of diatoms was found in Lake Kanono. A few observations on changes in generic dominance in Lake Waingata were made by Fish (1966); during 3 years from 1962 to 1965 there was a shift in dominance from desmids and diatoms to *Dinobryon*, *Ceratium*, *Zygnema*, and *Staurastrum*. Green (1975a) noted that *Dinobryon* was dominant for a time in Lake Ototoa and (1976) described an oligotrophic diatom–desmid assemblage associated with *Botryococcus*, *Dinobryon*, and *Sphaerocystis*. Stout (1975) made the general comment that the dominant phytoplankters in New Zealand sand dune lakes are diatoms, peridineans, and green algae.

The Northland dune lakes studied have basins that can be depressions in sand, of younger or older Pleistocene origin (Ferrar 1934). They consist of basin lakes, surrounded by flat or gently undulating slopes, and were formed by accumulation of rainwater in hollows of older consolidated dunes (e.g., Lake Waingata) or between consolidated and moving foreshore dunes (e.g., Lake Kanono). Few Northland lakes have outlet streams. A strong spring flows into Lake Kanono under recently blown sands; this drains a previous swampy area now filled with drift sand, which supports a rich growth of raupo (*Typha orientalis* C. B. Presl.). Fish (1966) notes that Lake Waingata has an underground water flow through the sandy soil surrounding it. Seasonal lake levels apparently do not fluctuate markedly.

All these lakes are exposed to prevailing westerly winds, which have rapidly eroded eastern

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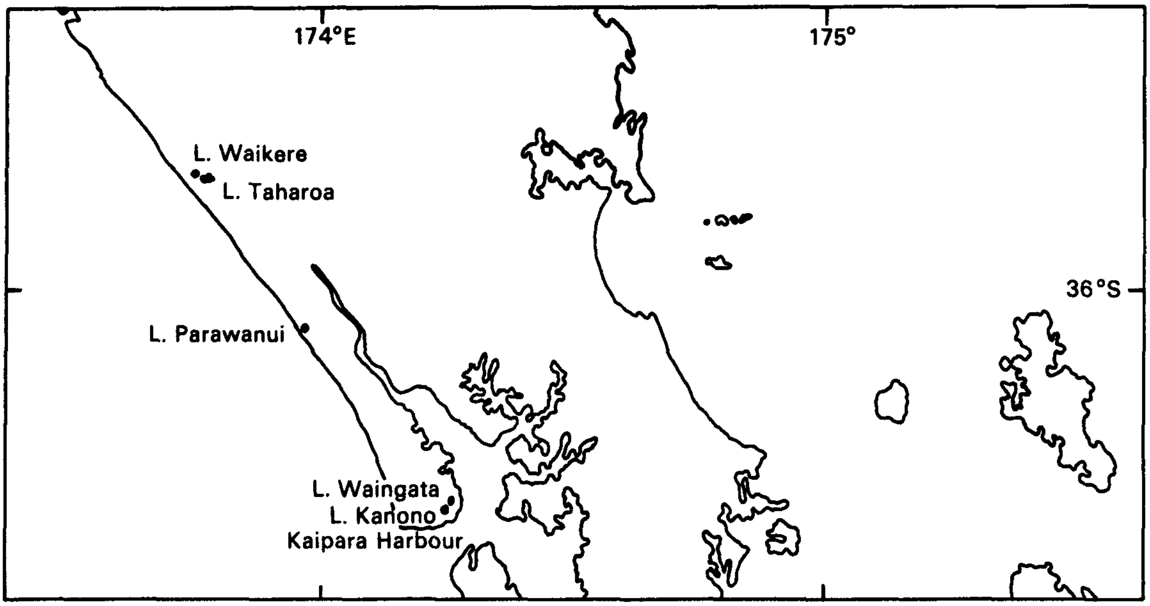

Fig. 1 Position of the five Northland dune lakes on the northern arm of Kaipara Harbour.

shorelines. That of Lake Kanono has prominent cliffs and stacks. Moving dunes encroach from the western foreshore of this lake.

METHODS

To carry out a sampling programme over 2 separate days the lakes were divided into two groups:

(a) Pouto group (L. Kanono, L. Waingata, L. Parawanui);

(b) Kai-iwi group (L. Waikere, L. Taharoa).

Samples were obtained from a boat anchored over the deepest part of each lake. The soft nature of the lake bottoms made the use of an echo-sounder ineffective in determining the deepest parts. Several visual position lines were used later to re-establish the sampling sites. Sampling of sub-surface waters was carried out by using a prototype depth sampling device consisting of a stainless steel cannister containing a 600-ml glass bottle (Fig. 2). A double-port sleeve valve (one port for water entry, the other for air escape) situated on top of the cannister permitted samples to be collected at the desired depth. The valve is activated by sharply jerking the suspension line which overcomes a spring-loaded catch and permits the barrel of the sleeve valve to rotate, thereby opening ports for water entry and air escape. After the bottle is filled, the valve is closed by a return spring when tension on the line is momentarily released (see Fig. 2). At least four samples were obtained from different depths, at intervals of 2–10 m according to the depth of the lake (Tables 2–7), the depth being read from the calibrated line of the sampling device. Samples for the identification of algae were obtained from the surface and bottom at the sites. Each 600-ml sample was chilled, kept in the dark, and then transported to the laboratory of the Northland Catchment Commission and Regional Water Board at Whangarei for analysis by P. T. Freeman up to 24 hr after collection*. Before being autoclaved the glass bottles were soaked in 50% sulphuric acid overnight, as recommended in American Public Health Association (1971), and the National Water and Soil Conservation Manual Vol. 2 (unpublished 1973–1974, Ministry of Works and Development, Wellington); as adequate preparation for samples containing NO_3-N and PO_4-P. Algal samples were preserved in Transeau's solution and posted to Auckland for investigation by V. Cassie.

Temperature, oxygen saturation, and conductivity were measured *in situ*. Oxygen and temperature were estimated with a pre-calibrated E.I.L. dissolved-oxygen meter. Temperature records were checked against a mercury thermometer. Conductivity was measured with a Y.S.I. conductivity meter and corrected to 25°c. All samples for soluble nutrient analysis were first filtered through G.F.C. filter paper to remove algae and detritus, and then analysed colorimetrically with a Bausch and Lomb "Spectronic 20" spectro-

*American Public Health Association (1971) suggests a reasonable maximum time limit of 72 hr for unpolluted samples (under the above conditions), and 48 hr for slightly polluted samples, between collection and analysis.

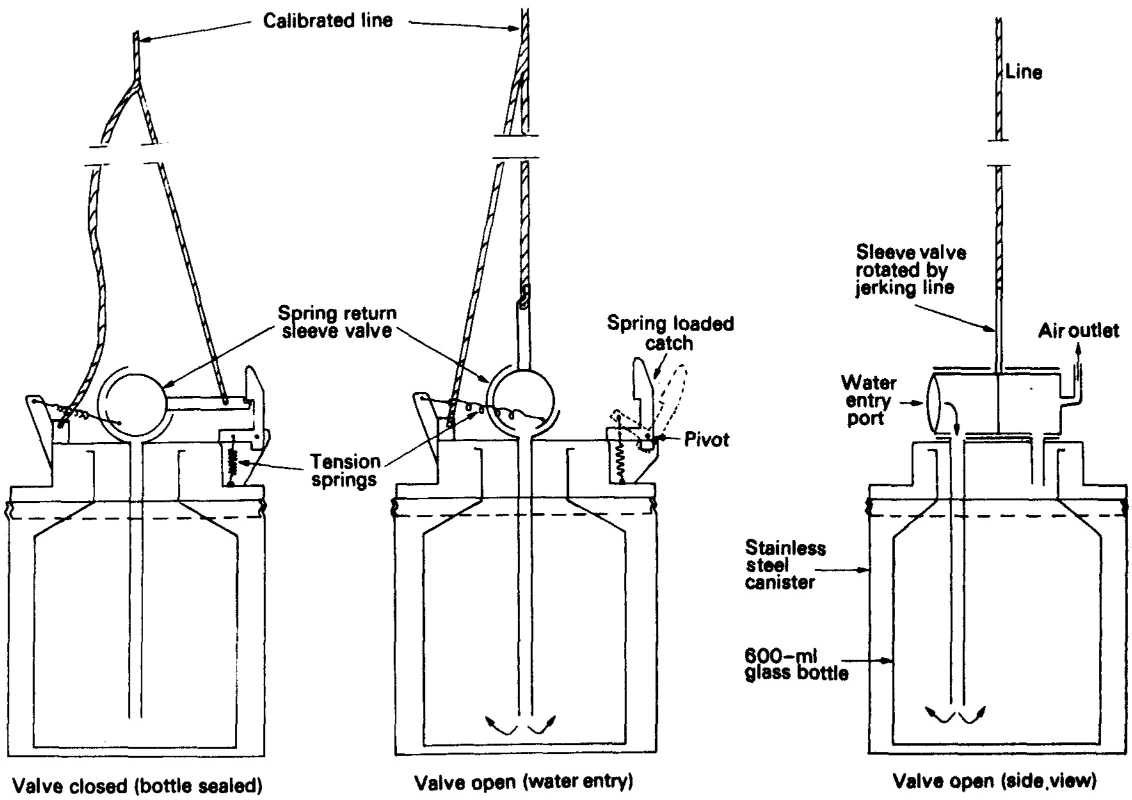

Fig. 2 Depth sampler designed by members of the Hydrology Department, Ministry of Works and Development, Christchurch.

photometer. Ammonia was determined by the direct nesslerization method (American Public Health Association 1971), minimum recordable value 16 $\mu g\ l^{-1}$. Soluble phosphate was measured by the ascorbic acid reduction method (American Public Health Association 1973), minimum recordable value 10 $\mu g\ l^{-1}$. Nitrate was determined by the semi-micro modification of the cadmium column reduction method (American Public Health Association 1971; Chemistry Division [DSIR] Report on Nitrate by Cadmium Column Reduction, unpublished 1973), minimum recordable value 5 $\mu g\ l^{-1}$.

