Pacific Science (1974), Vol. 28, No. 4, p. 467-504
Printed in Great Britain

Algal Flora of Some North Island, New Zealand, Lakes, Including Rotorua and Rotoiti[1]

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FROM AN EXAMINATION over a 3-year period of more than 370 samples, an account is given of the chief components of the phytoplankton, together with brief mention of neuston, aufwuchs, and benthos communities. The specific composition of algal classes and pollution tolerance of different species are discussed.

From 1966 to 1969 lakes Rotorua and Rotoiti possessed a rich and varied algal flora in which the same three species of diatoms predominated in fluctuating amounts through all or part of each year. Chlorophyceae, particularly Chlorococcales and desmids, were numerous in species but less prolific than diatoms in cell numbers, except for planktonic *Mougeotia*.

Blue-green algae are known to form noxious blooms at times, though no such blooms occurred within the sampling period. Dinophyceae and Cryptophyceae were relatively unimportant.

The present study was undertaken to determine the basic composition of the algal flora comprising the phytoplankton and other communities in several North Island, New Zealand, lakes. Of the 370 samples, 260 came from lakes Rotorua and Rotoiti. In addition, 91 samples were examined from the hydroelectric lakes constructed on the Waikato River (lakes Ohakuri, Atiamuri, Whakamaru, Maraetai, and Karapiro), and 22 from Lake Horowhenua near Levin (Fig. 1 and Table 1).

METHODS

During the first 2 years, 200-ml samples of lake water from lakes Rotorua and Rotoiti were preserved in Lugol's Solution and the organisms were counted and identified according to the method described by Cassie (1969). In the 3rd year, net samples were examined. Vertical hauls were made at selected stations from bottom to surface with a tow net having a 160-μ mesh. Net samples provided a picture of biomass, whereas jar samples gave information on abundance of smaller nannoplankton. For counts from concentrated jar samples, cells rather than colonies were estimated, in an attempt to give a precise picture of total preserved phytoplankton. For net estimates, colonies instead of single cells were taken as units for assessment of abundance. Samples from Lake Ohakuri and other hydroelectric lakes were collected with a Mikrops tow net (50 meshes per cm), and those from Lake Horowhenua were concentrated by settling from jars containing 300 ml of lake water.

MORPHOMETRY

Lake Rotorua occupies a basin produced by subsidence, whereas Lake Rotoiti fills a drowned valley. Both are affected by aerial top dressing and sewage effluent, though the effect of effluent in the latter is much less than in the former (Fish 1969*b*). Both are tectonic lakes, i.e., owe their origin to volcanic action. Hot springs occur at various places along their shores (but algae from these habitats have not been studied in this survey). Both lakes are 86 m above sea level. The drainage area into Lake Rotoiti (67 km^2) is much less than that into Lake Rotorua. According to the Ministry of Works Kaituna Investigation Report, 1965, the catchment area of Lake Rotorua is 526 km^2. (Maximum recorded depth is 44.5 m [Fish and Chapman 1969].) Lake Rotoiti descends more abruptly to depths ranging from 40 to 70 m and has a maximum of 93.5 m in the center basin (Irwin 1969). The waters of Lake Rotorua that flow into Lake

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[1] This work was supported by grants from the Fisheries Research Division, Marine Department, and from the Botany Department, The University of Auckland. Manuscript received 4 May 1973.

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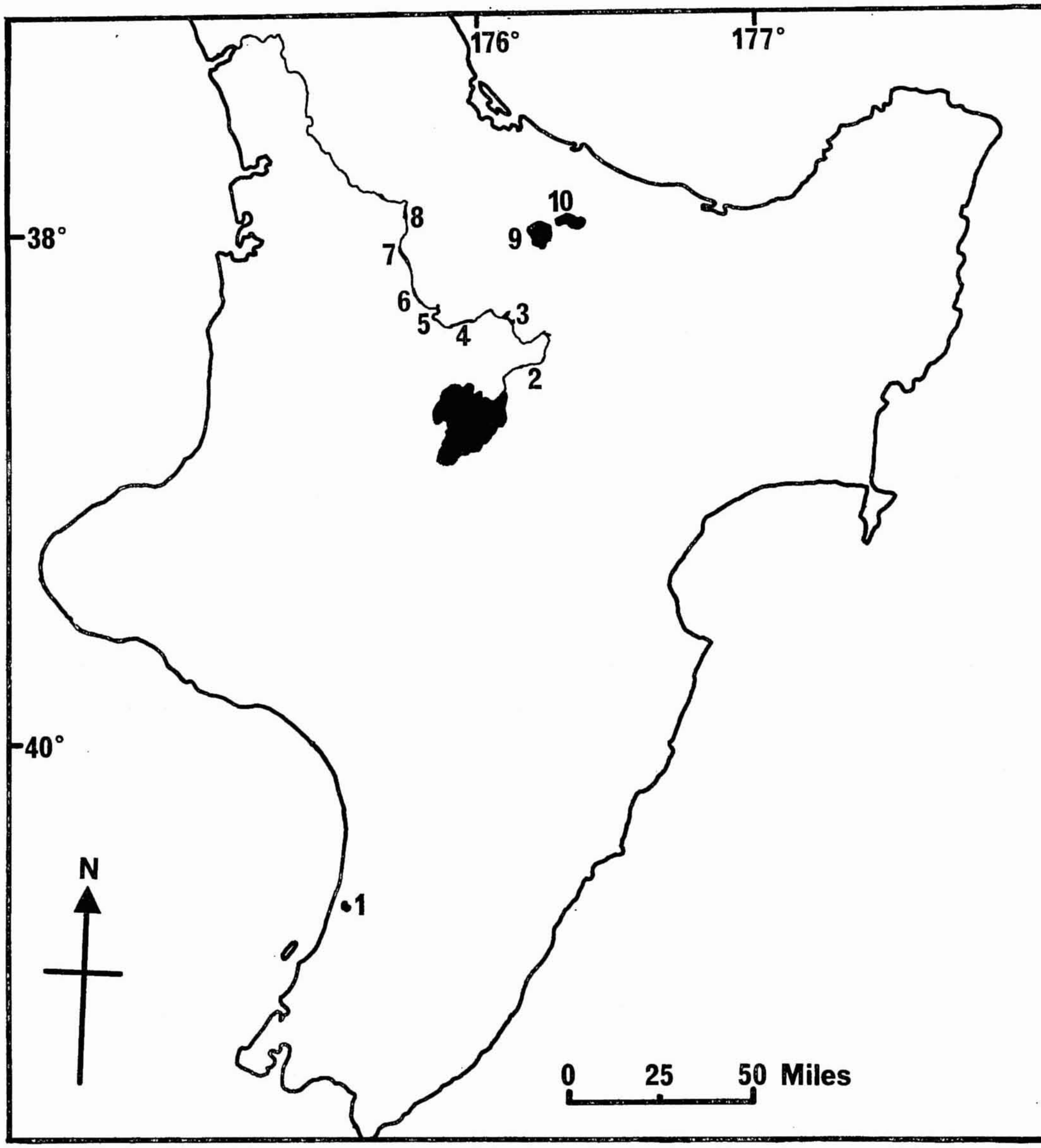


FIG. 1. Southern part of the North Island of New Zealand, showing location of lakes studied and sequence of hydroelectric lakes on Waikato River, with its origin in Lake Taupo.

KEY: *1*, L. Horowhenua; *2*, L. Aratiatia; *3*, L. Ohakuri; *4*, L. Whakamaru; *5*, L. Maraitai; *6*, L. Waipapa; *7*, L. Arapuni; *8*, L. Karapiro; *9*, L. Rotorua; *10*, L. Rotoiti.

Rotoiti via the Ohau Channel mix with those of the latter only in the shallow basin at the western end, after which they flow down the main outlet, the Kaituna River (Fish 1969*b*). Lake Rotorua has been classified by Jolly (1968) as being among those lakes directly affected by their proximity to improved pasture farming; whereas only part of Lake Rotoiti is affected by farming, much of the surrounding drainage area being clothed in bush. Jolly found the former to be usually homothermous, whereas the latter, with some stratification, was warm monomictic (cf. Hutchinson 1957).

TABLE 1

SAMPLING STATIONS IN LAKES ROTORUA AND ROTOITI

DATE	STATION	DESCRIPTION
		LAKE ROTORUA
May 1966–May 1969	A	offshore (Open Lake Station; surface, 9 m, 17 m)
	B	inshore (Kawaha Point; pooled sample)
	C	inshore (Mokoia Island; pooled sample)
June 1967–May 1968	A	offshore (Open Lake Station; surface, bottom)
	D	offshore (Hamurana–Mokoia Island; surface, bottom)
June 1968–May 1969	A	offshore (Open Lake Station; bottom to surface)
		LAKE ROTOITI
January–May 1967	Wrights Bay (Te Pohoe Bay)	offshore (surface, 4 m, 8 m)
June 1967–May 1968	1	inshore, west end (surface, in 11 m)
	2	offshore, opposite Wrights Bay (surface, in 42 m)
	3	offshore, opposite Hauparu Bay (surface, in 59 m)
June 1968–May 1969	3	offshore, opposite Hauparu Bay (bottom to surface)

NOTE: For location of Rotorua stations see Cassie (1969, fig. 1); for location of Rotoiti stations 1–3 see Fish and Chapman (1969, fig. 1).

ENVIRONMENTAL FACTORS

Climate and Temperature

During the 3-year period, monthly rainfall varied from 0.83 inches in March 1969 to 20.87 inches in August 1967. The warmest month also was March 1969 with 116 hours of sunshine. Lowest insolation (70.5 hours) occurred in June 1968. There was no pronounced rainy season, but hours of sunshine were more numerous from January to March than in other months. October 1967 was notable for its warm air temperatures (4° C above normal) and low rainfall (1.4 inches below normal [N. G. Robertson, personal communication]).

In Lake Rotorua surface water temperatures at the open lake station (O.L.S.) were also higher in November 1967 than at any time in the preceding and following years. Figures from the first sampling year are given in Cassie 1969, fig. 2. Subsequent data show that the lowest temperature was 8.6° C on 22 July 1968 and the highest was 21.4° C on 12 March 1968 (G. R. Fish, personal communication).

Surface temperatures in Lake Rotorua (measured by bathythermograph in daylight) were found to vary from 13° to 14° C (2 to 4 May 1967) and varied from 22.5° to 24.5° C in mid-February 1966 (Irwin 1968). Maximum and minimum temperatures in Lake Rotorua at a depth of 1 m were found to exceed those at the surface in November 1966 and May 1967. Below 1 m there was also a decrease of up to 1.0° C in temperature with depth; but the decrease never exceeded 1.0° C and at the many bathythermograph stations there was no change. However, a decrease of 1.6° C was recorded by officers of the Marine Department between surface and bottom at the O.L.S. on 27 February 1967 (Cassie 1969, table 3).

In Lake Rotoiti Irwin detected a thermocline between 10 and 20 m where temperatures ranged from 20° to 16° C (a gradient 0.4° C per m). Hypolimnion temperatures ranged from 11.9° to 12.8° C. Jolly (1968) recorded surface and bottom winter temperatures in Lake Rotoiti as being 11.0° C and 10.5° C, respectively. In Lake Rotorua Irwin found that thermal stratification was ill-defined or absent; whereas in Lake Rotoiti stratification did occur.

Chemical Conditions

The 1955–1956 values quoted by Jolly (1968) for ammonia-nitrogen and phosphate were fairly low; whereas nitrate nitrogen was hardly detectable in either lake. Silicate ranged from

TABLE 2

NUMBERS OF SPECIES IDENTIFIED FROM DIFFERENT ALGAL CLASSES AND HABITATS

	PLANKTON	AUFWUCHS	BENTHOS	TOTAL NUMBER IDENTIFIED
Chlorophyceae	44	7	–	51
Xanthophyceae	2	–	–	2
Chrysophyceae	7	–	1	8
Bacillariophyceae	8	11	5	24
Euglenophyceae	1	1	4	6
Dinophyceae	6	–	–	6
Cryoptophyceae	1	–	–	1
Myxophyceae	10	3	5	18
Total	79	22	15	116

2–5 mg/liter in Lake Rotoiti and from 1–6 mg/liter in Lake Rotorua—low values for thermal waters (Jolly 1968: 240). Fish (1969*b*) reported that in Lake Rotorua during the last 2 decades there has been a tremendous increase in the forces promoting eutrophication, due particularly to land development, causing erosion and water runoff. The population of Rotorua City has increased greatly, and phosphate-phosphorus and nitrate-nitrogen have been retained in the lake in vast quantities. As a result the standing crop of organisms is now much greater.

Data on the phosphate-phosphorus, nitrate-nitrogen, and ammonia-nitrogen content of Lake Rotorua from June 1967 to May 1968 (Fish 1969*b*: table 1) show that the total inflow of these nutrients greatly exceeds the surface outflow. The maximum amount of phosphate-P recorded by Fish (7,692 kg or 22 percent) came from the Hamurana Stream. Nitrate-N was most abundant from the Awahou Stream (30,583 kg or 28 percent). The bulk of ammonia-N (95,500 kg or 66.5 percent) flowed into the lake through the Waiohewa Stream. The amount of phosphate-P and ammonia-N entering the lake from sewage outflow during the same period was smaller (14.2 percent and 19.9 percent, respectively). No nitrate-N was recorded from this source. It seems likely, according to Fish, that agricultural development provides more nutrients that promote eutrophication than does sewage inflow. Further, during periods of flooding the quantity of nutrients in the lake can increase within a few days by two or more orders of magnitude.

Dissolved Oxygen

As with the surface waters of other New Zealand lakes, those of Rotorua and Rotoiti showed a high percentage saturation at most seasons, especially in spring when there was a high rate of photosynthesis. Jolly (1968) gave the following figures to indicate the range in percentage saturation of dissolved oxygen from surface to bottom in the two lakes: Lake Rotoiti—surface 122–90, bottom 130–29; Lake Rotorua—surface 138–95, bottom 130–94.

During March and April in Lake Rotoiti, minimal values for oxygen were recorded just below the thermocline. In the hypolimnion a mean annual minimum of dissolved oxygen was estimated by Jolly as being 3.1 ppm. More recently, in 1967–1968, Fish (1969*a*) found the mean annual minimum in the hypolimnion to be no greater than 0.08 ppm. A comparison between the figures of Jolly (1968) and those of Fish (1969*a*) shows that minimal values were lower in 1967–1968 than in 1956–1957. In 1956–1957 the dissolved oxygen in ppm in Lake Rotorua ranged from 12.4 to 9.0 (Jolly 1968); in 1967–1968 those values were 11.2–3.5 (Fish 1969*a*).

COMMUNITIES

Phytoplankton

The appendix at the end of this work constitutes a list of all algae identified during the survey, together with their abundance on a 1-to-5 scale (Cassie 1961). The symbols p, a, and b indicate their habitat: whether phytoplankton, aufwuchs, or benthos. Records for

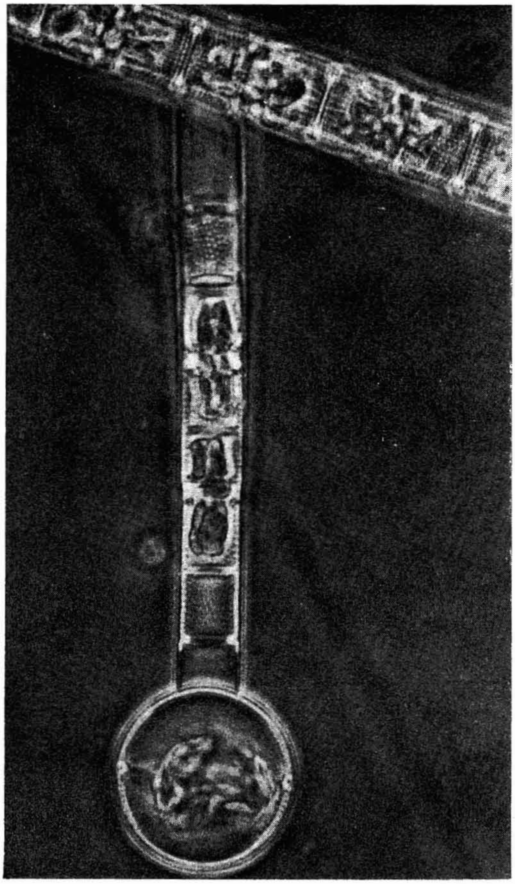


FIG. 2. *Melosira granulata* Ralfs. Auxospore. Film 14/24A. ×2135.