Algal genera and species were determined using a Zeiss Universal Microscope with interference and phase-contrast objectives and photo-automatic attachments. Scanning electron micrographs were taken with a JEOL JSM-U3 scanning electron microscope. The chief texts consulted for identifications were those of Nordstedt (1888), Geitler (1932), Huber-Pestalozzi (1938, 1942, 1955, 1968), Desikachary (1959), Prescott (1962), Prescott *et al.* (1972, 1975), Krieger & Gerloff (1962–1969), Thomasson (1960, 1972, 1973, 1974a, b), Patrick & Reimer (1966, 1975), and Bourrelly (1966, 1968, 1970). Subjective estimations of abundance were made on a 1–5 scale (after Cassie 1974; Appendix 1).

RESULTS

Hydrological and chemical data (Tables 2–7) were recorded from samples collected in September and December 1976, and in May and September 1977.

Temperature

Water temperatures ranged at the surface from 11.0 to 23.5°C, and at the bottom from 11.0 to 20.5°C (Lake Waingata). In December 1976 thermal stratification was found in Lake Parawanui and Lake Waingata, and probably occurred elsewhere at times (Tables 3, 4). Stratification probably occurred at times in the summer in the absence of wind. Green (1975a) found Lake Ototoa to be homothermous during winter, but marked stratification occurred in December and January; and Fish (1966) noted that the open waters of Lake Waingata were isothermal except on a few occasions in summer. Cunningham *et al.* (1953) did not find a thermocline in Lake Kanono.

Table 1 Geographic and morphometric data (after Irwin 1975).

Lake	NZMS 1 grid ref.	Location	Altitude (m)	Type	Area (sq. km)	Maximum length (km)	Maximum width (km)	Notes
Kanono	N33:688190	3.0 km WSW of Pouto township	30–61	W[a]	0.84	1.5	0.8	Adjacent to bare sandhills in sand and swampland. Coastal.
Waingata	N33:675204	2.8 km NW of Pouto township	30–61	W	0.29	1.0	0.6	In sandhills and swampland.
Parawanui	N27:376552	7.1 km SW of Te Kopuru township	30–61	W	0.13	0.7	0.2	In coastal sand-dunes.
Taharoa	N22:170860	3.2 km NNE of Kai-iwi stream mouth.	70–0	W	2.10	2.6	1.3	In consolidated sand-dunes near coast adjacent to swampland. Maximum depth 37.0 m (Irwin 1971).
Waikere	N22:152868	3.7 km NNW of Kai-iwi stream mouth	79–0	W	0.35	0.8	0.7	Landward side of consolidated coastal sand-dunes adjacent to swampland. Maximum depth 30.0 m (Irwin 1971).

[a]Formed by wind

pH
The pH was lowest in Lake Taharoa (Table 5) and highest at the surface of Lake Kanono (Table 2). Surface values tended to be slightly higher than those at depth in summer (cf. Green 1975a for Lake Ototoa, who recorded a range of 7.2–8.7, the lowest values occurring when phytoplankton stocks were low).

Oxygen
The percentage oxygen saturation was high at most depths and in all seasons, values reaching super-saturation in nearly all samples. An exceptionally low value of 14% was recorded at the bottom of Lake Taharoa at Massey Basin on 22 April 1976. This low oxygen level together with a higher ammonia value (q.v.) probably results from the presence of an unmixed anaerobic layer of mud on the bottom.

Ionic concentration
Major ions were not investigated. Ammonia values were mostly very low, being scarcely detectable, with one exception (Lake Taharoa, at 24 and 28 m, on 22 April 1976, when 450 $\mu g\ l^{-1}$ was recorded). Values were slightly higher in Lake Parawanui (up to 200 $\mu g\ l^{-1}$). Amounts of nitrate and phosphate were also scarcely detectable in many samples from all lakes, except Lake Parawanui where 60 $\mu g\ l^{-1}$ of nitrate were recorded 2 m below the surface. Maximum values for phosphate generally did not exceed 42 $\mu g\ l^{-1}$ and there was no pronounced seasonal variation. By comparison, Green (1975a) recorded a minimum nitrate concentration in the nearby Lake Ototoa of 0.17 mg l^{-1}, and a maximum of 0.6 mg l^{-1}. Phosphate concentrations in Lake Ototoa were lower than in the Pouto and Kai-iwi lakes (1.0–10.2 $\mu g\ l^{-1}$).

Conductivity
Values tended to be high in all five lakes. Highest values were recorded for Lake Parawanui (367–408 μmho, Table 4).

Coliform counts
In most samples fewer than 1 colony per ml^{-1} was counted. Again Lake Parawanui provided an exception, having up to 52 coliform bacterial colonies ml^{-1} at the surface (5 May 1977).

PHYTOPLANKTON
The chief feature of the planktonic algal populations of the lakes was the extreme paucity of cell numbers — a fact which was evidenced by the difficulty of finding algae even in the concentrated samples. Seldom were any species found to be abundant and single-species dominance was rare. Diatoms were the commonest algae in Lakes Kanono and Parawanui. The other three lakes supported a mixture of desmids and dinoflagellates with other classes being poorly represented or absent, except for Cyanophyceae in Lake Kanono (Appendix 1, Table 8). Eighty-four algal species were identified (excluding varieties), distributed among the major classes (after Bourrelly 1968):

Chlorophyceae	35
Diatomophyceae	28
Cyanophyceae	10
Dinophyceae	5
Chrysophyceae	3
Euglenophyceae	2
Xanthophyceae	1
Total	84

Table 2 Hydrological and chemical data for Lake Kanono.

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O^2	NH^3–N ($\mu g.l^{-1}$)	NO^3–N ($\mu g.l^{-1}$)	PO^4–P ($\mu g.l^{-1}$)	Conductivity (μmho)
22.9.76	13.05	Surface	14.0	7.80	108	—	tr	—	151
22.9.76		2.0	14.0	7.90		—	tr	16	150
22.9.76		4.5	14.0	7.90		tr	tr	56	153
22.9.76		7.0	13.9	7.90		tr	5	tr	156
22.9.76	12.35	9.0	13.5	7.60	100	40	5	—	156
7.12.76		Surface	21.3	8.25	112	—	—	tr	157
7.12.76		3.0	20.5	8.85	103	tr		tr	154
7.12.76		6.0	20.0	7.90	102	—		tr	154
7.12.76		9.0	20.0	7.45	100	tr		tr	162
7.12.76	10.50	12.0	19.0	7.40	92	tr	tr	10	161
5.5.77	11.45	Surface	14.5	7.70	104	—	5	13	
5.5.77		5.0	14.8	7.70	108	tr	5	13	
5.5.77		10.0	14.8	7.70	108	tr	tr	16	
5.5.77	11.30	12.0	15.0	7.80	98	—	tr	20	
8.9.77		Surface	11.5	7.35	110	16	tr	tr	162
8.9.77		4.0	11.5	7.35	112	tr	—	—	162
8.9.77		8.0	11.5	7.30	110	—	5	—	156
8.9.77	10.45	11.0	11.5	7.30	110	—	tr	tr	156

tr = trace

Table 3 Hydrological and chemical data for Lake Waingata.

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O_2	NH_3–N ($\mu g.l^{-1}$)	NO_3–N ($\mu g.l^{-1}$)	PO_4–P ($\mu g.l^{-1}$)	Conductivity (μmho)
22.9.76	14.15	Surface	15.0	6.9	120	40	7	tr	150
22.9.76		2.5	15.0	7.0		—	tr	tr	148
22.9.76		5.0	14.2	6.6		—	tr	tr	150
22.9.76	14.00	7.5	14.0	7.0	100	—	5	26	148
7.12.76		Surface	23.5	6.95	120	tr	tr	13	146
7.12.76		3.0	22.0	6.85	113	40		10	148
7.12.76		6.0	21.0	6.60	98	40		20	146
7.12.76	11.45	8.0	20.5	6.50	80	tr	—	10	152
5.5.77	11.45	Surface	14.0	7.0	110	16	5	13	
5.5.77		3.0	14.0	7.0	110	tr	5	20	
5.5.77		6.0	14.0	7.0	112	tr	10	16	
5.5.77	12.30	7.0	14.0	7.1	112	40	7	26	
8.9.77		Surface	11.0	7.35	108	tr	tr	—	156
8.9.77		3.0	11.0	7.40	114	—	tr	—	156
8.9.77		6.0	11.0	7.50	112	16	5	tr	162
8.9.77	11.30	8.0	11.0	7.40	112	tr	5	7	162

tr = trace

Table 4 Hydrological and chemical data for Lake Parawanui.

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O_2	NH_3–N ($\mu g.l^{-1}$)	NO_3–N ($\mu g.l^{-1}$)	PO_4–P ($\mu g.l^{-1}$)	Conductivity (μmho)
7.12.76		Surface	23.5	7.10	132	120	50	13	372
7.12.76		2.0	22.0	7.00	120	160		13	311
7.12.76		5.0	21.0	7.00	104	120		13	367
7.12.76		7.0	19.0	7.05	82	140		10	375
7.12.76	15.00	9.0	18.5	6.90	66	140	160	13	370
5.5.77		Surface	15.0	7.00	99	200	tr	33	
5.5.77		5.0	15.0	6.90	100	120	5	33	
5.5.77		8.0	15.0	7.00	100	80	5	26	
5.5.77	14.45	10.0	15.0	6.90	100	120	7	42	
8.9.77		Surface	12.7	7.10	116	40	20	tr	384
8.9.77		4.0	12.5	7.05	116	40	20	tr	384
8.9.77		8.0	12.5	7.05	116	70	20	tr	384
8.9.77	13.30	9.5	12.5	7.10	112	tr	9	7	408

tr = trace

Table 5 Hydrological and chemical data for Lake Taharoa (Massey Basin).

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O_2	NH_3−N ($\mu g.l^{-1}$)	NO_3−N ($\mu g.l^{-1}$)	PO_4−P ($\mu g.l^{-1}$)	Conductivity (μmho)
22.4.76	11.45	Surface	18.2	6.40	104	—	—	—	179
22.4.76		10.0	18.0	6.45	100	tr	—	tr	175
22.4.76		25.0	18.0	6.30	95	—	tr	—	176
22.4.76	11.00	32.0	16.5	6.10	14	450	tr	—	167
9.12.76		Surface	20.0	6.65	118	—	tr	—	187
9.12.76		10.0	19.8	6.80	114	—	tr	tr	176
9.12.76		20.0	19.0	6.60	112	—	—	7	178
9.12.76		30.0	18.0	6.30	98	—	—	tr	170
9.12.76	12.00	35.0	17.5	6.50	94	—	—	7	173
10.5.77		Surface	15.0	6.5	110	16	—	—	
10.5.77		10	15.0	6.45	116	—	—	tr	
10.5.77		20	14.8	6.60	118	16	—	—	
10.5.77	13.15	27	14.8	6.70	100	—	—	7	
14.9.77		Surface	13.0	6.75	108	—	—	—	174
14.9.77		20	12.8	6.70	108	—	—	—	174
14.9.77		30	12.8	6.70	108	16	—	tr	180
14.9.77	11.40	34	12.8	6.70	100	—	—	tr	180

tr = trace

Table 6 Hydrological and chemical data for Lake Taharoa (Hauhatoki Bay).