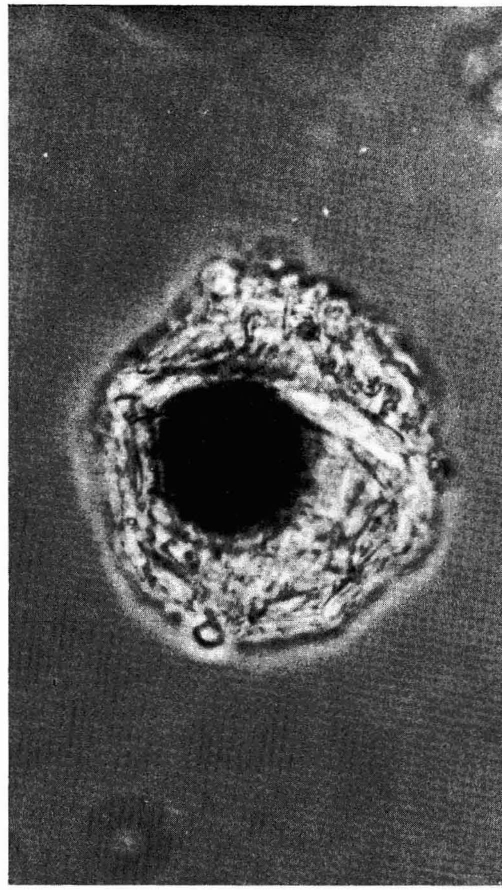


FIG. 3. *Peridinicum striolatum* Playf. Film 5/12A. ×1500.

a and b are fragmentary. Table 2 indicates the distribution of species among the different algal classes. The phytoplankton component is by far the largest, mainly because it was the principal object of study. Numbers of species in each category are therefore merely an interim guide to those actually present. Seventy-nine of the total list of 116 species were found to lead a planktonic existence. These were not necessarily obligate phytoplankters, but were the ones that most characteristically occupied that habitat. Within the phytoplankton community the chlorophycean component was the strongest one when numbers of species are considered. Only rarely did green algae dominate, however. The most abundant were Bacillariophyceae (Cassie 1969), with Myxophyceae, Dinophyceae, and Chrysophyceae seldom achieving ecological importance, at least in preserved samples. In general, no single phytoplankter dominated to the exclusion of all others. Over the 3-year sampling period the pattern of abundance of the different dominants and subdominants (5 and 4 on the abundance scale in the appendix) did not vary greatly.

Fish and Chapman (1969) noted that greatest phytoplankton production in Lake Rotorua occurs in the northeastern quadrant where waters move toward the main outlet, Ohau Channel. These workers have also published maps showing beds of submerged *Lagarosiphon* and *Elodea* that occur at intervals near the western shore of the lake. Lower cell counts in samples from inshore western waters are consistent with the fact that Fitzgerald (1969) found an antagonism between aquatic macrophytes and competing phytoplankton. (Cf. Cassie 1969, who recorded lower cell numbers at Kawaha Point.) It is interesting to note in this connection that Mitchell (1971) found in Tomahawk Lagoon (no. 2) on the south side of Otago Peninsula that large crops of either phytoplankton or macrophytes were always present, though never both together.

R. M. Cassie (personal communication) has shown by statistical analysis of a detailed set of samples taken over 24 hours that the phytoplankton population of Lake Rotorua is relatively homogeneous despite differences due to depths and stations. *Melosira granulata* (Fig. 2) in particular shows a fairly consistent vertical homogeneity in distribution. By comparison Jolly (1959) found in her net samples that *Melosira* was by far the most abundant phytoplankter and Chlorophyceae were subordinate though several genera, including *Mougeotia*, *Cosmarium*, *Dictyosphaerium*, *Spondylosium* (probably including *Sphaerozosma*), and *Closterium*, were conspicuous. All but the first two were represented by small numbers. Jolly also found *Staurastrum*, *Dinobryon*, and *Peridinium* (probably *P. striolatum*, Fig. 3) to be more abundant in Lake Rotoiti. *Asterionella* was insignificant. It appears from a comparison of Jolly's records with those of the present survey that, apart from the scarcity of *Asterionella*, the proportion of most of the planktonic algae has remained approximately the same. Two chlorophycean genera not recorded by Jolly but which achieved dominance at times between 1967 and 1969 were *Actinotaenium pyramidatum* and *Actinastrum hantschii*.

A single fresh neuston (surface film) sample collected in September 1969 from the surface of Lake Rotoiti between Wrights (Te Pohoe) Bay and Cherry Bay was examined. Here the surface water displayed parallel rows of golden brown organisms which, on microscopic examination, consisted of a number of normally planktonic species intermingled with masses of winged pine pollen embedded in clumps of amorphous golden brown organic matter, which could have been a disintegrated phytoplankton bloom. Very frequent were rapidly moving uniflagellate *Chromulina* sp., no more than 6 to 12 μ in diameter. It is not confined to the neuston, however, since specimens have been observed in fresh subsurface samples from both lakes. Small flagellated chrysomonads are known to become attached to the surface film, surround themselves with an envelope, and orient their chromatophores at right angles to the incident light. When light rays are concentrated on them, the cell acts as a lens from which the light is reflected (Ruttner 1963: 136). It could be that the phenomenon observed on Lake Rotoiti was a similar one, but the exact species responsible for the present phenomenon was not identified. Although 12 other species were observed in the sample, none was as abundant as the minute *Chromulina*. Other species, including *Anabaena flos-aquae*, *Melosira distans*, *Mougeotia* sp. (narrow filaments), *Rhizosolenia eriensis*, *Cystodinium cornifax*, *Asterionella formosa*, and *Botryococcus braunii* are all known to occur in subsurface phytoplankton. (See Cassie 1969: figs. 4, 6, 8, 9.)

Other species common or occasional in the phytoplankton at various times of the year included *Microcystis aeruginosa*, *Anabaena circinalis*, *Pandorina morum*, *Trachelomonas volvocina*, *Dinobryon cylindricum*, and *Nephrocytium agardhianum* (Figs. 4–9).

Staurastrum and *Staurodesmus* were nearly always present, though seldom in large numbers; e.g., *Staurastrum floriferum* (Fig. 4), *S. leptocladum* var. *insigne* (Fig. 10), *S. sexangulare* (Fig. 11), and *Staurodesmus unicornis* var. *ceylonensis* (Fig. 12). *Staurodesmus convergens* var. *laportei* (Fig. 13) has been found to date only in the "hydroelectric" lakes on the Waikato River and in Lake Rotoma (near Lake Rotoiti). *Cyclotella stelligera* (Fig. 14), though dominant once in Lake Rotorua, was usually more abundant in Lake Rotoiti.

Aufwuchs

The aufwuchs community, i.e., organisms attached to or moving upon a living substrate, occurs in lakes Rotorua and Rotoiti most commonly on the macrophytes *Lagarosiphon major* and *Nitella hookeri*. A few samples have been examined from the littoral zone (shallow inshore

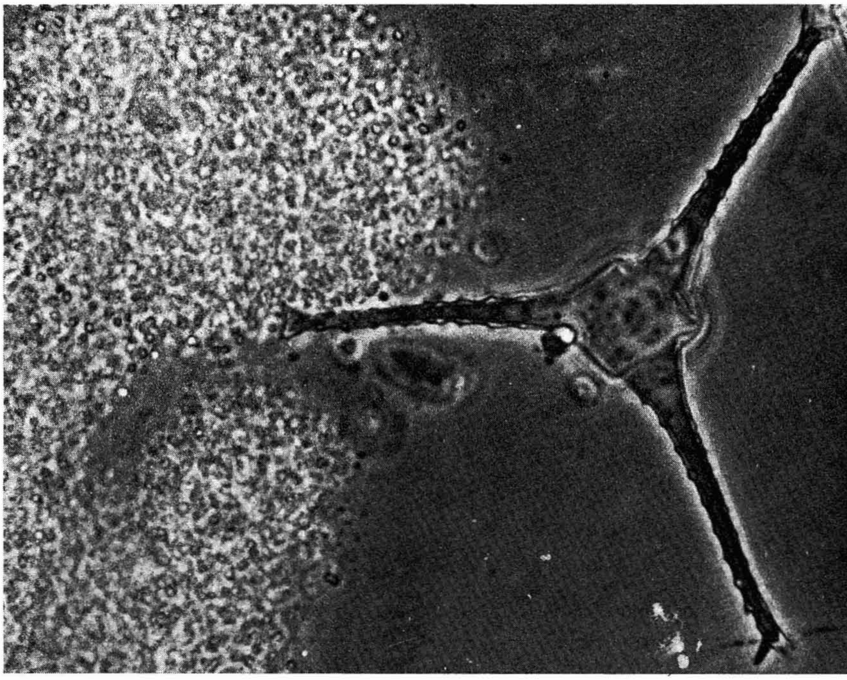


FIG. 4. *Microcystis aeruginosa* Kütz. and *Staurastrum floriferum* (West & West) Brook. Film 14/19A. ×3400.

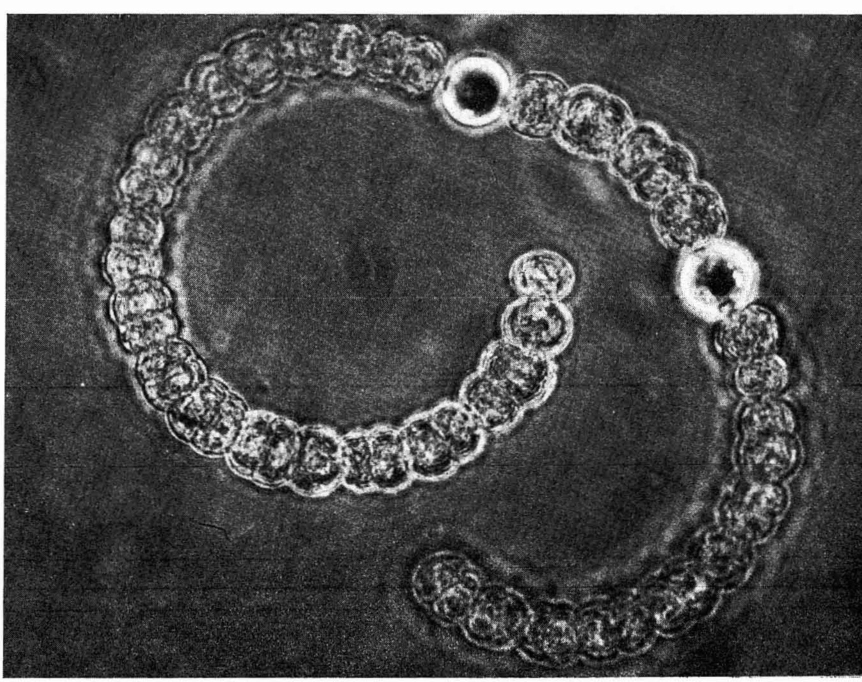
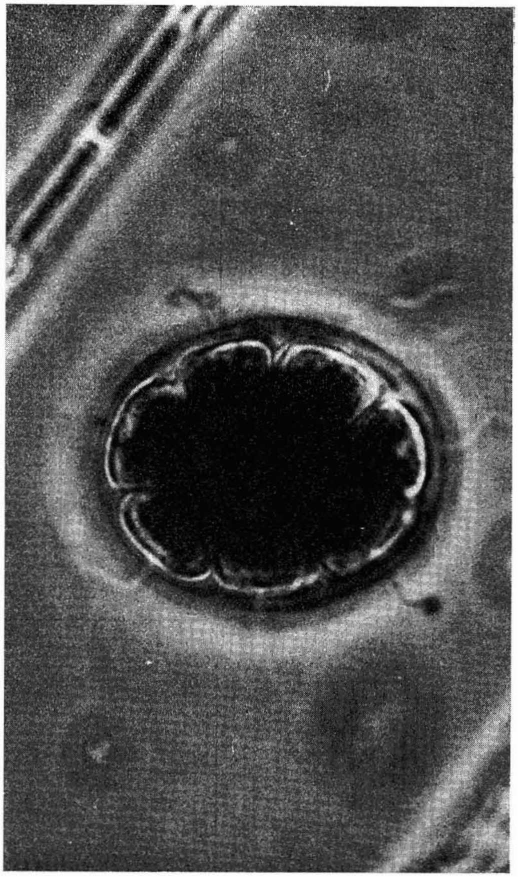


FIG. 5. *Anabaena circinalis* Rabenh. Film 9/31. ×3600.



areas up to 5 m deep). Twenty-two species of algae have been identified from the aufwuchs (Table 2). Diatoms predominate (11 species) and *Chlorophyceae* are abundant (7 species). There was no opportunity to study seasonal behavior of the principal species. Many more will doubtless be revealed by some intensive investigations. Among the diatoms, pennate forms are the most conspicuous. *Epithemia sorex*, rather like a set of false teeth when two adjacent fructules are seen in girdle view (Fig. 15), is one of the commonest (cf. Flint 1938, who noted a winter dominance and a year-round occurrence of *E. sorex* in Lake Sarah, Cass District, S. Island, New Zealand; and Castenholz 1960, who recorded this species in Alkali Lake, Lower Grand Coulee, Washington, as a prominent member of a pennate diatom community during autumn).

Epithemia zebra (Fig. 16) is less frequently encountered.

Epithemia and *Eunotia* sp. attach themselves firmly to leaf and stem apices of *Lagarosiphon* and *Nitella*. Of the unattached species, *Melosira lineata* (3 to 10 cells per chain, Figs. 17, 18) and *Fragilaria crotonensis* (Fig. 19) are less frequently encountered. *Fragilaria virescens* (Fig. 20) may

FIG. 6. *Pandorina morum* (Müll.) Bory. Film 9/28. ×4000.

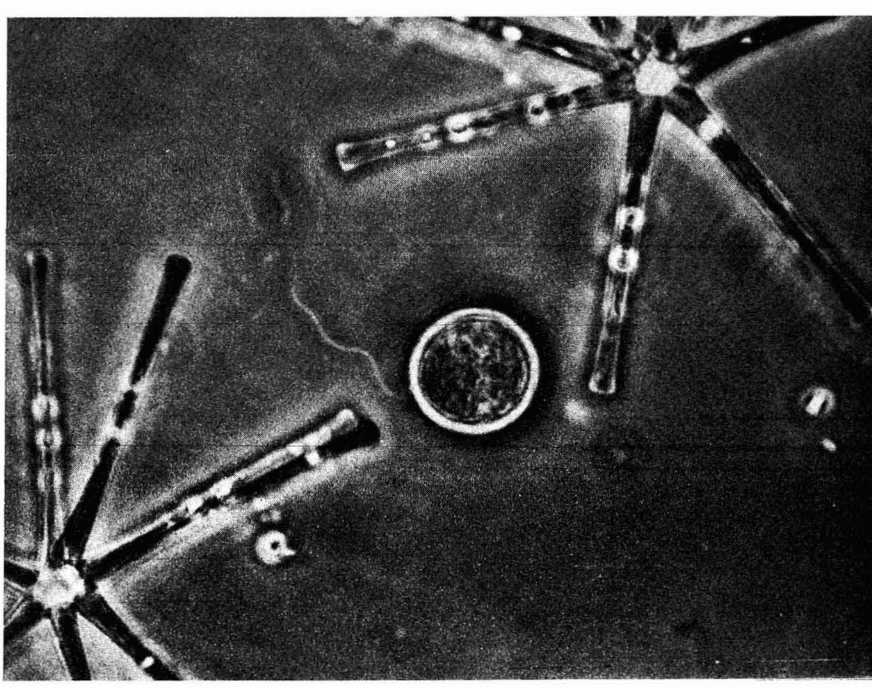


FIG. 7. *Trachelomonas volvocina* (Ehr.) and *Asterionella formosa* Hass. Film 9/17A. ×4000.

FIG. 8. *Dinobryon cylindricum* var. *alpinum* (Imh.) Bachm. Film 12/16. ×1125.

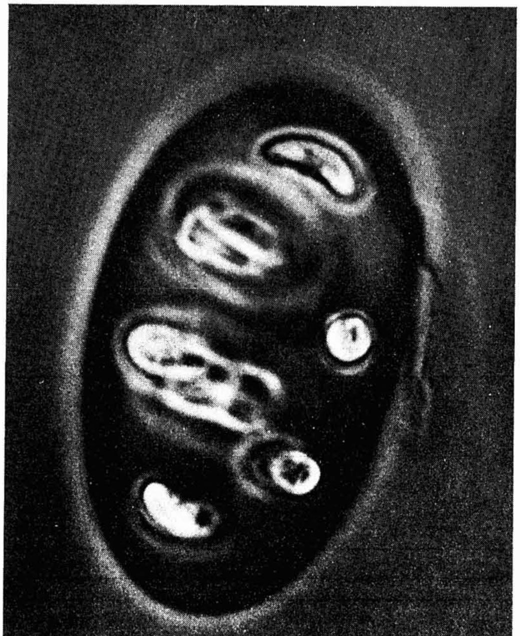


FIG. 9. *Nephrocytium agardhianum* Nag. Film 6/20A. ×4000.

also occur. Many different small green algae, including *Closterium parvulum* and *C. aciculare* (Figs. 21, 22), *Scenedesmus*, *Kirchneriella*, *Crucigenia* (Fig. 23), *Selenastrum*, and *Mougeotia* (wide cells), are intermingled with normally planktonic species such as *Melosira granulata*, *M. distans*, *Mougeotia* (narrow cells), and numerous species of *Staurastrum*. Filaments of *Lyngbya* frequently enmesh fronds of the macrophyte *Lagarosiphon* near the surface. Others worthy of mention among the aufwuchs community are *Rhopalodia gibba*, *Ankistrodesmus falcatus*, and the desmid *Sphaerozosma aubertianum* var. *compressum*, and *Tabellaria flocculosa* (Figs. 24–26).

Equally common among aufwuchs or phytoplankton are *Eudorina elegans*, *Pediastrum duplex*, and *P. boryanum* (Figs. 27–29), as well as *Ankistrodesmus* and *Sphaerozosma*. The position of *Peroniella planktonica* (Fig. 30) is hard to categorize, since it is planktonic merely by growing as an epiphyte and being carried up into the phytoplankton by its filamentous host.

A specimen of *Nitella hookeri* collected from Cherry Bay by B. Coffey showed a growth at branch apices of an alga closely resembling the genus *Thamniochaete* (cf. Bourrelly 1966). The

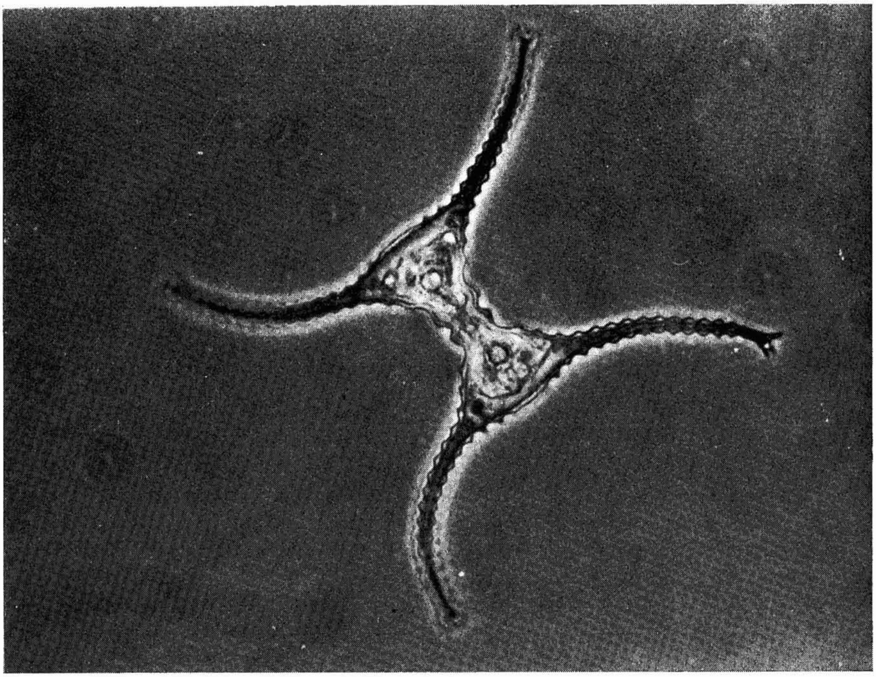


FIG. 10. *Staurastrum leptocladium* var. *insigne* West & West. Film 15/10. ×1800.

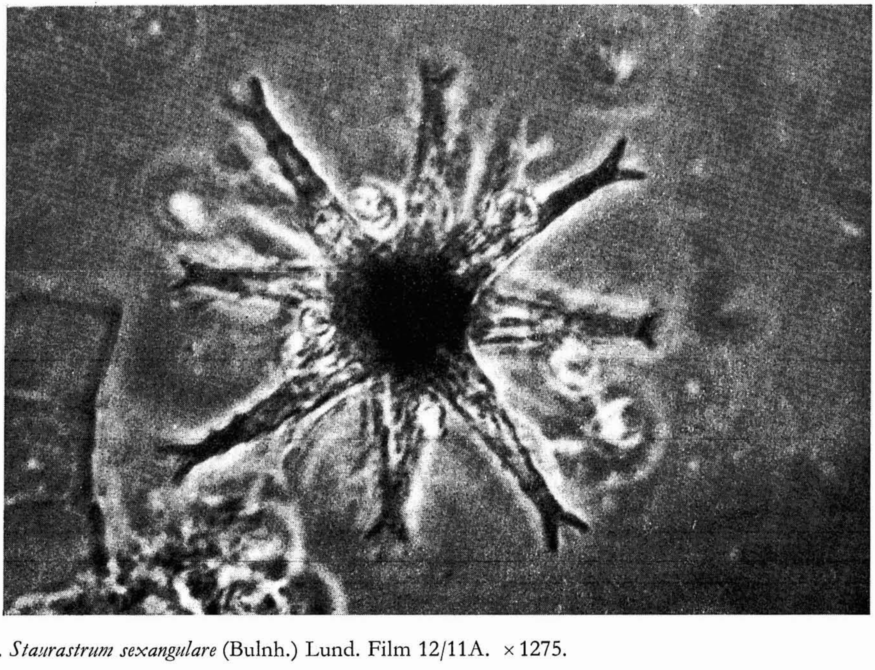


FIG. 11. *Staurastrum sexangulare* (Bulnh.) Lund. Film 12/11A. ×1275.

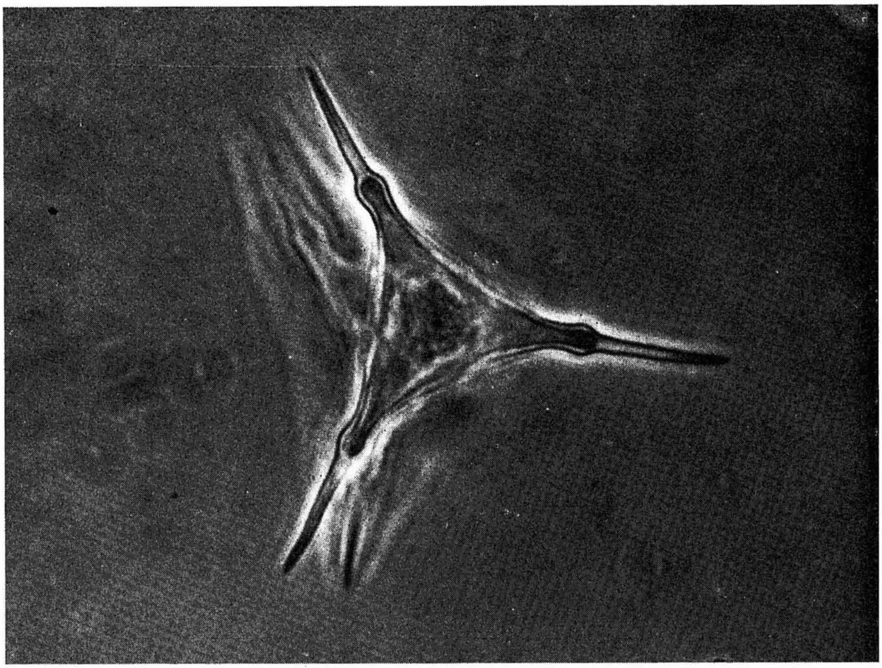


FIG. 12. *Staurodesmus unicornis* var. *ceylonensis* Teiling. Film 14/23A. ×4000.

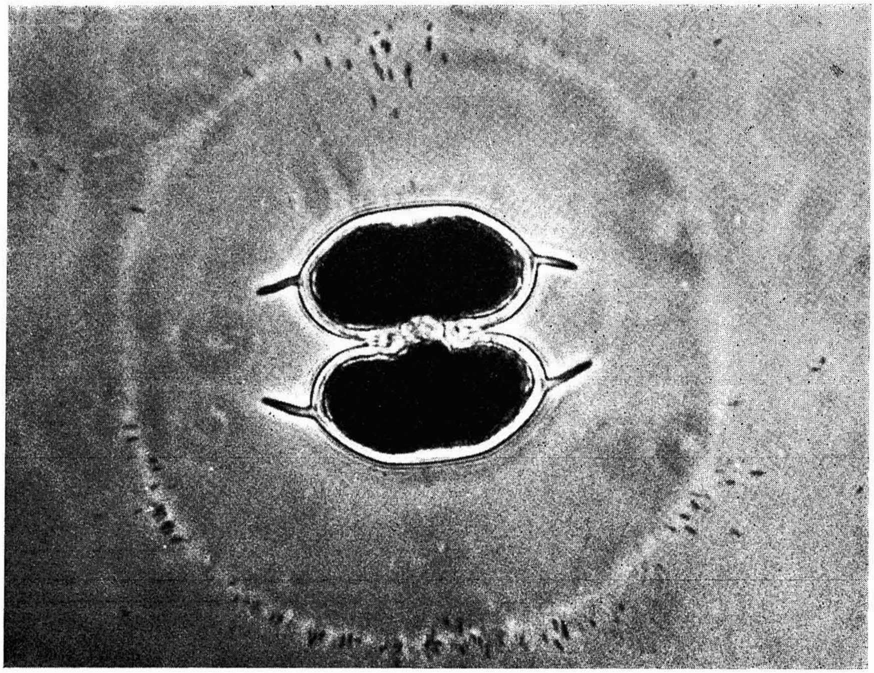


FIG. 13. *Staurodesmus convergens* var. *laportei* Teiling. Film 10/3. ×2500.

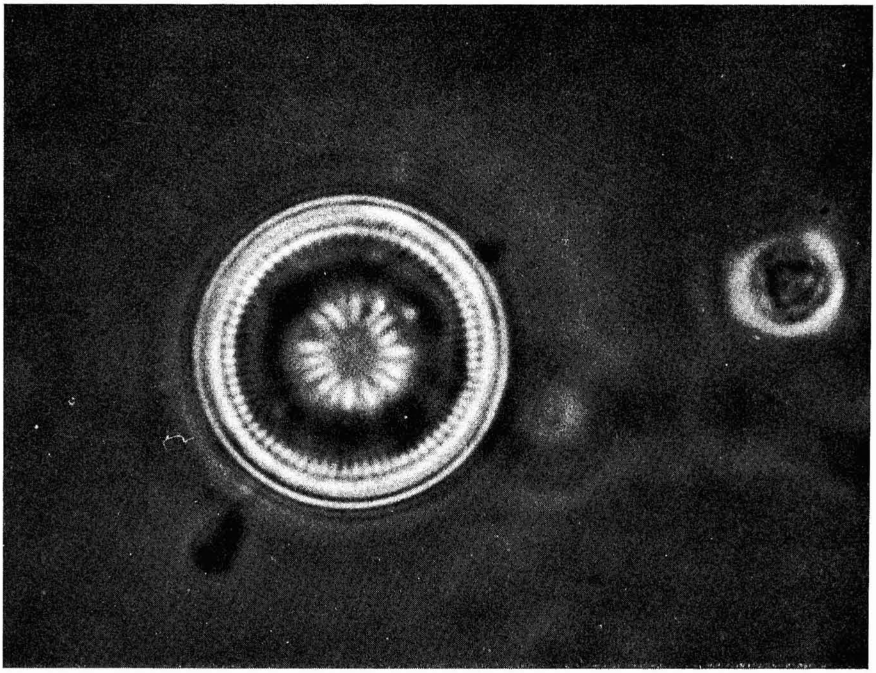


FIG. 14. *Cyclotella stelligera* Cleve & Grun. Film 4/28. ×3200.

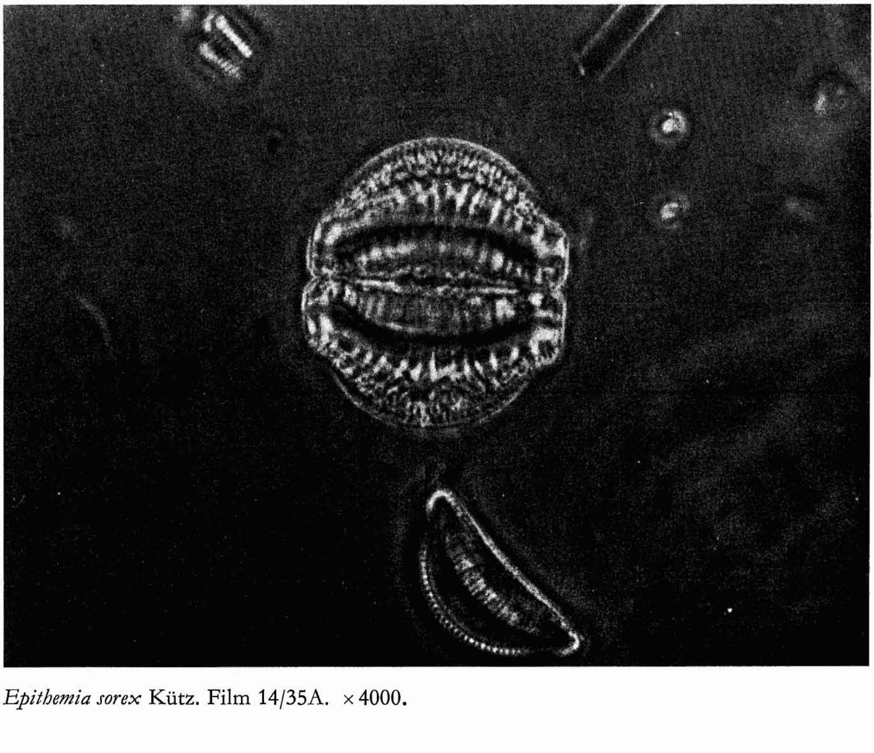


FIG. 15. *Epithemia sorex* Kütz. Film 14/35A. ×4000.

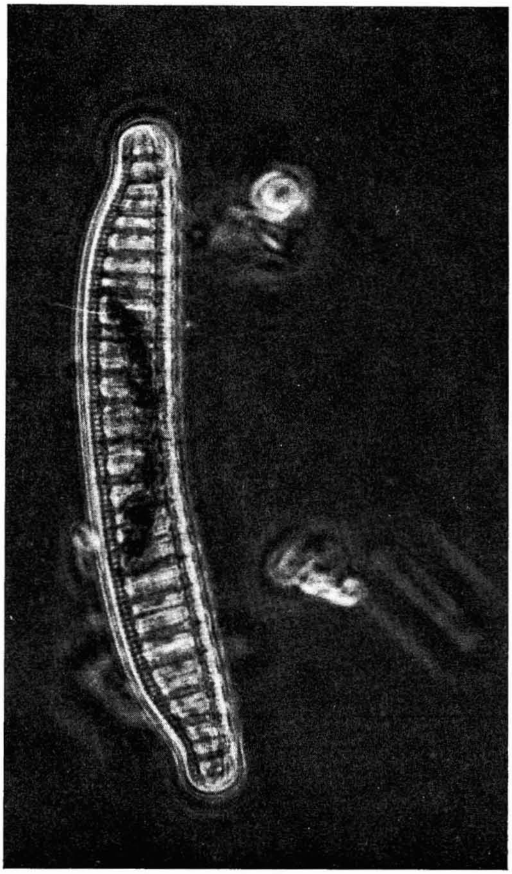


FIG. 16. *Epithemia zebra* (Ehr.) Kütz. Film 14/2A. ×3800.

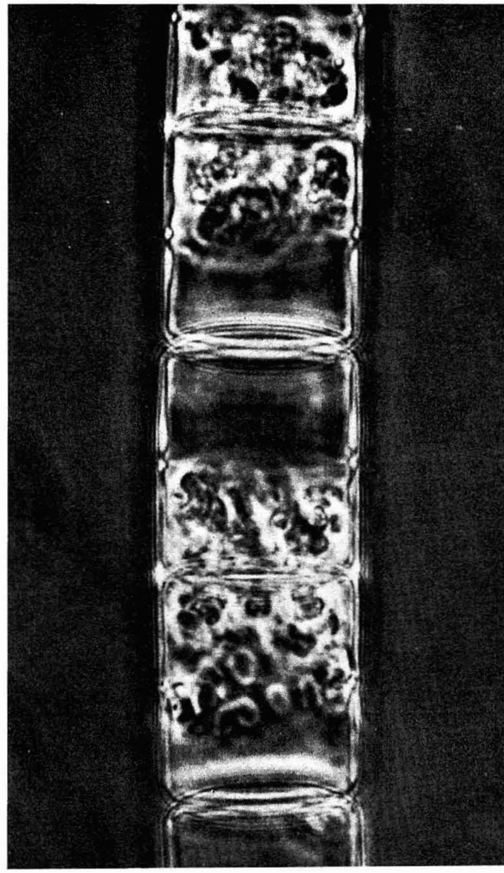


FIG. 17. *Melosira lineata* (Dillw.). Film 6/15A. ×3600.

Nitella plant was growing in a depth of 2 ft inshore of a *Lagarosiphon* bed, on a sandy bottom. No previous record of this genus is known in New Zealand.

There follows a list of algae that are regarded as aufwuchs members in lakes Rotorua and Rotoiti: CHLOROPHYCEAE—*Crucigenia rectangularis*, *Kirchneriella elongata*, *Pediastrum tetras* var. *tetraödon Scenedesmus acuminatus* (Lag.) Chod., *Scenedesmus quadricauda*, *Selenastrum gracile*, *Closterium wallichii*, *Mougeotia* sp. (wide cells); XANTHOPHYCEAE—*Bumilleria sicula*; BACILLARIOPHYCEAE—*Melosira lineata*, *Stephanodiscus* sp., *Amphora* sp., *Epithemia sorex*, *Eunotia* sp., *Fragilaria crotonensis*, *Gomphonema* sp., *Navicula* sp., *Rhopalodia gibba*, *Synedra acus*, *Tabellaria flocculosa*; EUGLENOPHYCEAE—*Trachelmomonas scabra* var. *pygmaea*; MYXOPHYCEAE—*Merismopedia elegans*, *Lyngbya birgei*, *Lynygba hieronymusii*.