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O_2	NH_3−N ($\mu g.l^{-1}$)	NO_3−N ($\mu g.l^{-1}$)	PO_4−P ($\mu g.l^{-1}$)	Conductivity (μmho)
22.4.76		Surface	18.6	6.40	104	160	tr	—	177
22.4.76		10.0	18.0	6.30	102	—	tr	—	176
22.4.76		20.0	18.2	6.35	102	—	tr	—	175
22.4.76		24.0	17.0	6.15	58	450	5	—	175
22.4.76	12.40	28.0	16.0	6.15	18	100	—	16	174
9.12.76		Surface	20.0	6.75	122	tr	tr	7	182
9.12.76		10.0	19.5	6.60	120	—	tr	tr	178
9.12.76		20.0	18.0	6.30	110	—	—	tr	181
9.12.76		25.0	17.5	6.05	92	200	tr	—	178
9.12.76		29.0	17.0	6.05	90	16	tr	—	180
10.4.77		Surface	15.8	6.35	108	—	—	20	
10.4.77		10.0	15.8	6.35	110	—	tr	—	
10.4.77		20.0	15.8	6.30	108	tr	—	7	
10.4.77	13.35	29.0	15.5	6.20	98	40	—	7	
14.9.77		Surface	12.8	6.75	104	—	—	—	179
14.9.77		10.0	13.0	6.75	108	—	—	—	176
14.9.77		10.0	13.0	6.70	110	tr	—	—	181
14.9.77	12.05	27.0	12.8	6.75	106	—	—	tr	176

tr = trace

Table 7 Hydrological and chemical data for Lake Waikere.

Date	Time	Depth (m)	Temperature (°c)	pH	% Sat. O_2	NH_3−N ($\mu g.l^{-1}$)	NO_3−N ($\mu g.l^{-1}$)	PO_4−P ($\mu g.l^{-1}$)	Conductivity (μmho)
9.12.76		Surface	21.0	6.90	124	16	—	tr	178
9.12.76		10.0	20.0	6.70	118	16	5	7	176
9.12.76		20.0	19.0	6.50	108	tr	tr	7	174
9.12.76		25.0	18.5	6.40	104	16	tr	7	170
9.12.76	13.00	29.0	18.0	6.25	104	40	5	tr	172
10.5.77		Surface	15.2	6.60	112	40	—	7	
10.5.77		8.0	15.2	6.60	120	—	—	7	
10.5.77		15.0	15.0	6.55	116	16	tr	tr	
10.5.77	14.05	20.0	15.0	6.50	116	40	—	13	
14.9.77		Surface	12.8	6.75	108	—	—	—	168
14.9.77		8.0	13.0	6.75	106	—	—	tr	168
14.9.77		15.0	12.8	6.70	108	—	—	—	174
14.9.77	13.00	21.0	12.8	6.75	104	tr	tr	—	174

tr = trace

Lake Kanono

Diatoms were dominant at the surface in winter and spring. The commonest species were *Synedra rumpens*, *Synedra ulna* (very long cells: up to 400 μm), *Melosira granulata* var. *angustissima*, *Rhizosolenia eriensis*, *Cyclotella stelligera*, and *Nitzschia acicularis*. By midsummer there was a marked increase of the thecate stages of *Peridinium sydneyense* at the bottom. Gymnodinioid stages were found at the same time in surface samples, though they were scarce. At the same time *Ceratium hirundinella* was occasional at the surface. A feature of the phytoplankton of this lake was the presence of several species of potentially toxic blue-green algae, notably *Microcystis aeruginosa*, *Aphanizomenon flos-aquae*, and three species of *Anabaena*. Two first New Zealand records were *Anabaena macrospora* (Fig. 3(1)) and *Oscillatoria annae* (Fig. 3(2)). The presence of these species together with that of the diatom *Fragilaria crotonensis*, though in small numbers, indicates a trend towards eutrophication, or even pollution (Connor 1977, Cassie 1979). Blooms of blue-green algae have been reported from the more northerly Lake Waiparera (Flint 1970). *Salpingoeca frequentissima* (Chrysophyceae) was a frequent epiphyte on the diatoms *Rhizosolenia eriensis* and *Synedra acus* var. *radians* (Fig. 4(3)).

Lake Waingata

Although it is geographically so close to Lake Kanono, Lake Waingata supported a different phytoplankton. Desmids were the most widely represented group of algae, although they seldom occurred in appreciable quantities. The commonest genera were *Staurastrum* and *Staurodesmus*, including *Staurodesmus glaber*, *S. cuspidatus*, *S. spetsbergensis* var. *limneticus*, and *S. leptodermus* var. *subcorniculatus* (Fig. 3(10–12)).

Staurodesmus glaber was dominant in spring at both surface and bottom. *Staurastrum* was scarcer in numbers. The most frequently encountered *Staurastrum* species were *S. floriferum* (as in Lakes Rotorua and Rotoiti (Cassie 1974)), *S. tohopekaligense* var. *minus*, and *S. sexangulare*. Dinoflagellates were conspicuous components of the spring and summer phytoplankton, again with both thecate and gymnodinioid stages of *Peridinium sydneyense* (Fig. 5 (4)), and *Ceratium hirundinella* f. *gracile*. *Dinobryon* and *Zygnema*, observed in previous years in this lake by Fish (1966), were scarce or absent in the samples examined.

The filamentous desmids *Teilingia excavata*, *T. granulata* (Fig. 3 (7, 8)), and *Sphaerozosma laeve* var. *micracanthum* are interesting new records for this lake.

Lake Parawanui

Of all the five lakes, Lake Parawanui possessed the sparsest phytoplankton. The only species found in any quantity was a *Cyclotella* (Fig. 4 (1)) resembling *C. stelligera* in its fine structure (Fig. 6 (1–3)). Loosely aggregated, brick-like tiers of cells, narrowly rectangular in girdle view, were dominant at the surface in all sampling seasons. Other scarce diatoms were *Cocconeis placentula* and *Synedra ulna* (straight cells up to 408 μm long). The placoderm desmid *Staurastrum floriferum* and the saccoderm desmid *Gonatozygon brebissonii* (Fig. 3 (6)) (up to 302 μm long) were rarely encountered. Bottom samples contained cells of *Ceratium hirundinella* f. *gracile* and *Trachelomonas volvocina*.

Lake Taharoa

Desmids and dinoflagellates were the main surface phytoplankters in this lake, including *Ceratium hirundinella* f. *robustum* (Fig. 4(9)), together with a colonial chlorococcalean species, *Nephrocytium agardhianum*. A chytridiaceous fungus was observed to be parasitising some cells of the *Nephrocytium* colonies — particularly in bottom-dwelling specimens (Fig. 3(5)). Rod-shaped bacteria were growing attached by one end of their cells to the mucilaginous colony walls. *Staurastrum* spp.* (mainly *S. floriferum*, *S. pingue*, *S. gracile*, and *S. sagittarium*) were present in small numbers at both surface and bottom of Massey Basin and Hauhatoki Bay, together with *Euastrum ansatum* var. *suprapositum* (Fig. 5 (2)).

September samples from Massey Basin provided specimens of a sparse, pennate diatom assemblage comprising mostly dead frustules of *Epithemia argus*, *Navicula peregrina*, *Rhopalodia gibba*, *Surirella* sp. (Fig. 4 (5)), *Tabellaria flocculosa*, and *Frustulia rhomboides*. *Dinobryon* was represented by only a few isolated loricas.

Lake Waikere

Dinoflagellates were the most conspicuous phytoplankters in nearly all samples. The *Peridinium* complex appeared to outnumber all other algal types, the gymnodinioid stages being relatively common in winter and spring. The May sample featured also the filamentous desmid *Hyalotheca dissiliens* (Fig. 5(3)) as well as *Staurastrum avicula*, *Staurodesmus* spp., *Gonatozygon brebissonii* (Fig. 3 (6)), *Nephrocytium agardhianum*, and *Elakatothrix gelatinosa*.

DISCUSSION

The five dune lakes studied are basically similar in their location and surroundings. No striking chemical differences have emerged from this survey between the Pouto and Kai-iwi lakes. All had a

*For illustrations of *Staurastrum* spp. in New Zealand see Thomasson (1960, 1972, 1973, 1974a).

Table 8 Classification of five Northland west coast dune lakes according to their most common species of phytoplankton (after Hutchinson 1967, Wood 1975).

Lake	Community	Principal species
L. Kanono	Oligotrophic diatom plankton	*Cyclotella glomerata* Bachm. *Rhizosolenia eriensis* H. L. Smith *Melosira granulata* var. *augustissima* (O. Mull.) Hust. *Synedra rumpens* Kütz *Fragilaria crotonensis* Kitt. *Epithemia sorex* Kütz. *Nitzschia acicularis* W. Smith *Ceratium hirundinella* f. *robustum* (Amberg) Bachm. *Peridinium sydneyense* (Playf.) Thom.
L. Waingata	Oligotrophic desmid–dinoflagellate plankton	*Staurodesmus glaber* (Ehr.) Teil. *Staurastrum floriferum* West et West *Staurastrum tohopekaligense* f. *minus* (Turn.) Scott et Prescott *Peridinium sydneyense* (Playf.) Thom. *Ceratium hirundinella* (O.F.M.) Schrank.
L. Parawanui	Extremely oligotrophic diatom plankton	*Cyclotella glomerata* Bachm. *Cocconeis placentula* Ehr. *Gonatozygon brebissonii* de Bary
L. Taharoa	Oligotrophic desmid–chlorococcal–dinoflagellate plankton	*Nephrocytium agardhianum* Nag. *Staurastrum floriferum* West et West *Staurastrum gracile* Ralfs *Staurastrum pingue* Teil. *Staurastrum sagittarium* Nordst. *Ceratium hirundinella* f. *robustum* (Amberg) Bachm. *Peridinium sydneyense* (Playf.) Thom.
L. Waikere	Oligotrophic dinoflagellate–desmid plankton	*Peridinium sydneyense* (Playf.) Thom. (thecate and gymnodinioid stages) *Hyalotheca dissiliens* (J.E.S.) Bréb. *Staurastrum avicula* var. *exornatum* Messik.

similar temperature range, a high percentage of oxygen saturation, a high conductivity, and minimal values for ammonia and nitrate (except Lake Parawanui, which is richer in solutes than the other lakes). The only comparable information for the same lakes comes from the survey of Cunningham *et al.* (1953) who quoted values for Lake Kanono of phosphate at 0.02 ppm (7μg l^{-1} PO_4–P) and of nitrate at 0.10 ppm (23 μg l^{-1} NO_3–N). Ammonia was recorded as only a trace; results which are similar to those in the present survey. In the absence of secchi disc and productivity measurements, and a much more detailed sampling programme in space and time, it is not possible to make an accurate assessment of their trophic status; but the available evidence suggests that, with the possible exception of Lakes Kanono and Parawanui, they are generally clear and unpolluted by organic matter, despite their somewhat dark appearance. Additional evidence for this statement comes from the phytoplankton flora, the species composition of which was mostly typical of an oligotrophic assemblage (Table 8). Single-species dominance occurred only in Lake Parawanui. Diatoms predominated in Lakes Kanono and Parawanui, and desmids in the other lakes, together with dinoflagellates, and, in Lake Taharoa, also Chlorococcales. Dinoflagellates were the dominant algae in Lake Waikere. *Cyclotella*, though common in Lake Kanono, did not dominate as it did in the winter in Lake Ototoa (Green 1976).

Preservation of phytoplankton samples precluded the possible investigation of the ultra-plankton now known to be of considerable significance in many New Zealand lakes (Paerl 1977). However, some tiny unicells resembling *Chlorella minutissima* Fott et Nováková were observed in samples from Lakes Kanono and Parawanui. Blue-green algae in Lake Kanono were too scarce to cause nuisance blooms.

Lake Parawanui, although diatom-dominated, possessed by far the sparsest phytoplankton of any of the five lakes. *Cyclotella stelligera*, the dominant diatom, has been recorded by Lowe (1976) as an oligotrophic diatom indicator; although the commonest species, it was still relatively scarce.

Although the general classification of the phytoplankton of Lake Kanono is that of an oligotrophic diatom plankton, there were several species such as *Fragilaria crotonensis*, *Aphanizomenon flos-aquae*, and *Microcystis aeruginosa*, the presence of which suggests that an advance towards eutrophy, or even pollution, might occur (Connor 1977, Cassie 1979), though they were not common in the samples examined. As far back as 1953

Cunningham recorded a sparse occurrence of diatoms in this lake. Blooms of blue-green algae have not yet been recorded from the lakes studied, as they have been from the more northerly dune lake, Lake Waiparera (Flint 1970).

Nitzschia communis (Fig. 6, (5, 6)), a diatom which indicates a certain degree of organic pollution (Lowe 1974), was extremely scarce in Lake Parawanui samples.

Compound indices (Nygaard 1949) were calculated for four lakes: L. Kanono: 1.86, L. Waingata: 0.33, L. Waikere: 0.33, and L. Taharoa: 0.25. Data from L. Parawanui were not applicable. These figures point to Lake Kanono as being the only one of the five approaching eutrophy. It emerges as being slightly more eutrophic than the North Island Lakes Rotoiti and Rotoma (Cassie 1978). These figures are inconsistent with the data of Fish (1975) who recorded heavy standing crops of algae at certain seasons in Lake Rotoiti. The compound index is therefore not a satisfactory means of estimating the trophic status of these mainly oligotrophic lakes. Further quantitative work is necessary to establish this with certainty, both in the investigation of other limnological parameters such as productivity and light penetration as well as quantitative enumeration and volumetric estimation of the phytoplankton and periphyton. The absence of *Dinobryon* as a dominant is noteworthy; but it could have occurred as such in the wide intervals between sampling, and remain undetected. The need for a more intensive sampling programme is obvious; but this account provides preliminary data.

NOTES ON SOME LESS WELL-KNOWN MICRO-ALGAE

Brief descriptions are given of the most obvious features of the specimens examined. For a full taxonomic account of each species the reader is referred to the texts cited. These include works which are readily available in scientific libraries in New Zealand. Drawings and photomicrographs have been provided to assist with identification of local forms, in view of the paucity of published illustrations.

CYANOPHYCEAE (blue-green algae)

Anabaena macrospora Klebahn Fig. 3 (1)
Huber-Pestalozzi 1938: p. 208, pl. 39, fig. 120.
Prescott 1962: p. 517, pl. 117, figs 4–6.

A planktonic species with flexuous filaments and globose to ellipsoidal cells, attached in uniseriate trichomes by a tubular connection, this *Anabaena* had spherical heterocysts approximately the same size or slightly smaller than the vegetative cells. Akinetes were not observed.
Cell length: 7–9 μm.
Cell width: 6–7 μm.
Locality: Lake Kanono, Lake Waingata. First New Zealand record.
Habitat: Planktonic in hard water lakes (Prescott 1962).

Oscillatoria annae Van Goor Fig. 3 (2)
Geitler 1932: p. 943.
Desikachary 1959: p. 203, pl. 38, fig. 13.

Trichomes were blue-green, slightly bent, and wider than in the described species. Cells were shorter than broad and barrel shaped with distinctly constricted cell walls and densely granular contents. Few gas vacuoles were present.
Cell length: 3.0–4.2 μm.
Cell width: 10.2–11.5 μm.
Locality: Lake Kanono, Lake Waingata. First New Zealand record.
Habitat: Previously reported on pneumatophores of mangroves (Desikachary 1959).

Phormidium rotheanum Itzigsohn var. *capitatum* Fig. 3 (3)
Geitler 1932: p. 1004, Skuja 1949: p. 52, pl. 8, figs 31, 32.
Desikachary 1959: p. 258, pl. 45, figs 14, 15.

Filaments were narrower than in the described variety, more or less straight, and with an indistinct sheath. Cells were much shorter than broad, slightly constricted at the cross-walls, with granulated septa. The end cells were obtuse-conical as in the specimen figured by Desikachary. No calyptra was seen.
Cell length: 0.4–0.6 μm.
Cell width: 2.6–3.0 μm.
Locality: Lake Kanono. First New Zealand record.
Habitat: Usually terrestrial, on barks of trees (Skuja 1949).

EUCHLOROPHYCEAE (green algae)

Chodatella quadriseta Lemmermann Fig. 3 (4)
Bourrelly 1966: p. 172, pl. 25, fig. 9. Philipose 1967: p. 169, fig. 80.
Prescott 1962: p. 251, pl. 46, fig. 11 as *Lagerheimia quadriseta*.

Cells were characteristically oval with pointed poles and four slightly curved setae emerging from near the poles. Setae tended to be more curved than those in Bourrelly's figure.
Cell length: 10.0–12.4 μm.
Cell width: 5.0–7.3 μm.
Locality: Lake Waikere.
Habitat: Planktonic.

Nephrocytium agardhianum Nägeli Fig. 3 (5)
Philipose 1967: p. 189, fig. 104.

Both four- and eight-celled colonies were found. Bacterial rods occasionally colonised the mucilaginous envelope, at right angles to it. Ramsay