Benthos

Only a few littoral benthic samples were examined: from Wrights (Te Pohoe) Bay and Te Weta Bay in Lake Rotoiti and from the mouth of the Waiteti Stream and Holdens Bay in Lake Rotorua (collected by M. A. Chapman and myself).[3]

In May 1949, about the mouth of the Waiteti Stream, the soft oozy mud bottom was coated with thin greenish black mats of *Oscillatoria tenuis* intermingled with *O. limosa* in discrete or confluent patches about 1 to 6 inches in diameter. No other algae were evident. Farther

[3] Localities sampled were Holdens Bay, Waitete, and Hamurana (Lake Rotorua) and Te Weta Bay, Cherry Bay, and Wrights Bay (Lake Rotoiti). These can be located on the Fisheries Research Division Bathymetry of lakes Rotorua and Rotoiti (Irwin 1969).

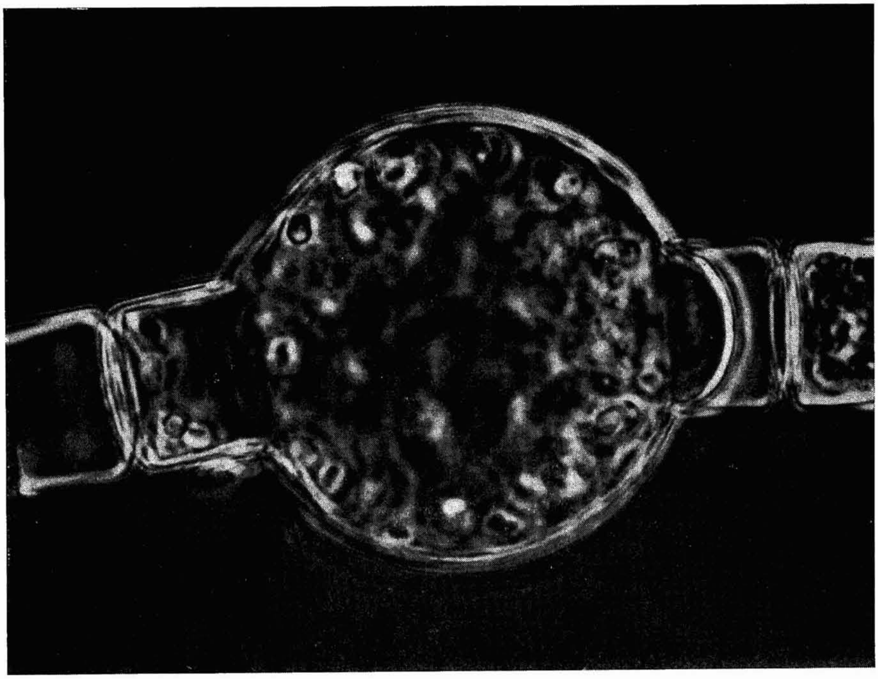


FIG. 18. *Melosira lineata*. Auxospore. Film 6/14A. ×3600.

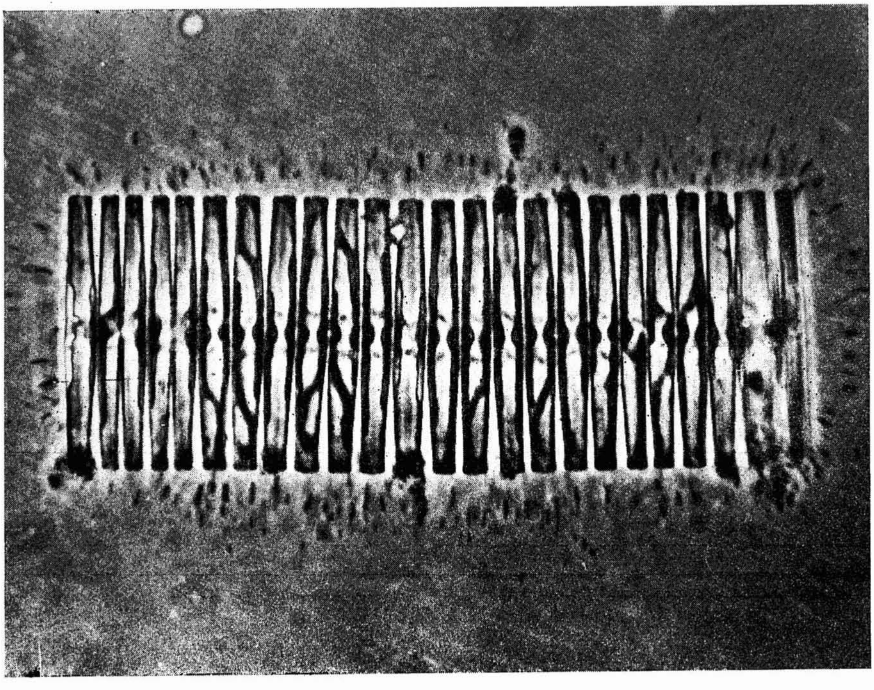


FIG. 19. *Fragilaria crotonensis* Kitt. Film 16/23. ×925.

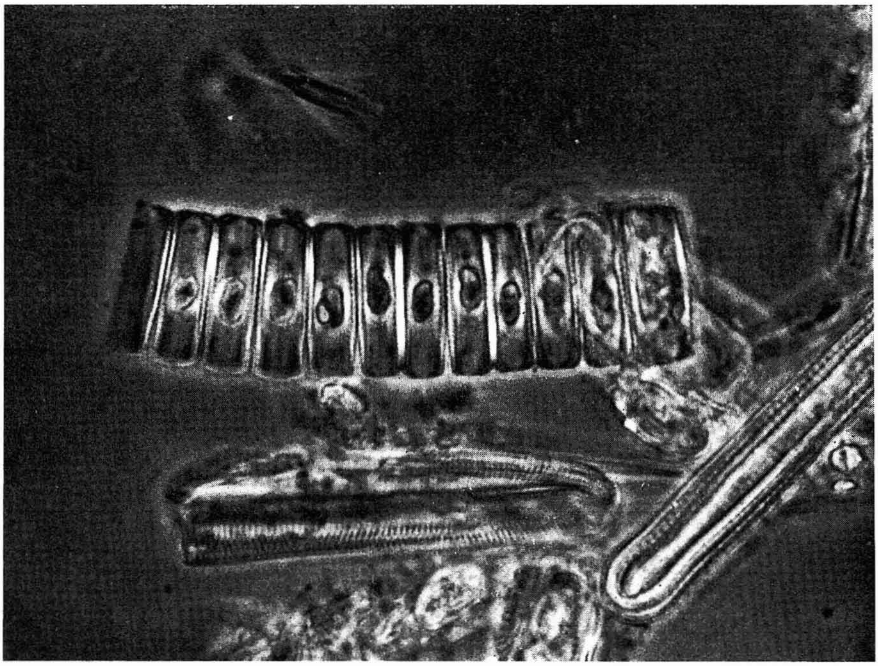


FIG. 20. *Fragilaria virescens* Ralfs. Film 24/1A. ×3600.

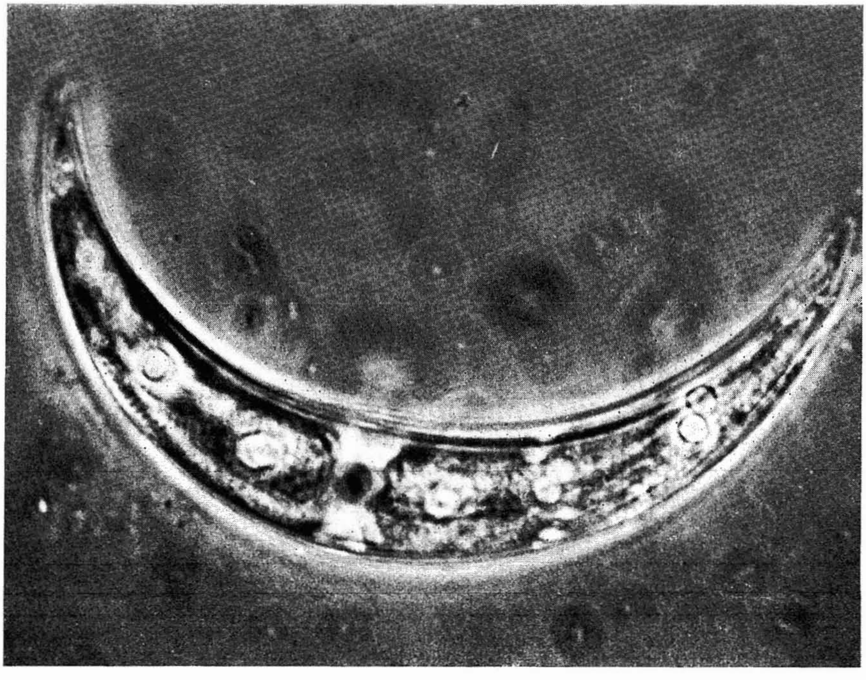


FIG. 21. *Closterium parvulum* Nag. Film 12/16. ×1125.

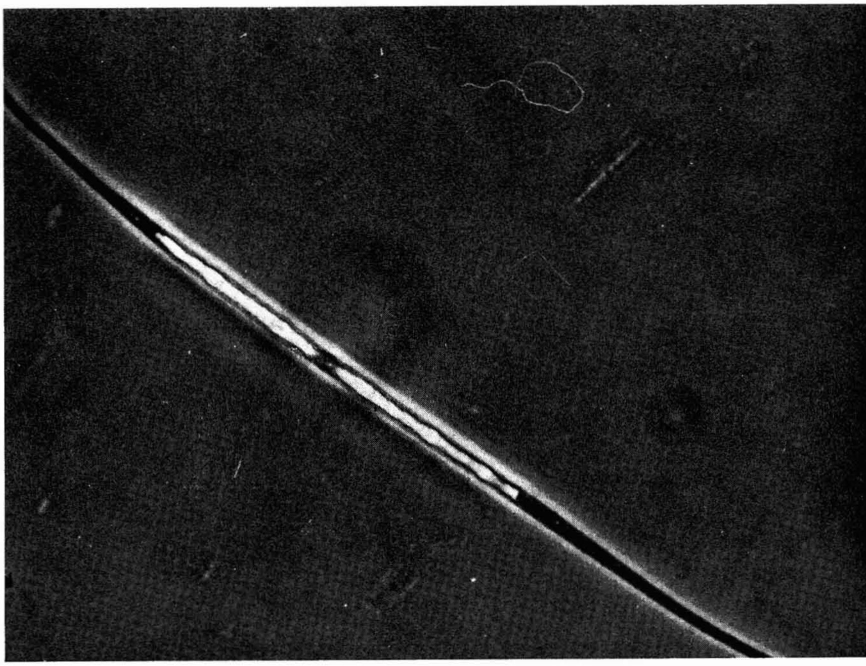


FIG. 22. *Closterium aciculare* T. West. Film 4/38A. ×1125.

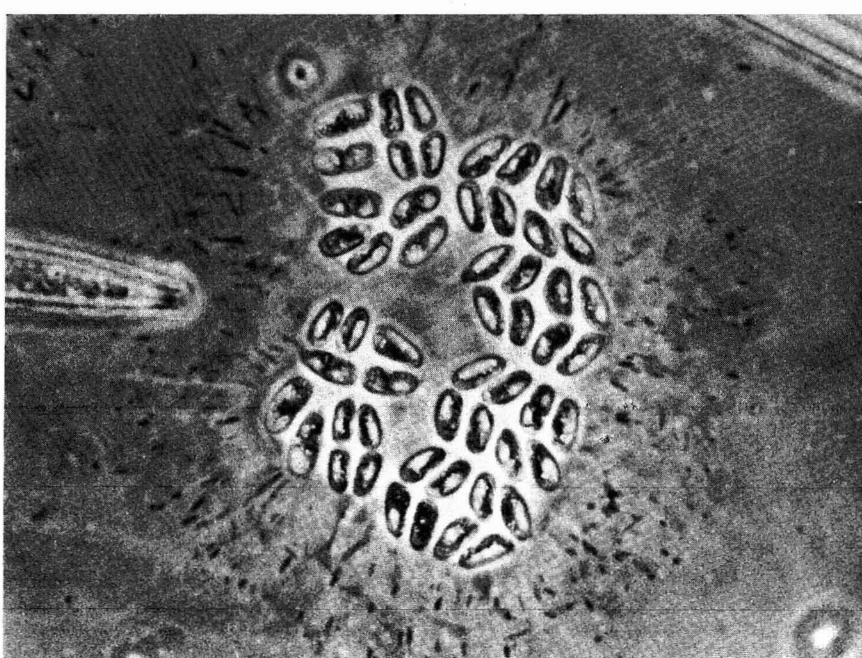


FIG. 23. *Crucigenia rectangularis* (Nag.) Gay var. *irregularis* (Wille) Brunnth. Film 16/36. ×1800.

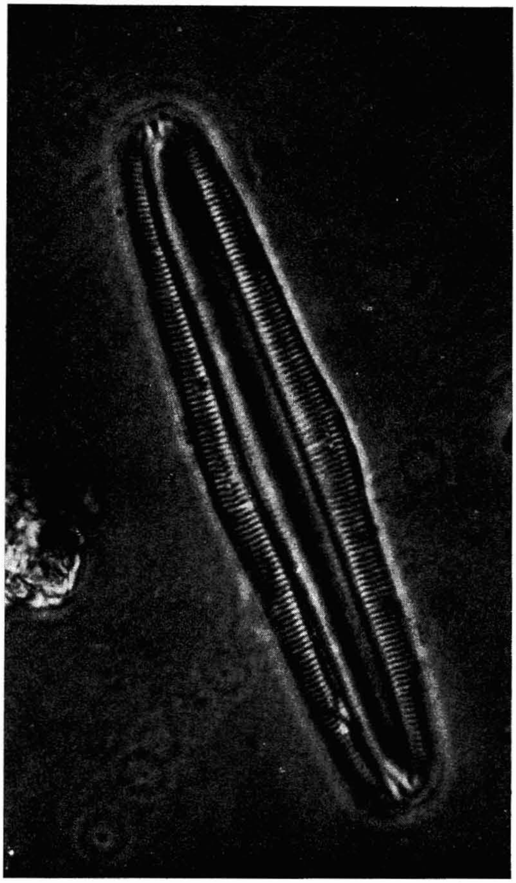


FIG. 24. *Rhopalodia gibba* (Ehr.) Müll. Girdle view. Film 14/42A. ×3600.

north inshore at Hamurana Springs the water was very clear and poor in phytoplankton but a filmy yellow-brown cover of naviculoid diatoms and encrusting blue-green algae grew on firm substrates provided by roots and concrete boat ramps. A similar community was found near the mouth of the Ohau Channel. The sample from Holdens Bay (near Rotorua Airport) contained mainly planktonic species but also a reasonably large number of naviculoid diatoms and a small amount of *Nodularia spumigena*. A variety of this species has been reported by Flint (unpublished) as causing nuisance blooms poisonous to stock in Lake Forsyth, Canterbury, New Zealand, during summer 1968–1969.

Inshore near the Ohau Channel entrance, examination of the algae from a bottom net tow revealed a dense community of 14 species, enmeshed among the tortuous threads of *Oscillatoria*-wide straight filaments of the *O. princeps* type, narrower straight and flexed *O. limosa*, and very narrow *O. tenuis* (4 to 5 μ diameter). *Oscillatoria limosa* was moving actively when examined fresh, traversing a distance of up to 760 μ in 1 minute. Intertwined among the *Oscillatoria* threads were other filamentous forms: the desmids *Spondylosium planum* and *Sphaerozosma aubertianum* var. *compressum*, with abundant *Melosira granulata*. Colonial species included *Cosmocladium* sp., *Eudorina elegans*, and *Anabaena flos-aquae*. *Closterium setaceum*, a colorless flagellate, and an amoeba were also in evidence—the whole assemblage suggesting an advanced state of eutrophication.