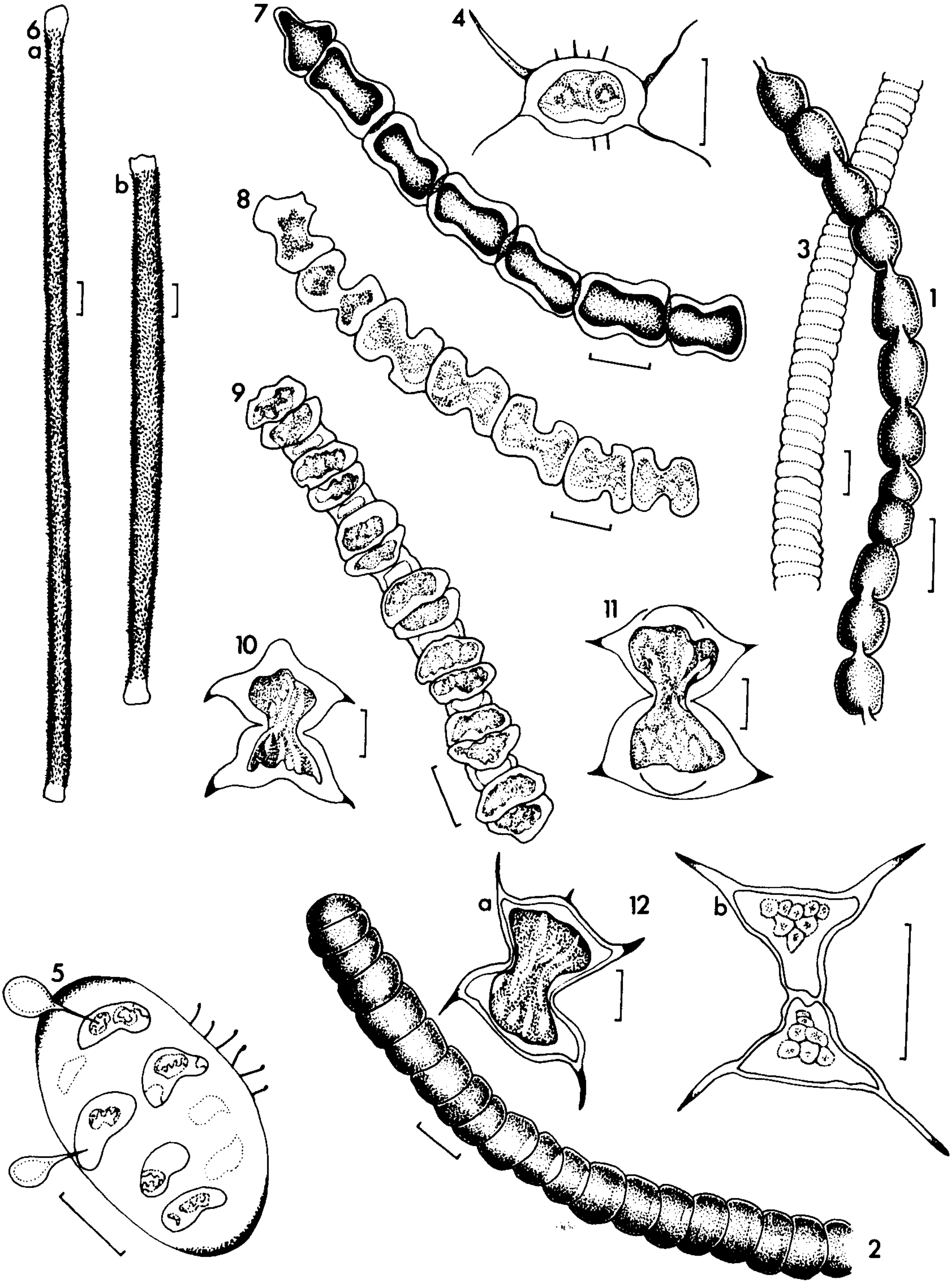

Fig. 3 The scale in each figure is indicated by a line equal to 10 μm.
(1): *Anabaena macrospora* Kleb. L. Waingata. (2): *Oscillatoria annae* Van Goor. L. Kanono. (3): *Phormidium rotheanum* Itzigs. L. Kanono. (4): *Chodatella quadriseta* Lemm. L. Waikere. (5): *Nephrocytium agardhianum* Näg, with parasitic chytrids and epiphytic bacteria. L. Taharoa. (6): *Gonatozygon brebissonii* de Bary. L. Kanono. (7): *Teilingia excavata* (Ralfs) Bourr. L. Waingata. (8): *Teilingia granulata* (Roy et Biss) Bourr. L. Waingata. (9): *Sphaerozosma laeve* var. *micracanthum* (Nordst.) Thom. L. Waingata. (10): *Staurodesmus leptodermus* var. *subcorniculatus* (Rich) Teil. L. Waingata. (11): *Staurodesmus glaber* (Ehr.) Teil. L. Waingata. (12): *Staurodesmus cuspidatus* (a) var. *curvatus* (W. West) Teil. L. Waingata. (b) var. *divergens*. L. Waikere.

(1972) noted a similar phenomenon with bacteria epiphytic on diatoms from Lake Grassmere, Canterbury. In one specimen a chytridiaceous fungus was seen to parasitise two of the oval to kidney-shaped cells, and to protrude by a stalk through the surrounding layer of mucilage.
Colony length: 36–40 μm.
Colony width: 19–23 μm.
Locality: L. Taharoa, L. Waikere.
Habitat: Benthic and planktonic.

Gonatozygon brebissonii de Bary Fig. 3 (6a, b)
Prescott *et al.* 1972: p. 34, pl. 8, figs 1–3, 11.

Cells were narrowly cylindrical, with capitate apices, and sometimes very long — up to 80 times as long as broad. Walls covered with dense, pointed granules were typical for the species. A slight swelling occurred in the middle of some cells.
Cell length: 84–302 μm.
Cell width: 3.8–5.0 μm.
Locality: Lake Kanono.
Habitat: Common in acidic and soft water lakes.

Sphaerozosma laeve var. *micracanthum* (Nordstedt) Thomasson Fig. 3 (9)
Scott & Prescott 1961: pl. 60, fig. 14, Thomasson 1974b; p. 723, fig. 4, 5.

Small lateral spines like granules were visible, as in Thomasson's specimen from Lake Rotoma. Cells were not as sharply angular as in the specimen illustrated by Scott and Prescott.
Cell length: 10–12 μm.
Cell width: 10–16 μm.
Locality: L. Waingata.
Habitat: Planktonic.

Staurodesmus cuspidatus Teiling
(a) var. *curvatus* (W. West) Teiling Fig. 3 (12a)
Teiling 1967: fac. 3, pl. 9, fig. 1–5, as *C. cuspidatus* var. *divergens* Nordst. Thomasson 1973: p. 134, fig. 6, 1.

Several different forms of this species occurred in the samples from Lakes Waingata and Waikere. The specimen in Fig. 3 (12a) shows the closest resemblance to those illustrated by Thomasson and Teiling. Spines curve upwards.
Cell length: 25–28 μm.
Maximum cell width: 22 μm.
Locality: L. Waingata.

(b) *Staurodesmus cuspidatus* Teiling fac. 2 Fig. 3 (12b)

Teiling 1967: pl. 9, fac. 2, fig. 13.

This form is straighter across the distal ends of each semicell and the spines are straight and diverted outwards at widely oblique angles from the cell apex.
Cell length: 22–31 μm.
Maximum cell width: 35 μm.
Locality: L. Waikere.
Habitat: Mainly planktonic.

Staurodesmus glaber (Ehrenberg) Teiling Fig. 3 (11)
Teiling 1967: p. 557, pl. 13, 15. Thomasson 1973: p.134, figs 5, 12–14.

Semicells were triangular in front view, with straight or slightly convex sides and apices (cf. Thomasson's specimen from Lake Rotokawau).
Cell length: 20–22 μm.
Maximum cell width: 20 μm.
Locality: L. Waingata.
Habitat: Mainly planktonic.

Staurodesmus leptodermus var. *subcorniculatus* (Rich) Teiling Fig. 3 (10)
Teiling 1967: p. 548, pls 12, 13. Thomasson 1973: p. 136, figs 4, 6–9.

Teiling describes this variety as having somewhat rounded corners and spines directed more vertically than in the nominate variety. Semicells were seen to be triangular in front view with slightly incurved radial sides. Apices were convex in the centre and corners acute, each extended into a short spine.
Cell length: 22–24 μm.
Maximum cell width: 25 μm.
Locality: L. Waingata.
Habitat: Mainly planktonic.

Teilingia excavata (Ralfs) Bourrelly Fig. 3 (7)
Bourrelly 1964: p. 190, fig. 10.

Each cell, with a well-marked median isthmus, resembles a small *Cosmarium* in a chain of cells, each looking somewhat like a "figure 8". The shape of the chloroplast follows closely the contours of the cell wall. Minute apical areas attach the cells in chains. Thomasson (1974b) has recorded this filamentous desmid from Lakes Rotoma and Tikitapu.
Cell length: 10–12 μm.
Cell width: apex, 4.2 μm; isthmus, 2.8 μm.
Locality: L. Waingata.
Habitat: Mainly planktonic.

Teilingia granulata (Roy et Biss) Bourrelly Fig. 3 (8)
Bourrelly 1964: p. 190, fig. 9; 1966: p. 448, pl. 108, figs 7–9.

Distinguished from the previous species by rounded granules at the poles of each cell. The middle granules help to unite the cells in chains. Recorded by Thomasson (1974b) from Lake Taupo.
Locality: L. Waingata.

DIATOMOPHYCEAE

CENTROPHYCIDAE (centric diatoms)

Cyclotella stelligera Cleve et Grunow Fig. 4 (1a, b), Fig. 6 (1–3)
Huber-Pestalozzi 1942: p. 397, fig. 484. Lowe 1975: p. 421, figs 26–30.

Specimens from Lake Parawanui were at first

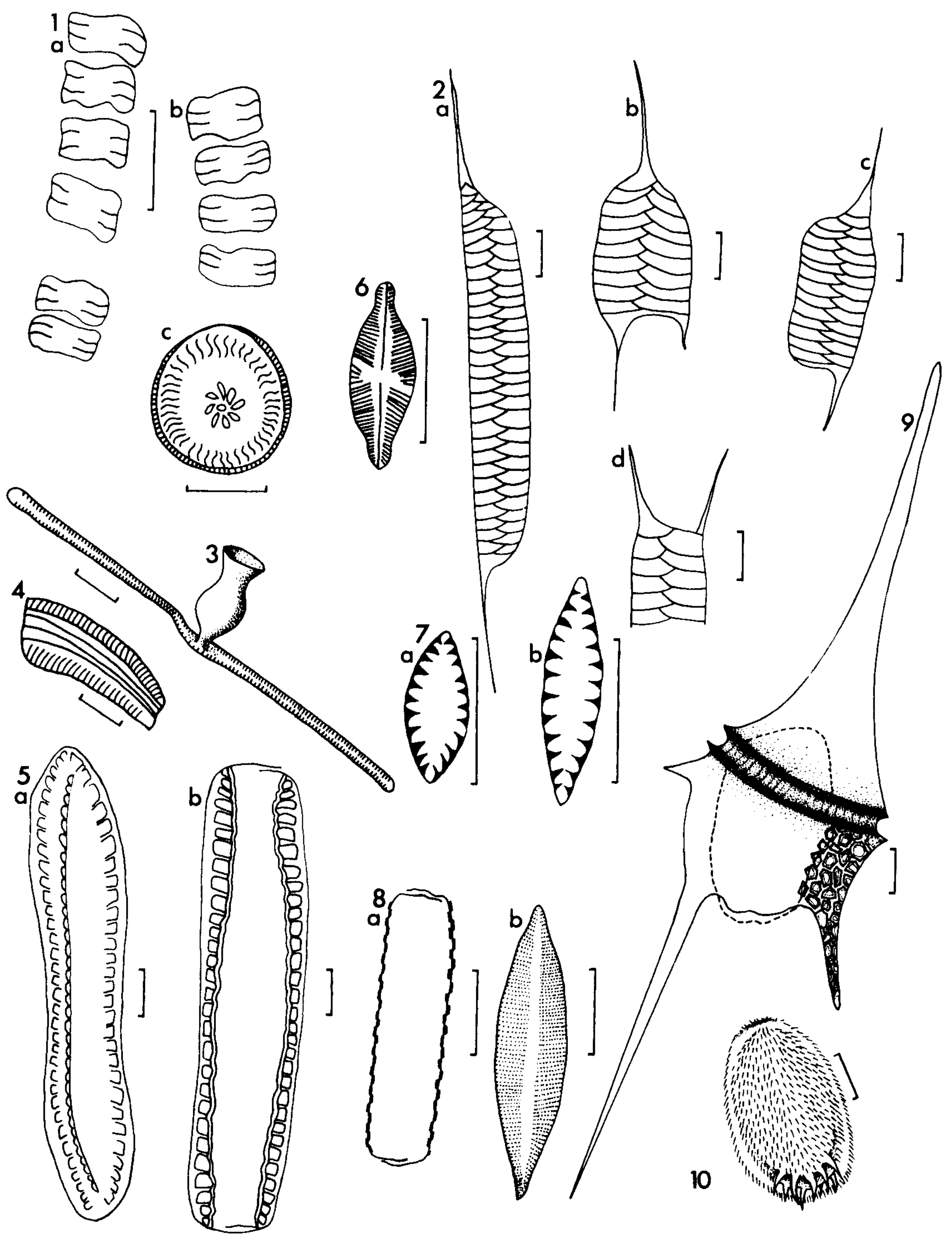

Fig. 4 The scale in each figure is indicated by a line equal to 10 μm.
(1): *Cyclotella stelligera* Cleve et Grun. (a, b) chain of cells, girdle view. L. Parawanui. (c) valve view. L. Kanono. (2): *Rhizosolenia eriensis* H. L. Smith (a) typical form. (b, c) variant forms. (d) form resembling *Attheya zachariasii* Brun. (3): *Salpingoeca frequentissima* (Zach.) Lemm. Epiphytic on *Synedra acus* var. *radians* (Kütz.) Hust. L. Kanono. (4): *Rhoicosphenia curvata* (Kütz) Grun. Girdle view. L. Kanono. (5): *Surirella* sp. (a) valve view. (b) girdle view. L. Taharoa. (6): *Capartogramma crucicula* (Grun. ex Cl.) Ross. Valve view. L. Kanono. (7): *Fragilaria construens* var. *venter* (Ehr.) Grun. (a) girdle view. (b) valve view. L. Taharoa. (8): *Fragilaria construens* var. *pumila* Grun. L. Parawanui. (9): *Ceratium hirundinella* f. *robustum* (Amberg) Bachm. L. Taharoa. (10): *Trachelomonas armata* var. *duplex* Playf. L. Waingata.

assigned to *Cyclotella glomerata* Bachmann because of their assemblage into regular chains (Huber-Pestalozzi 1942, Lowe 1975). However, scanning electron microscopy shows that the cells bear a closer resemblance to *Cyclotella stelligera* Cleve et Grun. (cf. the stellate striae in the centre and the ring of marginal strutted processes at every third or fourth stria). Lake Kanono specimens were larger than those from Lake Parawanui.
Cell width: 6.6–14.5 μm.
Cell length: 3.0–3.5 μm.
Locality: L. Kanono, L. Parawanui.
Habitat: Euplanktonic and acidophilous with pH optimum of <7 (Lowe 1976).

Rhizosolenia eriensis H. L. Smith Fig. 4 (2a–d)
Huber-Pestalozzi 1942: p. 419, pl. 125, figs 514–515.

Cells examined were very variable in size and shape but basically cylindrical with long pointed setae, typical of the described species in possessing flattened annulate frustules; the annulae (girdle bands) meeting to form a zig-zag pattern on the long axis of the cell. A few cells were much shorter and fatter than the nominate variety (Fig. 4 (2b, c)).
Cell length: 56–63 μm.
Cell width: 7–20 μm.
Locality: L. Kanono.
Habitat: Planktonic, alkaliphilous (optimum pH 7.5–8), eutrophic (Lowe 1974).

PENNATOPHYCIDAE (pennate diatoms)

Capartogramma crucicula (Grunow ex Cleve) Ross Fig. 4 (6)
Ross 1963: p. 69, pls 1B, 2A, figs 1A, 8–11. Patrick & Reimer 1966: p. 372, pl. 30, fig. 16.

Previously known as *Stauroneis crucicula*, this minute naviculoid diatom can be distinguished by an X-shaped stauros in the centre of each valve. The raphe is straight, the striae fine and radiate.
Valve length: 22–24 μm.
Valve width: 8.0–8.5 μm.
Locality: L. Kanono; rare (also reported from L. Wanaka, South Island — P. Coleman, pers. comm.). First New Zealand record.
Habitat: Mesohalobous? (Lowe 1974). Fresh and brackish waters (Patrick & Reimer 1966).

Diploneis elliptica (Kütz) Cleve (text fig. 3)
Patrick & Reimer 1966; p. 414, pl. 38, fig. 10.

Valves agreed closely with those of the species as described by Patrick & Reimer, being linear with broadly rounded ends, with an elliptical central area, and possessing somewhat curved striae, *c*. 15 in 10 μm, and a narrow axial area enclosed by strongly siliceous ribs.
Valve length: 48–50 μm.
Valve width: 20–21 μm.
Locality: L. Kanono.
Habitat: Fresh and brackish, eutrophic, saproxenous, in lakes, bogs, and springs (Patrick & Reimer 1966).

Epithemia intermedia Fricke? Fig. 6 (4)
Patrick & Reimer 1975: p. 179, pl. 24, fig. 2. Gerloff & Helmcke 1977: figs 989–995.

The scanning electron micrographs of Gerloff & Helmcke resemble the specimen in text fig. 11 more closely than the light micrograph drawing of Patrick & Reimer. The specimen was observed only on the coverslip prepared for the S.E.M. stub.
Locality: L. Parawanui.
Habitat: Found in water of high conductivity (Patrick & Reimer 1975).

Fragilaria construens var. *pumila* Grunow Fig. 4 (8)

Valves were typically elliptical with rostrate ends. The axial area was fairly wide in most specimens, and striae punctate or appearing solid under the light microscope: 15–17 in 10 μm. Cells were isolated, not in colonies.
Valve length: 21–31 μm.
Valve width at centre: 4.8–5.4 μm.
Locality: L. Parawanui.
Habitat: Planktonic and benthic, slightly alkaliphilous, indifferent to chlorides (Patrick & Reimer 1966).

Fragilaria construens var. *venter* (Ehrenberg) Grunow Fig. 4 (7a, girdle view; b, valve view)

The somewhat pointed, widely elliptical valves possess coarse dark striae appearing solid under the light microscope. Each stria tapers to a point adjacent to the axial area. Cells were isolated, not in colonies.
Valve length: 9.0–15.0 μm.
Valve width: 4.2–4.8 μm.'
Locality: L. Taharoa.
Habitat: Tychoplanktonic and periphytic, alkaliphilous, oligotrophic to mesotrophic, characteristic of standing waters (Lowe 1974).

Nitzschia communis Rabenhorst Fig. 6 (5, 6)
Okuno 1974: figs 913–914. Lange-Bertalot 1976: p. 275, pl. 7, figs 11–13.

The broadly elliptical linear valve with slightly capitate rounded ends and marginal canal raphe system strongly suggest this species.
Valve length: 25–32 μm.
Valve width: 4–5 μm.
Locality: L. Parawanui.
Habitat: Alkalibiontic to alkaliphilous, pH 4.3–8.2, indicative of a certain degree of organic pollution, and possibly of water with a higher salinity than freshwater (Lange-Bertalot 1976).

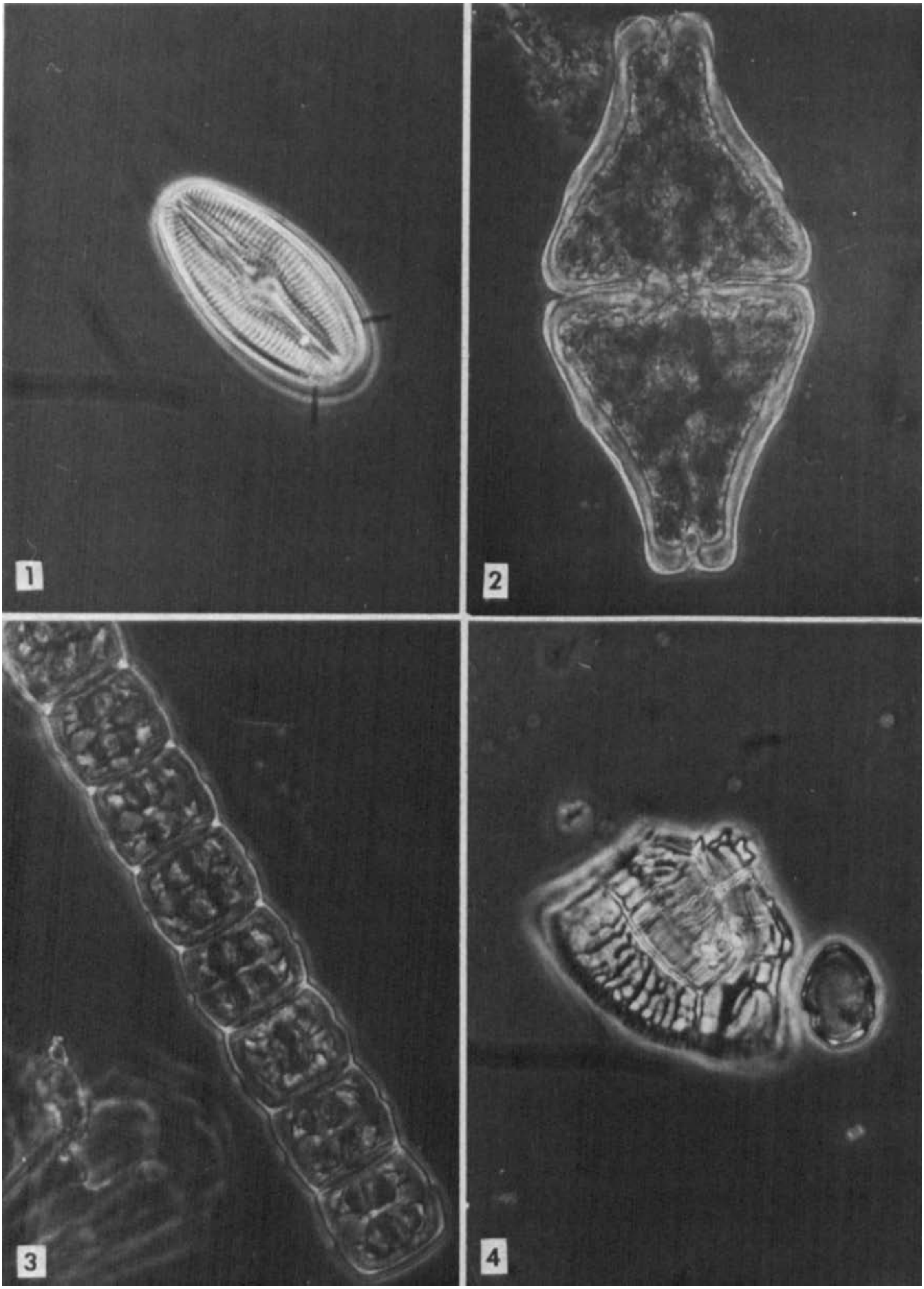

Fig. 5 (1): *Diploneis elliptica* (Kütz.) Cleve, with attached bacterial rods. L. Kanono. 5 May 1977. Original magnification ×640. (2): *Euastrum ansatum* var. *supraposition* Nordst. L. Taharoa. 10 May 1977. Original magnification ×640. (3): *Hyalotheca dissiliens* J. E. Smith) Brebisson. L. Waikere. 10 May 1977. Original magnification ×640. (4): *Peridinium sydneyense* (Playfair) Thomasson. Thecate stage (epitheca) and gymnodinioid stage. L. Waingata. 5 May 1977. Original magnification ×640.