Lund (1942) has outlined the difficulties of sampling mud strata and making accurate estimates of population. Presence or absence of a bottom-living community is determined by the degree of stability of the deposit and the amount of shelter. Most algae belonging to it have the power of movement, "avoiding" burial by wave-induced and animal movements. In deeper regions rate of decay of bottom materials and rate at which their decomposition products become available to the body of the water above them is extremely slow. Among benthic algae Chlorophyceae have been found by Lund (1942), Nygaard (1949), and Round (1957*b*) to be indicative of eutrophic waters. According to these authors, commonest genera of the Chlorococcales include *Pediastrum* and *Scenedesmus*. Desmids occur in calcium-poor lakes. Dinophyceae prefer more eutrophic habitats and ponds rather than lakes; and, along with Cryptophyceae and Chrysophyceae, they are scarce in benthic habitats. Round (1957*b*) noted an increase in the sediments of planktonic forms of *Asterionella formosa*, *Fragilaria crotonensis*, and *Oscillatoria agardhii* after peak production periods. The lower limit of benthic algae was placed by Round (1961) in Blelham Tarn and Lake Windermere (English Lake District) as 8 m where penetration of surface radiation is only 5 percent. Lower limit of the *Nitella hookeri* community in Lake Rotoiti is given by Chapman et al. (1971) as 7.5 m. Although many species were observed which also contribute to

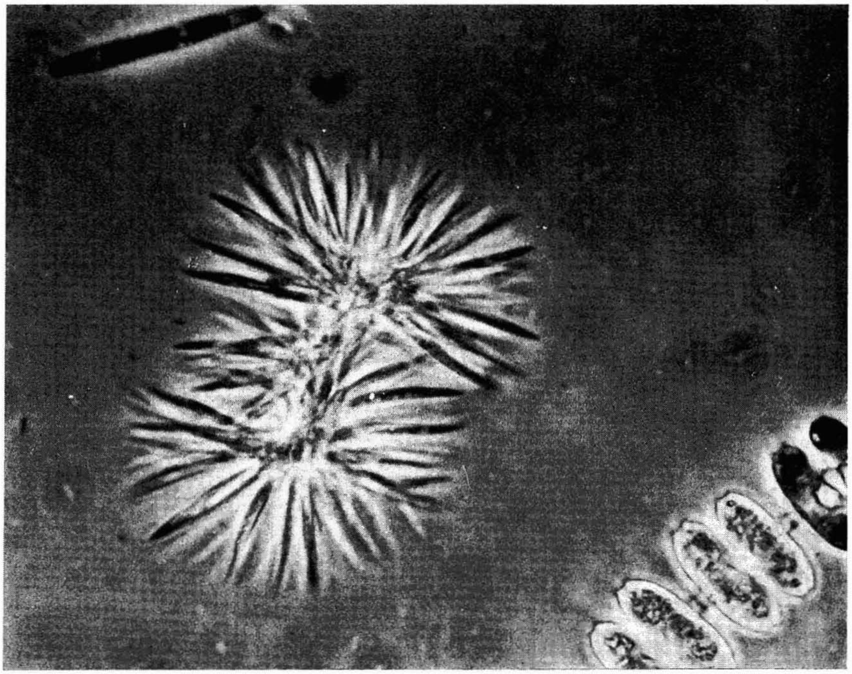


FIG. 25. *Ankistrodesmus falcatus* (Corda) Ralfs and *Sphaerozosma aubertianum* var. *compressum* Rich. Film 12/25. ×1800.

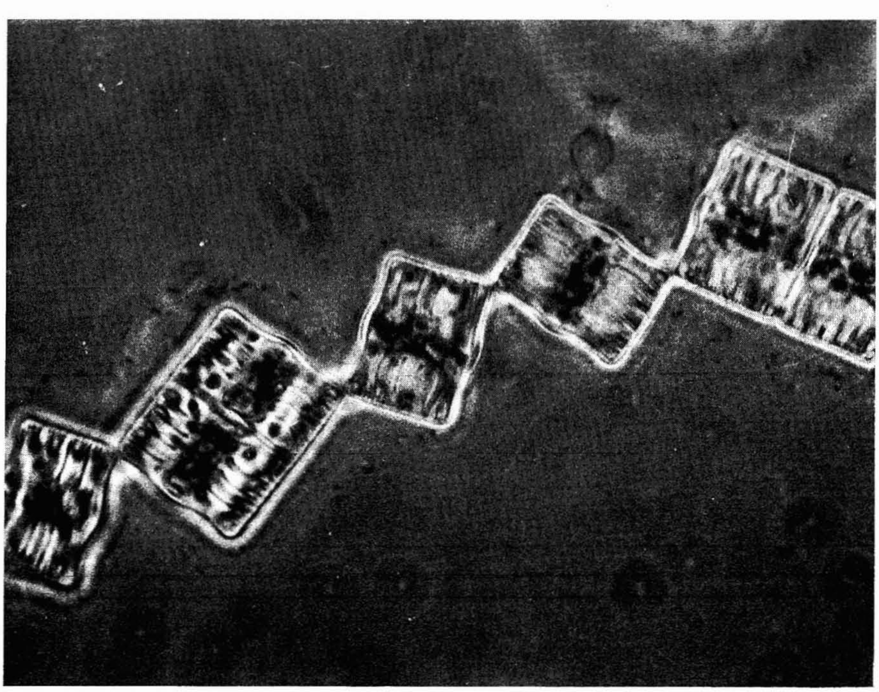


FIG. 26. *Tabellaria flocculosa* (Roth.) Kütz. Film 12/31. ×3800.

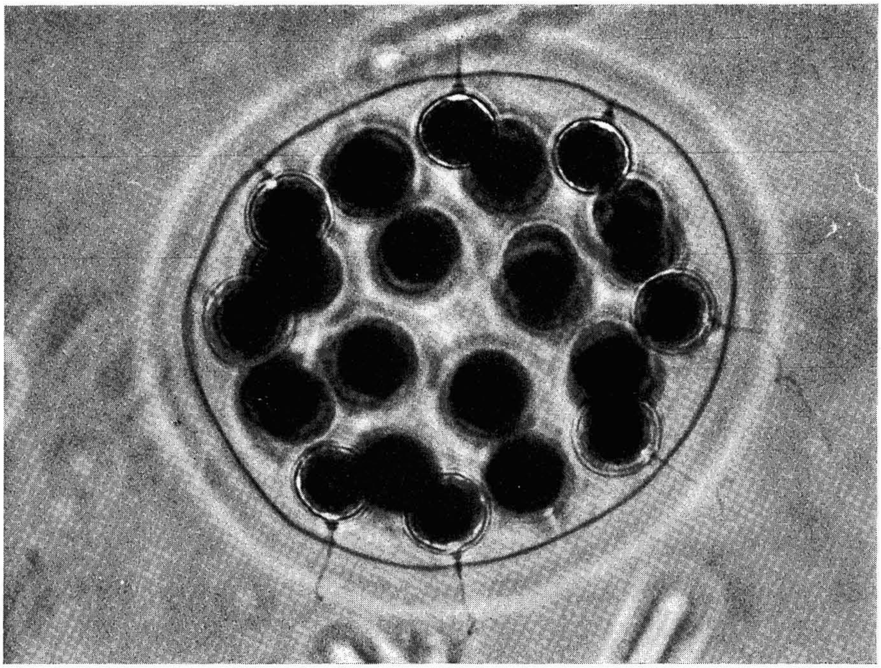


FIG. 27. *Eudorina elegans* Ehr. Film 9/26. ×2375.

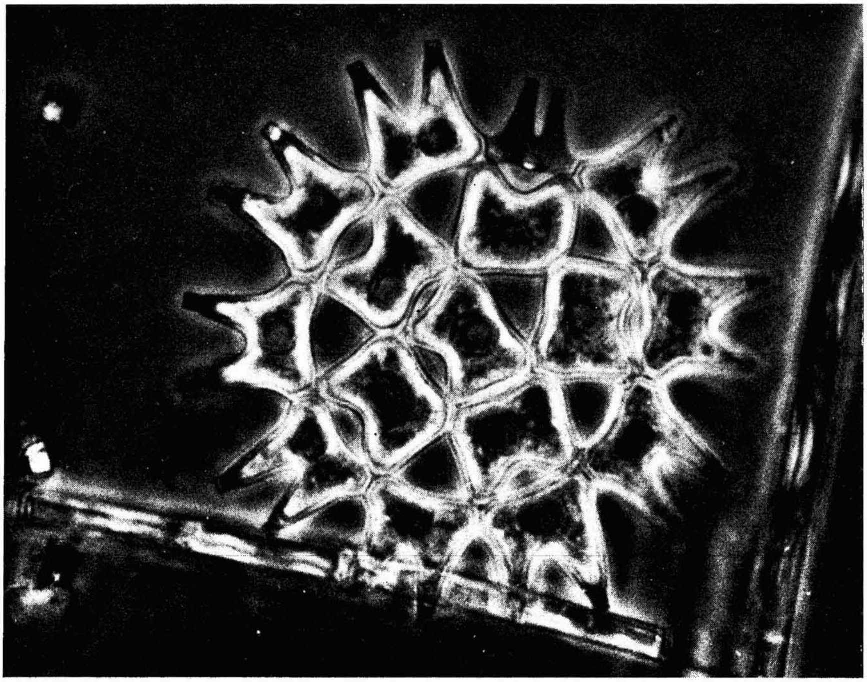


FIG. 28. *Pediastrum duplex* Meyen. Film 3/28A. ×3800.

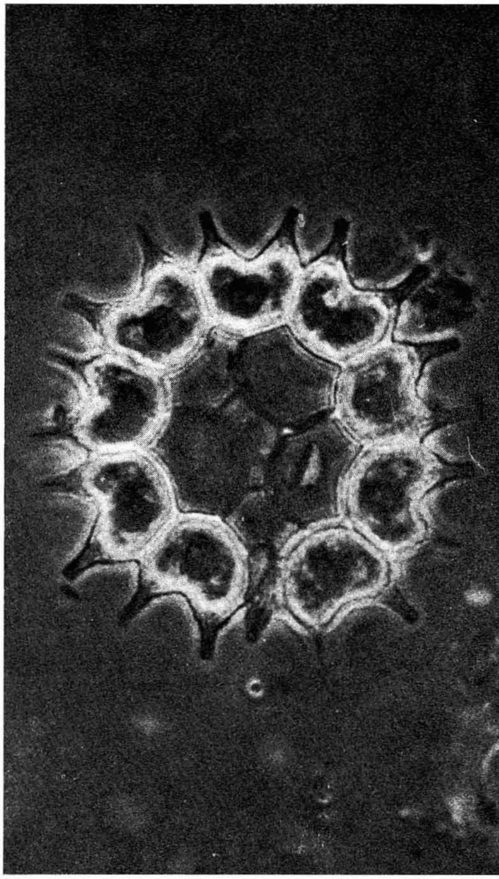


FIG. 29. *Pediastrum boryanum* (Turp.) Meneg. Film 11/17A. ×3800.

aufwuchs and plankton, the following were confined to benthic situations: BACILLARIOPHYCEAE—*Cocconeis placentula* var. *lineata* (Fig. 31), *Nitzschia palea*, *Nitzschia sigmoidea*, *Surirella biseriata*, *Surirella tenera* (Fig. 32); EUGLENOPHYCEAE—*Euglena* (four spp.); MYXOPHYCEAE—*Arthrospira platensis*, *Nodularia spumigena*, *Oscillatoria limosa*, *Oscillatoria princeps*, *Oscillatoria tenuis*.

If algae from all three communities—plankton, aufwuchs, and benthos—are considered, then it is apparent from the appendix that 20 species occurred only in samples from Lake Rotorua, and 15 species only in those from Lake Rotoiti.

SPECIES FOUND ONLY IN LAKE ROTORUA: *Volvox* sp., *Sphaerocystis schroeteri*, *Botryococcus braunii*, *Coelastrum microporum*, *Echinosphaerella limnetica*, *Kirchneriella elongata*, *Scenedesmus acuminatus*, *Tetraedron limneticum*, *Trochischia reticularis*, *Closterium cornu*, *Hyalotheca mucosa*, *Staurodesmus dickiei*, *Ochromonas perlata*, *Heliapsis mutabilis*, *Amphora* sp., *Eunotia* sp., *Surirella tenera*, *Coelosphaerium kuetzingianum*, *Lyngbya birgei*, *Lyngbya hieronymusii*.

SPECIES FOUND ONLY IN LAKE ROTOITI: *Pandorina morum*, *Crucigenia rectangularis*, *Selenastrum gracile*, *Mougeotia* sp. (wide cells), *Gomphonema* sp., *Nitzschia palea*, *Nitzschia sigmoidea*, *Gloeocapsa* sp., *Merismopedia elegans* var. *major*, *Microcystis flos-aquae*, *Anabaena flos-aquae*, *Anabaena miniata*, *Arthrospira platensis*, *Oscillatoria limosa*, *Oscillatoria rubescens*.

CONDITIONS IN NEW ZEALAND AND OTHER SOUTHERN HEMISPHERE COUNTRIES

Hydroelectric Lakes

A series of artificial lakes has been formed on the Waikato River north of Lake Taupo for the purpose of constructing hydroelectric power stations. These lakes are essentially similar in physical character, being mostly long and narrow, but of varying depth, and with a fairly rapid flow of water passing through in a northerly direction. Most of the phytoplankton samples examined from lakes Ohakuri, Atiamuri, and Whakamaru were kindly supplied by Dr. C. F. Hill. Species identified from the samples are included in this account for comparative purposes, but their ecology will be the subject of a separate publication (Hill, personal communication).

LAKE OHAKURI: Hill (1969) has analyzed samples for both chemical and physical factors in relation to the phytoplankton of this and other hydroelectric lakes on the Waikato River (North Island). He found a marked difference in quality of the water from the southern to the northern end of Lake Ohakuri (cf. Cassie 1969). In the more oligotrophic southern zone where the waters are turbulent and highly transmissive, dominant phytoplankters were usually *Melosira granulata*, *Botryococcus braunii*, *Dinobryon*, and *Staurastrum* spp. (as in lakes Taupo and Aratiatia). In the zone formed by markedly

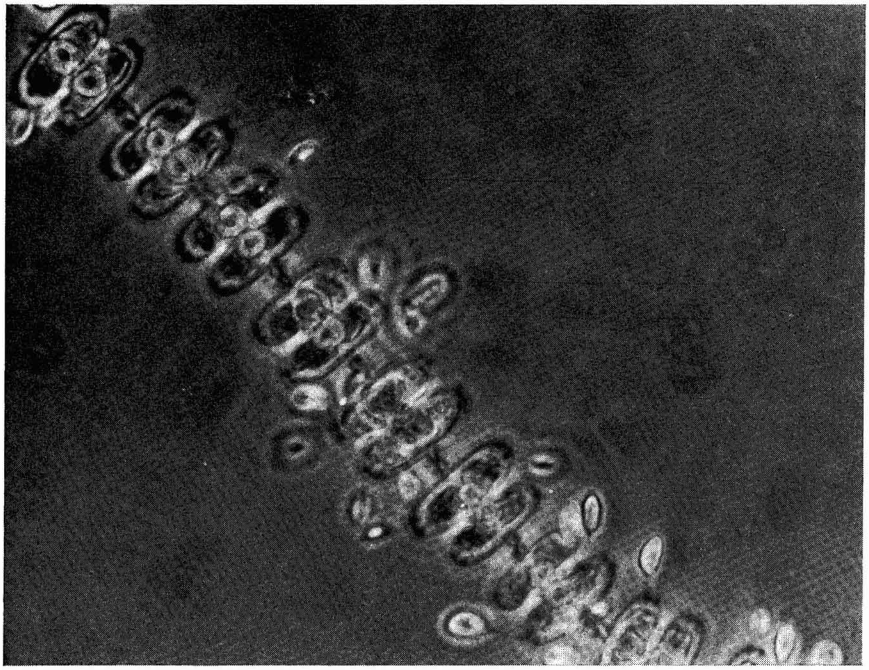


FIG. 30. *Peroniella planctonica* G. M. Smith on *Sphaerozosma aubertianum* var. *compressum* Rich. Film 12/25. ×1800.

eutrophic, brownish yellow, very opaque, calm waters of the Whirinaki Stream, blooms of *Volvox* spp., *Melosira granulata* var. *angustissima*, *Pediastrum duplex* var. *gracillimum*, the blue-green algae *Microcystis flos-aquae* (Fig. 33) and *M. aeruginosa* were common. The point of entry into Lake Ohakuri of *Melosira granulata* f. *angustissima*—just north of Orakei Korako—could be related to the requirement of this form for an organic growth factor (cf. Hutchinson 1967), and to slowing down of water flow as the surface area of the lake broadens out. Further work by Hill based on cell counts and chlorophyll analyses (personal communication) is proving that there is a progressive increase in cell numbers from south to north along the chain of lakes forming the Waikato River (Atiamuri, Whakamaru, Maraetai, Waipapa, Arapuni, Karapiro) as the water becomes more eutrophic. I found from examination of samples collected by Dr. Hill that up till mid-winter 1969 *Melosira granulata* var. *angustissima* had dominated the whole river system north of (and including the northern part of) Lake Ohakuri. Blooms have also occurred of *Microcystis flos-aquae* (Whakamaru, 11 February 1969), *Dinobryon sertularia* (Maraetai, 2 February 1969), and *Melosira lineata* (Atiamuri, 11 February 1969).