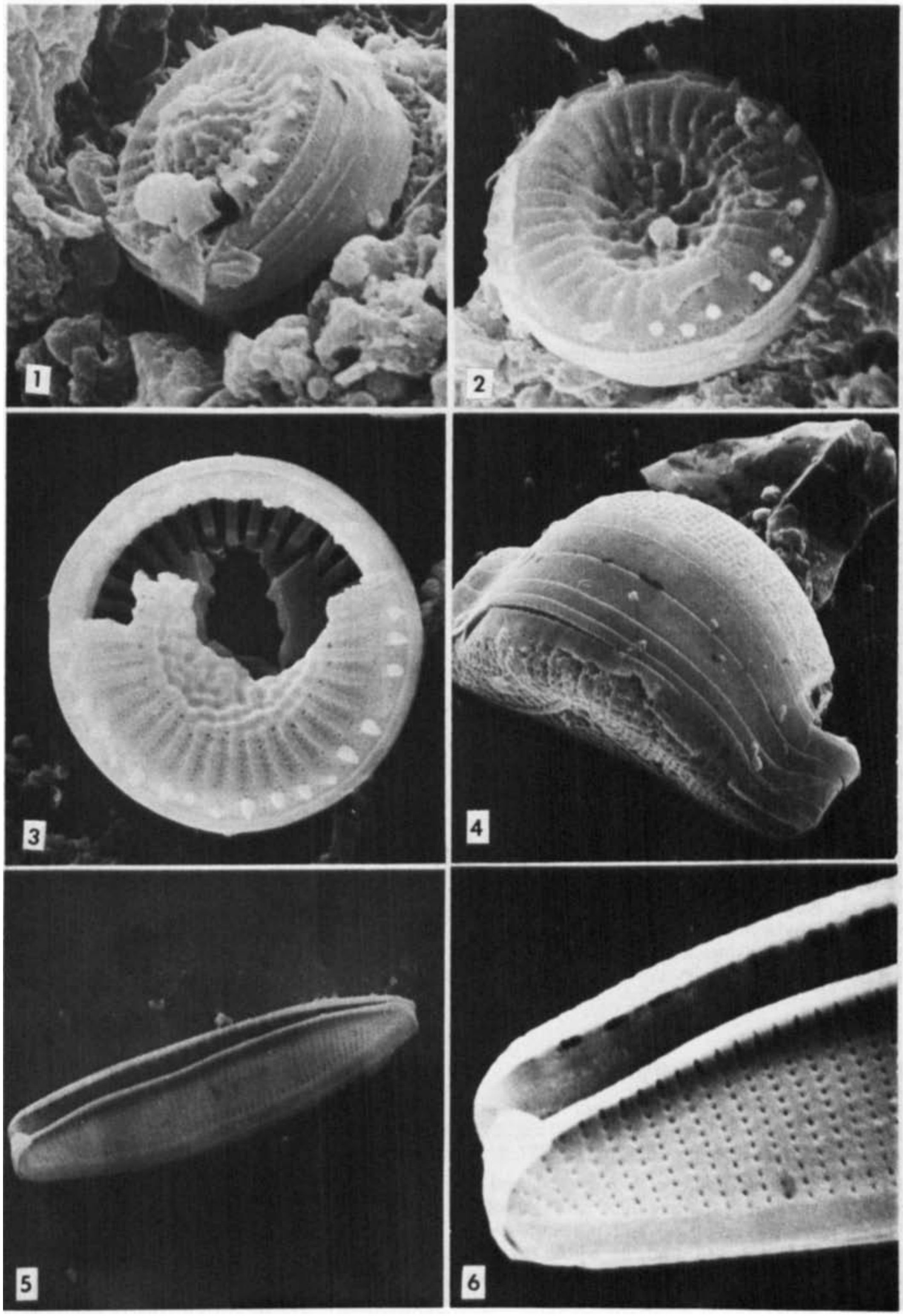

Fig. 6 (1): *Cyclotella stelligera* Cleve et Grunow. Scanning electron micrograph. Convex outside valve. L. Parawanui. 14 September 1977. Original magnification ×8000. (2): *Cyclotella stelligera* Cleve et Grunow. S.E.M. Concave outside valve. L. Parawanui. 14 September 1977. Original magnification ×7000. (3): *Cyclotella stelligera* Cleve et Grunow. S.E.M. Broken cell showing internal and external structure. L. Parawanui. 14 September 1977. Original magnification ×7000. (4): *Epithemia intermedia* Fricke? S.E.M. Valve and girdle. Original magnification ×4000. (5): *Nitzschia communis* Rabenhorst. S.E.M. L. Parawanui. 14 September 1977. Original magnification ×4500. (6): *Nitzschia communis* Rabenhorst. S.E.M. L. Parawanui. 14 September 1977. Original magnification × 12 000.

Rhoicosphenia curvata (Kützing) Grunow ex Rabenhorst Fig. 4 (4)

Patrick & Reimer: p. 282, pl. 20, figs 1–5.

Cells were typically wedge shaped in both valve and girdle views. The raphe-bearing valve was bent concavely and the other rudimentary raphe valve convexly. Striae were slightly radiate, parallel, and more widely spaced at the ends of each valve.
Valve length: 35–38 μm.
Valve width: 3.6–9.0 μm.
Locality: L. Kanono.
Habitat: Alkaliphilous: pH 5.4–9.0, optimum over 8. Characteristic of oligotrophic and eutrophic, slightly saline waters. Epipelic and epiphytic (Patrick & Reimer 1966, Lowe 1974).

Surirella sp. Fig. 4 (5a, b)

The identity of this taxon is doubtful. It bears a close resemblance to *Surirella biseriata* var. *constricta* Grunow (cf. Bourrelly 1968, pl. 111, fig. 3), in that the costae do not extend as far in as the axial area.
Valve length: 71–74 μm.
Valve width: 15.4–16.8 μm.
Locality: L. Taharoa.
Habitat: Freshwater, benthic (Boyer 1927).

Synedra acus Kützing var. *radians* (Kütz.) Hust. Fig. 4 (3)

Huber-Pestalozzi 1942: p. 458. Patrick & Reimer 1966: p. 135, pl. 5, fig. 1 as *S. radians* Kütz.

Cells were narrow, linear, attenuated near the ends, and with slightly swollen apices. Some valves were kinked in the middle, sometimes bearing epiphytic *Salpingoeca* cells, and with a narrow axial area.
Valve length: 84–90 μm.
Valve width: 1.8–3.0 μm.
Locality: L. Kanono.
Habitat: Periphytic, indifferent to pH (6.0–9.0), in lakes, ponds, and flowing streams (Patrick & Reimer 1966, Lowe 1974).

DINOPHYCEAE (dinoflagellates)

Ceratium hirundinella f. *robustum* (Amberg) Bachmann Fig. 2 (9)

Huber-Pestalozzi 1968: pp. 262–263, fig. 277: 8.

Two forms of *C. hirundinella*, f. *robustum* and f. *gracile* were present in the five dune lakes studied. In f. *robustum* the antapical and post-equatorial horns are turned outward, and the whole theca is dorsally convex. In f. *gracile* the apical and antapical horns are more or less in a straight line; also the cell has no dorsal convexity.
Cell length: 175–180 μm.
Maximum cell width: 70 μm.
Locality: L. Taharoa.
Habitat: Planktonic and benthic.

Peridinium sydneyense (Playfair) Thomasson Fig. 5 (4)

Thomasson 1974b: p. 717, fig.2/10, fig. 5/6–7.

The whole *Peridinium* complex in North Island lakes is difficult to elucidate (Thomasson 1974b). There appear to be several forms in the Northland dune lakes. Most of these agree in some respects with either the *P. volzii* type (with a small, straight longitudinal furrow) or with the *P. bipes* type (with two, small, foot-like projections at the base). Certain specimens of the *P. volzii* type also possessed an apical flange. The assemblage is obviously a heterogeneous one and needs further study. In the meantime it seems best to follow Thomasson and use the taxon *P. sydneyense*. Both thecate and gymnodinioid stages (Sargeant 1974) were observed frequently at different seasons of the year.
Cell length: (a) thecate stage: 45–70 μm.
(b) gymnodinioid stage: 19–28 μm.
Cell width: (a) thecate stage: 40–63 μm.
(b) gymnodinioid stage: 14–17 μm.
Locality: L. Kanono, L. Waingata, L. Taharoa, L. Waikere.
Habitat: Planktonic (gymnodinioid stage), planktonic and benthic (thecate stage).

EUGLENOPHYCEAE

Trachelomonas armata var. *duplex* Playfair Fig. 4 (10)

Huber-Pestalozzi 1955: p. 310, fig. 590.

The bright orange cells were relatively large for *Trachelomonas*, and oval to egg-shaped. The lower end of the cells were broader with a projecting ring of thorn-like spines. These did not cover the upper end of the cell, as in the figure of Huber-Pestalozzi (1955).
Cell length: (with spines) 32–35 μm.
Cell width: 27 μm.
Locality: L. Waingata.
Habitat: Planktonic.

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APPENDIX 1 Species list of algae identified from five Northland west coast dune lakes

Scale of abundance: 5 = dominant, 4 = abundant, 3 = common, 2 = occasional, 1 = scarce, r = one specimen seen.
S = surface sample; B = bottom sample.

Classification after Bourrelly 1966, 1968, 1970.
Desmids are identified from Thomasson (1960, 1972, 1973, 1974a).
Diatoms are identified mainly from Huber-Pestalozzi (1942) and Patrick & Reimer (1966, 1975).
* = first record for New Zealand.

	Lake Kanono		Lake Waingata		Lake Parawanui		Lake Taharoa Massey Basin		Lake Taharoa Hauhatoki Bay		Lake Waikere	
	S	B	S	B	S	B	S	B	S	B	S	B
CHLOROPHYTA												
EUCHLOROPHYCEAE												
Volvocales												
Eudorina elegans Ehr.			1 (Dec)									
Chlorococcales												
Ankistrodesmus fasciculatus (Lundb) Fott.	r (Dec)											
**Chlorella minutissima* Fott et Nováková?	2 (May)	1 (May)			1 (May)							
**Chodatella citriformis* (Snow) G.M.S.			r (Nov)								1 (Dec)	
Chodatella quadriseta Lemm.												1 (May)
Closteriopsis longissima Lemm.							1 (Sep)					
Dictyosphaerium pulchellum Wood			r (May)									
Elakatothrix gelatinosa Wille	r (Dec)						1 (Sep)					
Nephrocytium agardhianum Nag.							3 (Sep)	3 (Sep)	3 (Sep)	3 (Sep)	1 (May)	
ZYGOPHYCEAE												
Zygnematales												
Actinotaenium globosum (Bulnh.) K et G.			1 (Dec)	1 (Dec)			1 (Apr)					
Closterium acutum var. *variabile* (Lemm.) Krieger	1 (Dec)		1 (Sep)									
Cosmarium bioculatum Bréb.							1 (Sep)	1 (Dec)	1 (May)			
Cosmarium contractum var. *ellipsoideum* (Delp.) W. et W.			1 (Dec)	1 (Dec)							2 (May) 1 (Dec)	
Euastrum ansatum var. *suprapositum* Nordst.							r (May)					
Gonatozygon brebissonii de Bary	1 (Dec)		1 (May)									1 (Sep)
Gonatozygon kinehani (Arch.) Rabenh.	2 (May) 3 (Dec)	1 (May)						1 (May)				
Hyalotheca dissiliens (J.E.S.) Bréb.		r (Dec)									1 (May)	
Staurastrum avicula Bréb. var. *exornatum* Messik.			1 (Dec)				1 (Sep)				1 (May) 1 (Dec)	
Staurastrum floriferum W. et W.		1 (May)	2 (Dec)	1 (Dec)	1 (Sep)			2 (Dec)		1 (May)	2 (Dec)	
Staurastrum gracile Ralfs									3 (Sep)			
Staurastrum grande Bulnh.								1 (May)			1 (Dec)	

	Lake Kanono S	Lake Kanono B	Lake Waingata S	Lake Waingata B	Lake Parawanui S	Lake Parawanui B	Lake Taharoa Massey Basin S	Lake Taharoa Massey Basin B	Lake Taharoa Hauhatoki Bay S	Lake Taharoa Hauhatoki Bay B	Lake Waikere S	Lake Waikere B
Staurastrum leptocladum var. *insigne* W. et W.				1 (Dec)								
Staurastrum longibrachiatum (Borge) Gutw.								1 (Dec)	1 (May)			
Staurastrum longipes (Nordst.) Teil.					1 (May)				1 (Dec)	1 (Dec)		
Staurastrum pingue Teil.							2 (Sep)					
Staurastrum saggitarium Nordst.	1 (Dec)							r (Apr)	3 (Sep)			
Staurastrum sexangulare Lund b.				1 (May)						1 (May)		
Staurastrum tohopekaligense var. *minus* (Turn.) Scott et Prescott			1 (May)	1 (May)								1 (May)
Staurodesmus cuspidatus var. *curvatus* (W. West) Teil.			1 (Dec)	1 (Dec)		1 (Dec)				1 (Dec)		
Staurodesmus cuspidatus var. *divergens* Nordst.											3 (Sep) 2 (Dec)	1 (Sep)
Staurodesmus glaber (Ehr.) Teil.			1 (Dec) 5 (Sep)	1 (Dec) 5 (Sep)								
Staurodesmus leptodermus var. *subcorniculatus* (Rich.) Teil.			3 (May)									r (May)
Staurodesmus spetsbergensis var. *limneticus* Teil.				2 (Dec)							1 (Sep)	1 (May) 1 (Sep)
Staurodesmus triangularis (Lagerh.) Teil.			2 (Dec)				1 (Sep)				1 (May)	
Sphaerozosma laeve var. *micracanthum* Nordst.			r (May) 1 (Dec)									
Teilingia excavata (Ralfs) Bourr.			1 (Dec)									1 (Dec)
CHROMOPHYTA												
XANTHOPHYCEAE												
Mischococcales												
Peroniella planktonica G. M. Smith (on *Teilingia excavata*)			1 (Dec)									
CHRYSOPHYCEAE												
Ochromonadales												
Dinobryon sertularia Ehr.	1 (Dec)		1 (Dec)				1 (Sep)	1 (May)				
Dinobryon bavaricum Imhof.	r (Sep)	r (Sep)	1 (May)				1 (Sep)	1 (May)				
Monosigales												
Salpingoeca frequentissima (Zach.) Lemm.	2 (Sep)	r (May)										
DIATOMOPHYCEAE												
CENTROPHYCIDAE												
Coscinodiscales												
Cyclotella stelligera Cleve et Grun.	3 (May)				2 (Sep) 3 (Dec)	2 (Sep)						
Melosira distans (Ehr.) Kütz	1 (Dec)				1 (May)	1 (May)						
Melosira granulata Ralfs	2 (Sep)	3 (Sep)										

	Lake Kanono		Lake Waingata		Lake Parawanui		Lake Taharoa Massey Basin		Lake Taharoa Hauhatoki Bay		Lake Waikere	
	S	B	S	B	S	B	S	B	S	B	S	B
Melosira granulata var. *angustissima* (O. Müll.) Hust.	1 (May) 2 (Sep)	2 (Dec) 3 (Sep)										
Rhizosoleniales												
Rhizosolenia eriensis H. L. Smith	2 (May)								r (May)			
PENNATOPHYCIDAE												
Amphora sp.	2 (Dec)											
Asterionella formosa Hass.	2 (May)											
Fragilaria construens var. *pumila* Grun.					1 (May)							
Fragilaria construens var. *venter* (Ehr.) Grun.							2 (Sep)					
Fragilaria crotonensis Kitt	2 (May)											
Fragilaria virescens Ralfs						1 (Dec)						
Frustulia rhomboides var. *saxonica* (Rabenh.) de T.							1 (Sep)	1 (Apr) 1 (Sep)				
Synedra radicans Kütz. = *S. acus* var. *radicans* (Kütz.) Hust.	2 (May) 2 (Dec)											
Synedra rumpens Kütz.	3 (May)	2 (May)										
Synedra ulna (Nitzsch) Ehr.	2 (May)	2 (Dec)					1 (Sep)					
Achnanthales												
Rhoicosphenia curvata (Kütz.) Grun.	1 (May)											
Cocconeis placentula Ehr. var. *euglypta* (Ehr.) Cl.	1 (May)				1 (Sep)							
Naviculales												
**Capartogramma crucicula* (Grun. ex cl.) Ross	1 (May)											
Cymbella minuta Hilse ex Rabenh. (Grun. ex Cl.) Ross							2 (Sep)					
Diploneis elliptica (Kütz.) Cleve		r (May)										
Epithemia argus (Erh.) Kütz.							1 (Sep)	1 (Apr)				
**Epithemia intermedia* Fricke					1 (Sep)							
Epithemia sorex Kütz.	1 (May)	1 (Dec)										
Navicula peregrina Ehr.?								1 (Apr)				
Nitzschia acicularis W. Sm.		3 (May)		1 (Dec)								
Nitzschia communis Rabenh.					1 (Sep)							
Rhopalodia gibba (Erh.) O. Müll.		1 (Dec)						1 (Apr)				
Surirella sp.								1 (Apr)				
Tabellaria flocculosa (Roth) Kütz.								1 (Apr)				1 (May)

	Lake Kanono		Lake Waingata		Lake Parawanui		Lake Taharoa Massey Basin		Lake Taharoa Hauhatoki Bay		Lake Waikere	
	S	B	S	B	S	B	S	B	S	B	S	B
PYRROPHYTA												
DINOPHYCEAE												
Peridiniales												
Ceratium hirundinella (O. Müll.) Schrank. f. *gracile* Bachm.	2 (Dec)		3 (Sep) 1 (Dec)	3 (Sep)		1 (Dec)						
**Ceratium hirundinella* (O. Müll.) Schrank. f. *robustum* (Amberg) Bachm.							2 (Sep) 1 (May)	2 (Dec)	2 (Sep) 2 (Dec)	2 (Dec)	1 (Dec) 1 (May)	2 (Dec) 1 (Dec)
Ankistrodesmus fasciculatus (Lundb.) Legnerová									r (May)			
Peridiniopsis sp.	2 (Dec)											
Peridinium sydneyense (Playf.) Thom.			5 (Sep)								3 (Sep)	
(a) thecate stage		3 (Dec)	1 (Dec) 1 (May)	r (Dec) 3 (May)			4 (Dec)		1 (May)		3 (May) 3 (Dec)	r (Dec) 1 (May)
(b) gymnodinioid stage	1 (Dec)		1 (Dec)	1 (Dec)			3 (Dec)				1 (Dec)	
Peridinium volzii Lemm.				1 (Dec)				1 (Apr)			3 (May) 3 (Sep)	
EUGLENOPHYTA												
EUGLENOPHYCEAE												
Euglenales												
Trachelomonas volvocina Ehr.			1 (May)	1 (Dec)								
Trachelomonas armata var. *duplex* Playf.			1 (Sep)									
CYANOPHYTA												
CYANOPHYCEAE												
Chroococcales												
Aphanothece sp.								r (Dec)				
Chroococcus minutus (Kütz.) Nag.												1 (May)
**Gloeocapsa stegophila* (Itzigs.) Rabenh.					1 (Sep)							
Microcystis aeruginosa Kütz.	1 (Dec)											
Nostocales												
**Anabaena macrospora* Kleb.	1 (May)		1 (Dec)									
Anabaena sp.	3 (Sep)											
Aphanizomenon flos-aquae (L.) Ralfs	2 (Dec)											
**Oscillatoria annae* van Goor	1 (May)			2 (May)								
**Phormidium rotheanum* Itzigsohn?		2 (Dec)										

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