LAKE ATIAMURI: In February 1969 the level of some of the lakes was lowered to reduce the growth of macrophytes. Examination of the foreshore after the water level had been lowered 4 to 5 m for a month showed a belt of dead fronds of the macrophyte *Lagarosiphon major* lying exposed on the surface of soft, silty mud. On the underlying mud in pockets partly or wholly exposed to the light I found a thin cover of green algae, extending down to within a foot of the lowered lake level. Under the microscope it proved to be unicells of either *Chlorococcum* or *Chlorella*. Some were encased in a gelatinous sheath. Intermingled with the green scum were pockets of blue-green *Microcystis flos-aquae* and *M. aeruginosa*; green *Closterium acutum* var. *variabile*; and dead or dying frustules of diatoms, including *Melosira granulata* var. *angustissima*, *Epithemia sorex*, *Fragilaria construens*, *Pinnularia*, *Navicula* and *Cocconeis* spp.,

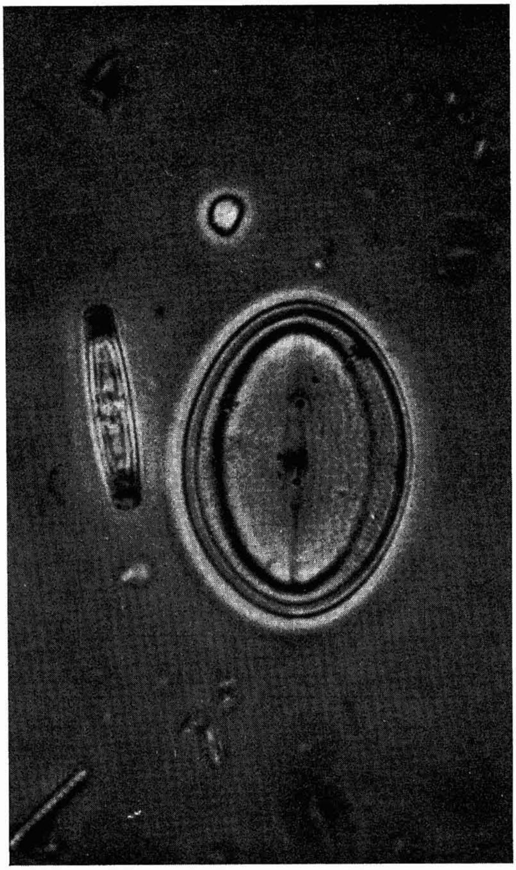


FIG. 31. *Cocconeis placentula* var. *lineata* (Ehr.) Cleve. Film 14/37A. ×4000.

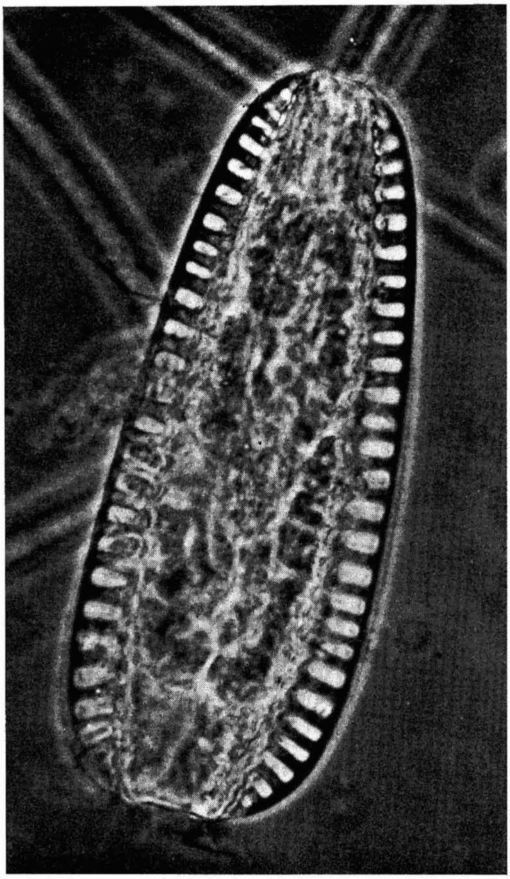


FIG. 32. *Surirella tenera* Gregory. Film 16/5. ×1125.

Synedra ulna, and *Gomphonema* sp. Filaments of *Oscillatoria rubescens* were also present. This was, in fact, the remains of the aufwuchs community, barely existing under a radically changed environment. But the algae were by no means all dead, sufficient live cells having survived the ordeal of exposure to enable regeneration of the community to take place upon reflooding, though they would be deprived of their living substrate for some time.

Among the phytoplankton in the quiet waters above the dam in Lake Atiamuri *Melosira lineata* dominated; but in the turbulent water below the dam the most prominent species was *M. granulata* f. *angustissima*.

LAKE WHAKAMARU: Inshore in the lowered water of Lake Whakamaru, which was examined on the same day as Lake Atiamuri, there was a fairly dense bloom of *Microcystis flos-aquae* and of the thin *Melosira*, together with *Anabaena spiroides* var. *crassa*, *A. circinalis*, and *Dictyosphaerium pulchellum* as subordinates. *Pandorina*, *Euderina*, and *Volvcx* were lodged among the masses of cells and colonies of *Microcystis*. Also present were *Oscillatoria limosa*, *Cryptomonas ovata*, and *Trachelomonas rotunda*.

LAKES MARAETAI, WAIPAPA, ARAPUNI, AND KARAPIRO: A similar specific composition was observed in samples from these lakes. Species apparently confined to the latter, the most northerly in the chain of hydroelectric lakes on the Waikato River, were the diatom *Surirella tenera* and the chlorophycean *Eremosphaera viridis*.

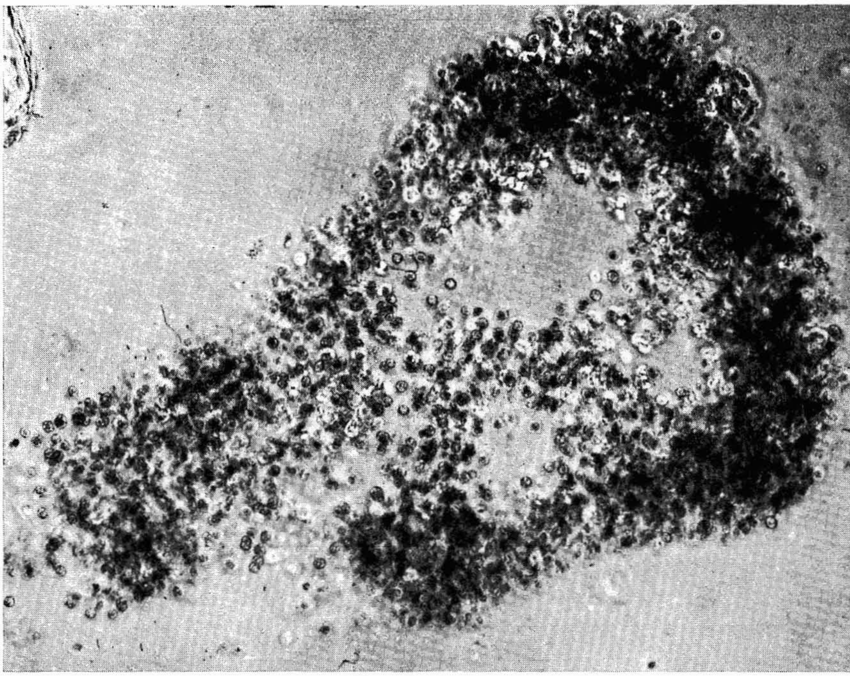


FIG. 33. *Microcystis flos-aquae* (Wittr.) Kirchn. Film 11/30A. ×850.

LAKE HOROWHENUA: A shallow lake 2 to 3 m deep with an area of 720 acres, Lake Horowhenua is located near Levin in the southwest of the North Island at lat. 40°36′ S (Fig. 1, *l*). It is surrounded by dairy- and sheep-farming land and is fed by a few small streams. Sewage effluent is discharged into the lake at the rate of 800,000 gallons per day. The average summer flow from the lake outlet is about 12 cusecs.

Fresh and preserved samples from this eutrophic, somewhat polluted lake near Levin were examined at monthly intervals from March 1968 to February 1969. During this period the most conspicuous feature of the phytoplankton (in both fresh and preserved samples) was the dominance of *Microcystis flos-aquae*, reaching bloom proportions in January and February 1969. At the same time *M. aeruginosa* was detected, but colonies were less frequent and much smaller in size than those of *M. flos-aquae* (Fig. 33). The two species were quite distinct morphologically. Cells of the latter were large and spherical (4 to 6 μ diameter), the colonies closely united when young and more laxly clathrate when older, and with irregular shapes. *M. aeruginosa* clumps tended to be much less obvious, this species having cells from 2 to 3 μ diameter. These algae, known to cause "nuisance" blooms, are classed by Palmer (1959) and others as toxic. Another cyanophyte not recorded from lakes Rotorua and Rotoiti was *Aphanizomenon flos-aquae*.

Subordinate species included many diatoms, green algae, cryptophytes and chrysophytes (especially *Chroomonas nordstedtii*, *Mallomonas*, and *Leukochrysis* spp.), colorless flagellates, and bacteria. *Scenedesmus quadricauda* var. *longispina* and *S. acuminatus* grew vigorously in enrichment cultures from fresh samples. *Pediastrum duplex* (Fig. 28) and *P. boryanum* (Fig. 29) persisted in smaller numbers throughout most of the sampling year. *Gomphonema* sp., *Fragilaria construens*, and *Melosira lineata* were conspicuous among the diatoms, while *M. distans* and *M. granulata* var. *angustissima* were also abundant—the latter usually in short filaments of two to three cells. On one occasion (31 July 1958) *Chlorella vulgaris* was dominant.

NOTES ON ALGAL CLASSES

Chlorophyceae

In both jar and net samples from lakes Rotorua and Rotoiti green algae were nearly always present but unobtrusive in comparison with the bulk of diatoms. *Mougeotia* sp. (a form with narrow filaments) was by far the commonest, usually as a phytoplankter. Occasionally a chlorophycean rose to dominance: *Actinastrum hantzschii* in May and June 1966 and 1967 and *Actinotaenium pyramidatum* at various times of year. Species of *Staurastrum* and *Dictyosphaerium* were frequently surrounded by a sheath of mucilage. Many planktonic desmids have been reported to have a mucilaginous envelope (Lund 1959), which implies that the shape of the cell is not related to the process of flotation. Brook (1959) believes that some of the supposedly planktonic forms of littoral-benthic desmids are nongenetic modifications of populations annually derived from the littoral.

Species of *Volvox*, *Botryococcus*, and *Pediastrum*, rare in samples from lakes Rotorua and Rotoiti, were much more abundant in the hydroelectric lakes. *Scenedesmus* spp., though present, were rare in fresh samples. Lund (1959) commented that *Scenedesmus*, with its flattened, often spinous, platelike colonies, is well adapted for a planktonic existence but is rare in plankton of large lakes, though common in littoral deposits. In Lake Victoria, East Africa, Talling (1966) found small increases in green algae among the plankton after a period of mixing of the water, whereas some species were present in almost constant numbers throughout the year. Such a situation is directly comparable to that prevailing in the New Zealand lakes under discussion.

Xanthophyceae

This class is poorly represented, the only species at all common being *Peroniella planktonica*. Whether this species is a member of the aufwuchs or of the phytoplankton is debatable. In habit it belongs among the former assemblage, being attached by a slender stalk to a living substrate (see Fig. 30 for filaments of *Sphaerozosma aubertianum* var. *compressum*). However, the substrate itself is planktonic, the *Sphaerozosma* threads enabling tiny clusters of *Perionella* to be buoyed up among the phytoplankton. Sporadic in appearance and sparse in numbers, *Peroniella* reached its maximum abundance in Lake Rotorua in October 1968.

Chrysophyceae

According to Nygaard (1949) and Round (1957*b*), chrysophytes are better developed in plankton of eutrophic than that of oligotrophic lakes. In general, they are poor among benthos. Others (Lackey 1941, Butcher 1949), however, regard chrysophytes and cryptophytes as being indicators of clear, unpolluted water. Chief representation (notably in Lake Rotoiti) was *Dinobryon cylindricum* var. *alpinum*. At times, *Dinobryon*, a dominant phytoplankter (cf. Cassie 1969, fig. 22), was particularly abundant in Lake Rotoiti during autumn, 1969, when, with a dense population of copepods (*Calamoecia lucasii*), its dendroid colonies were the main feature of the phytoplankton. In enriched cultures (Chu 10 + soil extract; see Fogg 1965, table 1), a number of flagellates grew vigorously, especially a *Chromulina* species closely resembling that found among the neuston (see section on phytoplankton).

Bacillariophyceae

The role of diatoms as the dominant phytoplankters has been stressed before (Cassie 1969), and the fact that they are major constituents of aufwuchs and benthos is now also apparent. In these communities pennate forms predominate, particularly those species possessing a raphe (Round 1957*a*). The list in the appendix is far from complete; many more species undoubtedly exist. Only species and genera identified with reasonable certainty have been included. Over the 3-year sampling period the dominant was consistently *Melosira granulata* (a form with large pores and lacking terminal spines [Thomasson 1960]). In Lake Rotorua it was ubiquitous from surface to bottom in almost every sample except those taken in March 1967 and 1969. Filaments varied in diameter from 17 to 30 μ. Auxospores (Fig. 2) were found only four times in natural populations: (1) in Lake Rotoiti, 8 m, Wrights Bay, 3 January 1967, jar

TABLE 3

PRINCIPAL ALGAL SPECIES IN LAKES ROTORUA, ROTOITI, HOROWHENUA, AND THE HYDROELECTRIC LAKES ON THE WAIKATO RIVER

LAKE ROTORUA	LAKE ROTOITI	HYDROELECTRIC LAKES	LAKE HOROWHENUA
Melosira granulata	*Melosira granulata*	*Melosira granulata*	*Melosira granulata* var. *angustissima*
Melosira distans	*Melosira distans*	*Melosira granulata* var. *angustissima*	*Melosira distans*
Asterionella	*Melosira granulata* var. *angustissima*	*Melosira lineata*	*Melosira lineata*
Cyclotella stelligera	*Asterionella formosa*	*Botryococcus braunii*	*Microcystis flos-aquae*
Mougeotia sp.	*Mougeotia* sp.	*Volvox* spp.	
Actinotaenium pyramidatum	*Actinotaenium pyramidatum*	*Dinobryon sertularia*	
Dinobryon cylindricum var. *alpinum*	*Dinobryon cylindricum* var. *alpinum*		
Staurastrum floriferum	*Dinobryon sertularia*		
Closterium aciculare	*Closterium aciculare*		
Actinastrum hantzschii	*Actinastrum hantzschii*	*Staurastrum floriferum*	*Scenedesmus acuminatus*
Ankistrodesmus falcatus	*Ankistrodesmus falcatus*	*Staurastrum johnsonii* var. *altius*	*Scenedesmus quadricauda*
Dictyosphaerium pulchellum	*Closterium acutum* var. *variabile*	*Pediastrum duplex* var. *gracillimum*	*Pediastrum duplex*
Closterium acutum var. *variabile*	*Closterium setaceum*	*Pandorina morum*	*Pediastrum boryanum*
Closterium setaceum	*Staurastrum floriferum*	*Synedra ulna*	*Chroomonas*
Cosmarium contractum var. *ellipsoideum*		*Microcystis flos-aquae*	*Leukochrysis* sp.
Sphaerozosma aubertianum var. *compressum*		*Microcystis aeruginosa*	*Mallomonas* sp.
Staurastrum floriferum		*Anabaena spiroides* var. *crassa*	*Fragilaria construens*
Staurastrum leptocladum var. *insigne*			*Gomphonema* sp.
Staurastrum muticum			*Aphanozomenon flos-aquae*
Peroniella planctonica			*Microcystis aeruginosa*

NOTE: Dominants and subdominants are those recorded as 5 and 4 on the abundance scale in the appendix. Abundant and common species have an abundance of 3 on the same scale.

sample; (2) in Lake Rotorua, surface, O.L.S., 12 February 1968, jar sample; (3) in Lake Rotorua, bottom to surface, net haul, O.L.S., 3 February 1969; and (4) in Lake Rotorua, bottom to surface, net haul, O.L.S., 28 April 1969. The maximum diameter of the filaments after auxospore formation was 30.5 μ. Minimum diameter immediately before auxospore formation was 17.4 μ.

Melosira granulata var. *angustissima*, the narrow form with elongated cells and a needlelike projection at one point on the rim of the valve (cf. Cassie 1961, plate 5, fig. 1) was rare in Lake Rotorua and subordinate, though common at times, in Lake Rotoiti. It rose to dominance but once (April 1969). At no time was it an ubiquitous dominant as it was in the hydroelectric lakes (see Table 3 and the section on hydroelectric lakes). Unlike representatives of the same variety which dominate in the Blue Nile (Talling and Rzóska 1967), the New Zealand specimens do not appear to show any intergrade between *M. granulata* and the narrow variety *angustissima*. *Melosira distans* and *Asterionella formosa* were much more poorly represented in net than in jar samples. In the case of *Asterionella*, this was probably because the bulk of the population floated at or near the surface most of the time. (Contrast, however, the vertical distribution of *Asterionella formosa* on 27 January 1967 [Cassie 1969, fig. 2].) *Melosira distans* cells and chains would be small enough to pass through the meshes of the phytoplankton townet. Thus, the picture of the phytoplankton composition depends on the method of sampling. A similar situation was encountered in Lake Michigan by Holland (1969), who experienced difficulty in comparing results from jar samples (which showed nannoplankton dominance) with reports from net samples compiled by previous workers (which showed larger diatoms to be the most conspicuous organisms). *Asterionella formosa* colonies, very abundant or dominant throughout the year in jar samples from both lakes Rotorua and Rotoiti, particularly in the spring–summer season of 1967–1968, did not appear to be nearly so frequent in net hauls made during 1968–1969. Unlike *Melosira distans*, *Asterionella* colonies should be quite easily caught in a 160-μ-mesh townet, if they are present. It seems more likely that the population was lower that year. The morphological form is f. *typica*, not the form that prevails in the hydroelectric lakes (Hill 1969). Hill suggested that the abundance in these lakes of *Asterionella* could be dependent on the quantity and quality of the nitrogen compounds present in the environment.

Euglenophyceae

Nygaard (1949) and Round (1957*b*) emphasized that euglenoids are almost entirely absent from oligotrophic habitats, and Round demonstrated the preference of euglenoids for nutrient-rich sediments. Palmer (1969) stressed that *Euglena*, especially *E. viridis*, is a reliable indicator of organic pollution. Unfortunately, specific identifications of *Euglena* spp. were not made in the present survey. At no time was this genus common in any samples examined; although, on the basis of lake quality, the sediments might be expected to be rich in nutrients, particularly near the sewer outfalls.

Dinophyceae

Although Nygaard (1949) and others reported dinoflagellates to be common in eutrophic waters, members of this class were not found in large numbers in Lake Rotorua. *Ceratium hirundinella* was scarce or absent for most of the 3-year period. When it was present, only one or two specimens were observed in subsamples. A small *Glenodinium*, *G. borgei*, was infrequent and inconspicuous in the Rotorua samples. In Lake Rotoiti an impressive peridinian was *Peridinium striolatum* (Fig. 3). Though low in number in counted samples, its large size, dark contents, and roughly spherical appearance made it conspicuous and easy to count.

Cryptophyceae

Usually well developed in small eutrophic bodies of water (Round 1957*b*), this group tends to intermingle with *Euglena* spp. Scarce among the phytoplankton in lakes Rotorua and Rotoiti, it was represented by but one common species, *Cryptomonas ovata* (maximum abundance in May and December). *Cryptomonas ovata* was almost entirely confined to Lake Rotorua. Haughey (1968) described a closely allied species, *C. erosa*, as being an almost pure growth in a large, wooden, oxidation tank at Papakura, Aukland; and Swale (1968) noted that *Cryptomonas* spp. in Oak Mere (Cheshire, England) occurred erratically and in small numbers per milliliter for short periods of a few consecutive weeks at a time.

Myxophyceae

Dominance of diatoms and blue-green algae is a characteristic of eutrophic waters.

No major bloom of *Myxophyceae* was detected in lakes Rotorua and Rotoiti between 1966 and 1969, but the most abundant phytoplankter in this class was *Anabaena circinalis*. Prior to 1966 this species has been known to bloom in vast quantities. Reid (unpublished) noted that, whereas Jolly's 1955–1956 samples did not appear to contain appreciable numbers of blue-green algae, his own samples, collected 8 to 9 years later, generally had considerable quantities. In January 1964, he states, an "almost pure culture" occurred off Mokoia Island; and, in October of the same year, a spectacular bloom covered many square miles of the lake surface. "The wind was light from the north-west. The algae accumulated in dense masses all along the lee shore . . . . Within a day or so this had died down, although clumped masses of it could be seen in the outflow of the Ohau Channel and down to Kaituna at Okeri" (Reid 1964). A similar phenomenon took place in December 1969 when an extensive dark greenish discoloration of *Anabaena* "thicker than pea-soup" was reported to cover vast areas of the lake surface, especially round Mokoia Island (*New Zealand Herald*, 9 December 1969). From the Tomahawk Lagoon (no. 2) on the south side of Otago Peninsula, Mitchell (1971) reported the occurrence of blooms of *Microcystis* (= *Anacystis*) in July 1963. *Anabaena* sp. bloomed in December to January 1963–1964, February to March 1965, and December 1966. The 1963–1964 bloom was accompanied by a decline in productivity but, within 2 weeks, a second bloom occurred in which small green algae and a *Cyclotella* dominated.

Relatively few small, discrete, oval or spherical colonies of *Microcystis aeruginosa* were seen during the present survey. They were detectable only in jar samples. In Oak Mere, England, Reynolds and Allen (1968) found *p*H to be a limiting factor for this species, which grew maximally at 10 but was severely limited at 8. Below 6 no growth occurred. Here, change in *p*H had been the cause of a shift in type of algal population from that of an acid oligotrophic lake to that of a mildly eutrophic body of water. Jolly (1968, table 7) noted a *p*H in Lake Rotorua which varied from 6.6 to 6.7. Hill (1969) observed frequent blooming of *Anabaena* and *Microcystis* during 1966 and 1967 in Lake Ohakuri and other hydroelectric lakes, but felt that the causative factors are probably complex (personal communication).

Requirements for combined nitrogen, higher than the amount that may be present in the environment, can be fulfilled by the fixation of nitrogen (by bacteria and certain species of blue-green algae). Nitrogen fixation is likely to be a mechanism supplementing, but not replacing, nitrogenous accumulation from the hydrosphere (Hutchinson 1967, Reynolds and Allen 1968). Prowse and Talling (1958) found in a reservoir on the White Nile, Egypt, that *Anabaena* can determine the succession of algae. A bloom of *A. flos-aquae* f. *spiroides* during a low nitrogen period there was followed by algae using nitrate regenerated from nitrogen fixed in the initial population. Shallow depth, high organic content, high temperature, and high insolation are considered by these authors to be necessary for a bloom of nitrogen-fixing blue-green algae.

POLLUTION-TOLERANT SPECIES OF ALGAE

I did not intend at the onset of this study to evaluate the state of pollution of the waters in lakes Rotorua and Rotoiti. Nonetheless, the information contained in the appendix that refers to algal species composition and abundance can be used as supporting evidence in assessing the state of these waters, at least from 1966 to 1969. Factors that are involved in the process of eutrophication and ultimate pollution of lakes and other bodies of water have been summarized by Hynes (1960), and concepts of eutrophication in northern Europe have been summarized by Rodhe (1969). In the terminology commonly used by European workers for river systems, these lakes could be classified as β-mesosaprobic (Kolkwitz and Marsson 1908, ref. in Hynes 1960)—possessing many algae, pollution-tolerant animals, and rooted plants. More recently it has been emphasized by Cholnoky (1958*a*) that Naumann had a more precise understanding of the relationship of algae to polluted conditions. According to Cholnoky, Naumann was the first European worker to recognize the importance of nutrient content (i.e., nitrogen content) of the water and he defined eutrophic, mesotrophic and oligotrophic regions.

Later, in South Africa, Cholnoky (1958*a*, *b*) discovered that the algal associations in rivers near Port Elizabeth were linked with gradual changes in nitrogen content rather than with self-purification of the water by bacterial action, as postulated by Kolkwitz (1950). Undoubtedly there has been a tremendous increase over the past 20 years—in Lake Rotorua at least—in the accumulation of nutrients from aerial top-dressing, sewage, and other sources. During this time the population has more than doubled: from 14,693 in 1951 to an estimated 35,300 in 1968 (*New Zealand Official Yearbook* 1969). Reference has already been made to the increased amounts of phosphate-phosphorus, nitrate-nitrogen, and ammonia-nitrogen in lake water samples over the past decade. It should be noted, however, that the nitrate-nitrogen is not as high in the lake water as it is in the inflowing water (Fish, personal communication). Algae can be used, along with other groups such as bacteria, fungi, and protozoa, as indicators of the degree of pollution of inland or coastal waters (Butcher 1947). Palmer (1969), who assessed published reports from 165 different authors, listed, in their order of importance, 80 species most often referred to as being pollution indicators. He believes organic pollution to be a more potent influence on the algal flora than other factors of the aquatic environment such as hardness of water, light intensity, *p*H, dissolved oxygen, rate of flow, size of water body, temperature, and other variables.

Of the first 10 species on Palmer's list, three were greens and three blue-greens. Among the first 25, diatoms predominated (nine species); among the first 50, pigmented flagellates outnumbered all others (16 species). Palmer devised a pollution index on a 1-to-5 scale for specimens present in samples at a concentration of 50/ml. Difficulties arise if this method of pollution assessment is applied to the Lake Rotorua flora, because the samples were collected mainly from stations in the open lake where nutrients are more scattered. Most of the pollution-tolerant forms were obtained from inshore samples among aufwuchs or benthos (cf. Sládecková 1962). Much more intensive sampling of algae, as well as of other organisms, will be needed to complete the picture from this angle. The existing data do show, however, that 12 species out of the 80 listed by Palmer as pollution indicators are present in Lake Rotorua and 16 in Lake Rotoiti (omitting those recorded as rare). Table 4 gives these in order of importance on Palmer's scale. I have already stated that *Euglena*, of prime importance as a pollution indicator (cf. Haughey 1968, who listed eight species from Mangere Oxidation Ponds), was not identified to species. Palmer noted that different species of this genus have greatly differing significance in their response to organic pollution. *Oscillatoria* spp., on the other hand, differ in their response but slightly.

Melosira granulata, the most persistent dominant and one regarded by some writers as being an indicator of eutrophic waters and by others as an indicator of oligotrophic waters, is relatively low (38th) in position of importance on the list of pollution-tolerant algae. *Oscillatoria* spp. form mats in the shallow littoral near mouths of streams and close to housing settlements. No large masses have been recorded buoyed up in the plankton, however. *Anabaena* spp., known to have caused nuisance blooms in summer months following the end of this survey, are notably absent from Palmer's list. *Scenedesmus quadricauda* was rare in fresh samples but grew prolifically in nutrient-enriched cultures (Chu 10 + soil extract) in the laboratory at 240 foot candles, and at a constant temperature of 20° C.

TABLE 4

POLLUTION-TOLERANT SPECIES IN LAKES ROTORUA AND ROTOITI

PALMER NUMBER	SPECIES	MAXIMUM ABUNDANCE LAKE ROTORUA	LAKE ROTOITI
2	*Nitzschia palea*	–	1
3	*Oscillatoria limosa*	3	5
4	*Scenedesmus quadricauda*	1	–
5	*Oscillatoria tenuis*	5	5
7	*Synedra ulna*	5	1
8	*Ankistrodesmus falcatus*	5	5
9	*Pandorina morum*	–	–
14	*Cyclotella meneghiniana*	1	3
18	*Oscillatoria princeps*	5	5
38	*Melosira granulata*	5	5
54	*Actinastrum hantzschii*	5	5
55	*Synedra acus*	–	1
57	*Synura uvella*	–	1
59	*Nitzschia sigmoidea*	1	–
60	*Coelastrum microporum*	1	–
64	*Fragilaria crotonensis*	3	2
65	*Microcystis aeruginosa*	3	5
72	*Trachelomonas volvocina*	5	1
73	*Dictyosphaerium pulchellum*	3	2
76	*Cryptomonas ovata*	3	1

NOTE: Species listed in order of decreasing importance, according to the list of Palmer (1969). Scale of abundance is the same as that used in the appendix.

DISCUSSION AND CONCLUSIONS

Space does not permit a detailed discussion of the vast range of studies that have already been made by such world authorities as Lund in England; Skuja, Thomasson, Steeman, Nielsen, and Rodhe in Sweden; and by Cholnoky and his associates in South Africa. Direct comparison between the lakes studied and those described by other workers is difficult because of the differing sampling techniques that have been used and because of the differing periods over which observations have been made. Nevertheless, though quantitative data may not be comparable, the occurrence of particular phytoplankters makes it possible to draw some conclusions about the character of some of the lakes.

Within New Zealand, Lake Taupo appears to be more oligotrophic than the Rotorua lakes, with *Melosira* and *Asterionella* being only prominent for short periods. *Botryococcus* and desmids, relatively uncommon in Rotorua and Rotoiti, are conspicuous summer elements of Lake Taupo; whereas *Dinobryon*, which has been taken by some workers as an indicator of oligotrophic conditions (cf. Thomasson 1963), is present throughout most of the year.

Lake Rotoiti, in turn, is more oligotrophic than is Lake Rotorua, which has a much greater biomass of phytoplankton. In addition, though the lakes are connected by the Ohau Channel, there are several species which are peculiar to one or the other, those more characteristic of eutrophic conditions being generally more common in Lake Rotorua (Cassie 1969).

At the time they were sampled the hydroelectric lakes were more markedly eutrophic, apparently becoming more so as the Waikato River flows northward. The chief difference in algal populations from the Rotorua lakes lay in the dominance of the narrow form of *Melosira granulata* var. *angustissima*. Hill (personal communication) found more recently that the wider filaments of *M. granulata* have replaced those of the narrow variety at certain times of year. The relationship between these two forms and their relative growth requirements needs further elucidation. Blue-green algae, notably *Microcystis aeruginosa* and *M. flos-aquae*, were much more prevalent in these lakes than in those at Rotorua. Lake Horowhenua was generally more eutrophic than any of the other preceding lakes, and approached in character the Tomahawk Lagoon described by Mitchell (1971), where the characteristic dominants were species of *Microcystis*, *Anabaena*, and *Cyclotella*.

Dominants most frequently encountered in the different areas studied in the North Island are listed in Table 3, in approximate order of their importance. It is obvious that all localities are *Melosira*-dominated, though not necessarily by the same species, or consistently by one species throughout the year. If one follows the argument that the fewer the number of dominant species present, the more advanced is the state of the water toward a condition of pollution (Prescott 1960), then it can be argued that, considered as a whole, the Rotorua lakes were in only a moderately advanced state of eutrophication up to 1969. Algal pollution can occur during single dominance of a noxious organism, such as a blue-green alga like *Anabaena*, which may bloom in vast enough proportions to form a surface cover that cuts out light from lower layers. Chemical factors causing such blooms are not completely understood. Factors responsible for bloom formation have been defined by Prescott (1960), who has pointed out that some species, such as *Dinobryon*, bloom more rapidly because of their quick method of zoospore formation; others, such as *Aphanizomenon*, *Microcystis*, and *Anabaena*, absorb nutrients very rapidly. Because the protein content of these blue-greens (56 to 63 percent) is much higher than that of green algae, their requirements for nitrates in order to elaborate proteins is also much greater.

Of the other Southern Hemisphere lakes for which phytoplankton information exists, Lake Victoria, because of its size, is not strictly comparable with the New Zealand lakes and has only three species—*Staurastrum muticum*, *Botryococcus braunii*, and *Anabaena flos-aquae*—in common with them (Talling 1966). A more direct comparison can be made with the lakes of southern Chile, which Thomasson (1963) has classified broadly. These can be compared and contrasted with the New Zealand lakes, the phytoplankton content of which is better known. Lake Taupo is more typical of a *Dinobryon* lake (probably undergoing change), and Rotorua is more typical of a *Melosira* lake. Most of the genera listed by Thomasson (1959, 1963) from Argentina and southern Chile are also present in lakes Rotorua and Rotoiti, but the number of species common to both areas is low (16 out of 79 in Lake Villarrica, 13 out of 56 in Lake Llanquihue, and 18 out of 78 in Lake Nahuel Huapi). The same applies to the tropical lakes of Java, Sumatra, and Bali (Ruttner 1955), where only 17 out of 178 algal species are common to the North Island lakes studied in New Zealand.

ACKNOWLEDGMENTS

I am deeply indebted to the following who have enabled this work to be completed: to Dr. G. R. Fish, and Mr. A. Parker for supplying regular samples; also to Dr. C. F. Hill, Dr. M. A. Chapman, Mr. B. Coffey, and Mr. B. E. Manson for many interesting samples; to Professor Kuno Thomasson for encouragement and invaluable help with problems of taxonomy; as well as to Dr. A. Jurilj, Dr. Maj-Britt Florin, and Dr. E. M. F. Swale for identification of diatoms and flagellates; to Dr. N. G. Robertson for climatological data; to Mr. J. Bahler and Mr. J. Lyon for help with photography; to Miss E. Dickson for help with culture work; and to Professor V. J. Chapman in whose department this work was carried out.

APPENDIX

LIST OF ALGAE IDENTIFIED FROM LAKES ROTORUA AND ROTOITI, MAY 1966 TO APRIL 1969

Colonies, not cells, have been counted for estimations of abundance of multicellular or colonial forms. Algae have been classified according to Prescott (1962), Bourelly (1968, Xanthophyceae and Chrysophyceae), and Hendey (1964, Bacillariophyceae). Taxonomic changes in the Staurastrum group as defined by Thomasson (1972) have been incorporated in this list.

SYMBOLS: A, Lake Rotorua; B, Lake Rotoiti; p, plankton; a, aufwuchs; b, benthos. The last three symbols—p, a, and b—signify the commonest habitat for each alga.

Abundance is indicated in this appendix by the following scale (numbers in parentheses indicate count scale): very abundant, 5 (41); abundant, 4 (21–40); common, 3 (11–20); occasional, 2 (6–10); scarce, 1 (2–5); one specimen seen, r (1).

	COMMUNITY	LAKE	MAY 66	MAY 67	MAY 68	JUNE 66	JUNE 67	JUNE 68	JULY 66	JULY 67	JULY 68	AUG. 66	AUG. 67	AUG. 68	SEPT. 66	SEPT. 67	SEPT. 68	OCT. 66	OCT. 67	OCT. 68	NOV. 66	NOV. 67	NOV. 68	DEC. 66	DEC. 67	DEC. 68	JAN. 67	JAN. 68	JAN. 69	FEB. 67	FEB. 68	FEB. 69	MAR. 67	MAR. 68	MAR. 69	APR. 67	APR. 68	APR. 69
CHLOROPHYTA																																						
CHLOROPHYCEAE																																						
Volvocales																																						
Eudorina elegans Ehr.	p	A	–	r	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	1	–	–	–	1	–	2	–	2	–	–	–	1	r	–	–
		B	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	r	–	2	–	–	1	–	–	–	–	–	–
Pandorina morum (Müll.)	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bory		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Volvox sp.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tetrasporales																																						
Sphaerocystis schroeteri	p	A	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	1	–	–
Chod.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ulotrichales																																						
Geminella mutabilis (Bréb.)	p	A	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	3	–	–	–	–	–	1	–	–	–	1	–	–
Wille		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ulothrix cylindricum	p	A	–	r	–	2	–	1	–	1	–	1	r	1	–	–	–	–	–	–	1	1	–	1	1	–	1	–	2	r	–	–	–	–	–	r	–	–
Prescott		B	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chlorococcales																																						
Actinastrum hantzschii	p	A	2	5	3	5	5	–	–	2	–	2	1	–	–	2	2	2	–	–	–	–	–	3	–	–	1	–	–	1	–	–	–	–	–	–	1	–
Lagerh.		B	–	–	1	–	–	5	5	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–
Ankistrodesmus falcatus	p	A	–	2	–	r	1	–	1	3	–	1	–	–	–	1	1	–	1	–	–	1	–	2	2	–	1	1	1	r	2	–	1	–	–	2	–	–
(Corda) Ralfs.		B	–	1	–	–	1	–	–	1	–	–	2	–	–	–	3	–	1	–	–	–	–	–	–	–	2	3	–	2	2	–	–	–	–	r	–	–
Botryococcus braunii Kütz.	p	A	–	–	–	–	–	–	–	–	–	–	–	r	–	1	1	–	–	–	–	1	–	1	–	–	r	–	–	r	–	–	1	–	–	r	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Coelastrum microporum Nag.	p	A	1	r	–	r	1	–	–	–	–	r	–	–	–	–	–	r	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	r	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Crucigenia rectangularis	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Nag.) Gay.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dactylococcopsis smithii	p	A	–	1	–	–	1	–	–	r	–	–	–	–	–	–	–	r	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	r	–	r	–	–
Chod. & Chod.		B	–	r	–	–	1	–	–	1	–	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	1	1	–	–	1	1	–	–	–	–	–	–
Dictyosphaerium ehren-	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	r	–
bergianum Nag.		B	–	–	–	–	–	–	–	r	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	1	–	–	–
Dictyosphaerium pulchellum	p	A	–	–	2	–	2	–	–	–	1	–	1	–	–	–	–	1	r	–	–	–	–	2	–	–	3	–	3	r	r	2	r	r	1	–	1	–
Wood		B	–	1	–	–	–	–	–	r	–	–	–	–	2	–	–	–	–	–	–	1	–	–	–	–	r	2	–	1	r	–	–	–	2	1	r	–
Echinosphaerella limnetica	p	A	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	–
G. M. Smith		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ererella bornhemiensis	p	A	–	–	–	r	–	–	–	–	–	r	–	–	–	r	1	–	r	–	–	1	–	–	–	–	1	–	–	–	r	–	–	–	–	–	–	–
Conrad		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Kirchneriella elongata	a	A	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
G. M. Smith		B	–	–	–	–	–	–	–	–			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

APPENDIX (*cont.*)

	COMMUNITY	LAKE	MAY			JUNE			JULY			AUG.			SEPT.			OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.		
			66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	67	68	69	67	68	69	67	68	69	67	68	69
Nephrocytium agardhianum Nag.	p	A	–	–	1	1	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	r	–	–	r	–	–	–	r	r	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	r	–	r	1	–	1	1	–	1	–	–	2	–	–	–	–	1	r	–	–	–	1	–	–	–	2	r	–	1
Pediastrum duplex var. *gracillimum* West & West	p	A	r	r	–	r	1	–	–	–	–	r	–	–	–	1	–	–	–	–	–	–	–	1	–	–	1	r	–	r	–	–	1	r	–	r	r	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–
Pediastrum tetras var. *tetraödon* (Corda) Hansg.	a	A	–	r	–	r	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	1	–	–	r	–	–
		B	–	r	–	–	–	–	–	1	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scenedesmus acuminatus (Lag.) Chod.	a	A	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scenedesmus quadricauda (Turp.) Bréb.	a	A	1	r	1	1	1	–	–	–	–	r	–	–	–	1	–	–	–	–	–	–	–	1	–	–	1	r	–	–	r	–	–	r	–	1	r	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Schroederia setigera (Schröd.) Lemm.	p	A	–	–	–	–	1	–	–	1	–	–	1	–	–	–	–	1	–	–	2	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	r	–	–	1	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	1	–	–	–
Selenastrum gracile Reinsch.	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Tetraëdon limneticus Borge	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Trochiscia reticularis (Reinsch.) Hansg.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Westella botryoides (W. West) Wilde	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	1	–	–	–	–	–	1	–	–	1	–	–	–
Zygnematales																																						
Actinotaenium pyramidatum (W. & W.) Teiling	p	A	5	2	5	5	3	–	–	r	2	–	1	–	–	1	–	–	–	r	–	1	1	5	–	2	5	1	1	1	–	–	3	1	1	1	1	2
		B	–	1	5	–	2	–	–	1	3	–	r	1	–	1	–	1	–	–	–	4	1	–	–	1	1	–	–	1	1	1	–	1	1	1	1	1
Closterium aciculare T. West	p	A	2	3	–	5	2	–	2	1	–	3	1	–	–	–	–	–	1	1	–	1	1	1	2	–	1	1	1	2	1	–	1	r	1	5	1	1
		B	–	1	1	–	3	–	–	1	–	–	r	–	–	1	–	–	2	–	–	2	r	–	–	–	1	–	–	1	1	–	–	1	–	1	4	1
Closterium acutum var. *variabile* (Lemm.) Krieger	p	A	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	2	–	–	1	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	4	1	–	–	–
Closterium cornu Ehr.	p	A	–	r	2	r	–	–	–	r	–	–	–	–	–	–	–	r	–	–	–	1	–	–	1	–	r	r	–	r	1	1	1	–	–	1	1	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Closterium setaceum Ehr.	p	A	1	1	3	1	3	–	–	1	–	–	r	1	1	–	–	1	–	–	1	1	–	–	–	–	–	–	–	2	2	–	1	–	–	r	1	–
		B	–	–	1	–	1	–	–	1	1	1	1	–	–	r	–	–	r	–	–	–	–	–	3	–	1	–	–	–	–	–	–	–	–	–	r	–
Closterium wallichii Turner	a	A	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	1
Cosmarium contractum var. *ellipsoideum* (Elfv.) G. S. West	p	A	–	–	1	2	–	–	1	–	–	2	–	–	–	–	–	–	r	1	1	–	1	3	–	3	4	–	2	1	–	–	–	–	–	–	–	2
		B	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	1	–	–	–	–	–	1	–	1	–	–	–	–	1	–	–
Cosmocladium sp.	p	A	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	4
Hyalotheca mucosa (Mert.) Ehr.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mougeotia sp. (narrow cells)	p	A	5	5	5	5	1	–	3	1	1	2	1	2	2	1	2	1	1	1	–	1	1	–	2	3	1	5	3	5	–	1	5	1	5	2	5	1
		B	–	5	3	–	5	–	–	2	1	–	1	2	–	2	3	–	2	1	–	–	3	–	–	1	2	1	2	5	5	–	–	5	1	–	–	1
Mougeotia sp. (wide cells)	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Sphaerozosma aubertianum var. *compressum* Rich.	p	A	1	1	3	–	1	–	–	1	1	1	1	1	1	–	1	–	r	2	1	1	1	2	–	1	2	1	2	2	–	2	1	1	1	r	1	1
		B	–	r	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	1	–	–	1	–	–	1	r	–	1	r	r	–	–	–	–	–	–	–
Spondylosium planum (Wolle) West & West	p	A	1	–	r	–	–	–	–	–	–	1	–	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	1	–	–	1	–	–	1	–	–	1
		B	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–

APPENDIX (*cont.*)

	COM-MU-NITY	LAKE	MAY			JUNE			JULY			AUG.			SEPT.			OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.		
			66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	67	68	69	67	68	69	67	68	69	67	68	69
Staurastrum aureolatum Playf.		A	–	–	2	–	–	–	–	1	–	–	–	1	–	–	r	r	–	–	–	–	–	–	–	–	–	–	–	r	1	–	1	–	–	1	–	–
		B	–	1	1	–	–	–	–	–	1	–	–	1	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Staurastrum cingulum (West & West) G. M. Smith	p	A	–	–	–	5	2	–	–	–	2	–	–	1	–	–	–	–	1	1	–	–	–	1	–	1	–	1	–	1	–	2	–	–	–	1	r	–
		B	–	–	1	–	1	–	–	–	1	–	–	1	–	1	–	–	1	1	–	1	1	–	–	–	–	–	1	r	1	–	–	1	2	–	r	1
Staurastrum floriferum (West & West)	p	A	–	1	2	2	1	3	–	1	1	–	–	1	2	1	3	r	–	4	1	–	4	–	–	3	1	1	3	2	2	2	2	1	2	1	1	–
		B	–	–	1	–	–	–	–	1	1	–	r	1	–	1	–	r	1	–	–	–	2	–	1	2	1	–	3	–	–	–	3	1	1	–	–	–
Staurastrum leptocladum var. *insigne* West & West	p	A	–	4	3	–	1	–	–	1	1	–	1	1	–	1	–	1	–	–	1	–	–	1	–	–	1	–	–	1	1	r	r	–	2	–	1	–
		B	–	r	–	–	1	–	–	–	1	–	–	1	–	r	–	r	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	r	–	–
Staurastrum muticum Bréb.	p	A	1	1	–	–	2	–	1	1	–	r	1	2	r	1	1	1	1	–	–	1	–	2	–	1	–	2	1	1	–	1	–	1	2	3	1	2
		B	–	1	1	–	2	–	2	1	–	–	1	2	–	1	–	–	1	2	–	–	–	–	–	–	–	1	1	–	1	–	–	5	–	1	1	2
Staurastrum rosei var. *novizelandicum* Thom.	p	A	–	–	–	–	1	–	–	1	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Staurastrum sexangulare (Bulnh.)	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Staurastrum subradians Fritsch & Rich	p	A	–	r	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
		B	–	1	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Staurastrum tohopekaligense var. *robustum* Wolle	p	A	r	2	–	1	–	–	–	1	–	1	–	–	r	–	r	–	–	–	–	–	–	2	–	–	1	–	1	1	r	1	r	1	1	1	r	–
		B	–	1	1	–	1	–	–	1	1	–	r	–	–	r	1	–	–	1	–	1	–	2	–	–	r	r	–	1	1	r	–	1	1	1	r	–
Staurodesmus dickiei (Ralfs) Lillier	p	A	1	–	2	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	2	–	–	–	1	–	r	–	–	–	–	–	–	r	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Staurodesmus leptodermus (Lund.) Teiling	p	A	–	1	2	–	1	–	–	1	r	r	1	1	r	1	–	r	1	–	r	1	1	1	–	–	–	r	–	1	1	–	2	r	1	–	1	–
		B	–	r	–	–	1	–	–	–	1	–	r	1	–	1	1	–	–	–	–	–	1	–	–	1	1	r	–	–	r	–	–	1	–	1	r	–
Staurodesmus unicornis var. *ceylonensis* Teiling	p	A	–	1	–	2	–	–	–	1	–	1	r	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	1	–	1
		B	–	r	–	–	–	–	–	–	–	–	r	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CHRYSOPHYTA																																						
XANTHOPHYCEAE																																						
Mischococcales																																						
Peroniella planctonica G. M. Smith	p	A	–	–	–	–	–	–		–	1	–	–	–	–	–	1	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
		B	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	2	–	–	1	–	–	2	–	–	–	–	–	–	–	–	1	–	–	–
Tribonematales																																						
Bumilleria sicula Borzi	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
CHRYSOPHYCEAE																																						
Monosigales																																						
Salpingoeca frequentissima (Zach.) Lemm.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chromulinales																																						
Chromulina sp.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ochromonadales																																						
Dinobryon cylindricum var. *alpinum* (Imh. Bachm.)	p	A	–	–	–	–	r	–	–	1	–	r	1	–	2	1	1	5	1	4	2	1	–	1	–	2	2	1	1	1	1	2	–	1	–	–	–	–
		B	–	1	–	–	r	–	–	–	–	–	1	2	–	1	–	–	5	4	–	1	3	–	2	5	2	1	1	1	1	5	–	r	2	r	–	5
Dinobryon sertularia Ehr.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	r	1	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–
Ochromonas perlata Dopl.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Synura uvella Ehr.	p	A	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	r	–	–
		B	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–

	COM-MU-NITY	LAKE	MAY			JUNE			JULY			AUG.			SEPT.			OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.		
			66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	67	68	69	67	68	69	67	68	69	67	68	69
Rhizochrysidales																																						
Heliapsis mutabilis Pascher	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BACILLARIOPHYCEAE																																						
Centrales																																						
Cyclotella stelligera (Cleve & Grun.) V.H.	p	A	–	–	–	2	–	–	–	–	–	–	–	–	–	1	–	–	3	–	1	1	–	–	5	–	–	1	1	–	–	r	1	–	–	r	r	–
		B	–	–	–	2	–	–	–	r	1	–	r	–	–	3	–	–	–	–	–	1	r	–	2	–	–	4	–	–	–	–	–	r	1	–	–	–
Cyclotella meneghiniana Kütz.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–
		B	–	–	–	–	–	3	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	1	–	–
Melosira distans (Ehr.) Kütz.	p	A	4	5	5	5	–	–	5	–	1	5	5	2	5	3	1	5	1	–	5	5	1	5	5	–	5	1	1	5	3	2	5	–	–	5	5	1
		B	–	–	5	5	5	–	–	5	3	–	5	2	–	5	1	–	5	–	–	3	2	–	3	1	5	3	1	5	5	–	–	5	2	5	5	1
Melosira granulata Ralfs	p	A	5	5	5	5	5	–	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	–	2	5	4	5	5	5
		B	–	5	5	–	–	–	–	5	5	–	5	5	–	5	5	–	5	5	–	5	5	–	5	5	5	1	3	5	5	4	–	5	5	–	5	5
Melosira granulata var. *angustissima* O. Müll.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	r	–	–	–	–
		B	–	–	1	–	2	–	–	1	–	–	–	–	–	1	–	–	r	–	–	1	–	–	–	2	–	–	–	1	–	–	–	1	1	1	5	2
Melosira lineata (Dillw.) Ag.	a	A	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–
Rhizosolenia eriensis H. L. Smith	p	A	–	r	–	–	2	–	–	5	–	–	1	–	–	1	r	1	–	–	r	1	1	–	–	–	–	–	1	r	–	–	–	–	–	r	–	–
		B	–	–	–	–	2	–	–	1	1	–	2	–	–	1	–	–	r	–	–	–	–	–	–	–	r	1	–	–	–	–	–	1	1	1	r	r
Stephanodiscus sp.	a	A	–	r	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pennales																																						
Amphora sp.	a	A	1	–	–	–	–	–	–	–	–	–	r	–	1	–	–	2	–	–	3	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asterionella formosa Hass.	p	A	4	5	5	4	5	–	4	5	1	5	5	1	3	5	2	3	5	2	3	5	2	4	5	–	5	5	1	5	1	1	5	5	–	1	5	2
		B	–	5	2	–	5	–	–	5	–	–	–	1	–	5	–	–	5	1	–	5	–	–	5	1	2	5	–	5	5	–	–	5	–	5	5	1
Cocconeis placentula var. *lineata* (Ehr.) V.H.	b	A	–	–	–	r	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	r	r	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Epithemia sorex Kütz.	a	A	–	1	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	r	1	–	–	–	–	–	1	–	–	1	–	–
		B	–	–	–	–	–	–	–	–	–	–	r	–	1	–	–	r	–	–	–	–	–	2	–	r	1	–	1	–	–	–	–	–	–	–	r	–
Eunotia sp.	a	A	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fragilaria crotonensis Kitt.	a	A	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	r	–	r	–	–	1	1	–	–	r	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	2	–	r	–	–	2	1	–	1	–	–	–	–	–
Gomphonema sp.	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Navicula sp.	a	A	1	–	–	1	–	–	–	–	1	–	–	–	1	–	–	r	–	–	–	–	–	1	–	–	–	–	r	–	–	–	1	–	1	1	–	–
		B	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	1
Nitzchia palea (Kütz.) W. Smith	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Nitzschia sigmoidea (Ehr.) W. Smith	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	r	r	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	r
Rhopalodia gibba (Ehr.) Müll.	a	A	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	r

	COMMUNITY	LAKE	MAY			JUNE			JULY			AUG.			SEPT.			OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.		
			66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	67	68	69	67	68	69	67	68	69	67	68	69
Surirella biseriata Bréb.	b	A	–	–	–	–	r	–	–	1	–	–	r	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surirella tenera Gregory	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Synedra acus Kütz.	a	A	–	–	–	–	–	–	–	–	–	–	r	–	–	–	r	–	r	–	–	–	1	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	-	–	1	–	–	1	–	–	–	–	1	–	–	–
Synedra ulna (Nitzsch.) Ehr.	p	A	1	r	–	1	–	–	3	1	–	5	1	1	4	1	–	2	1	–	1	–	1	2	–	–	1	–	–	r	–	–	1	–	–	–	–	–
		B	–	r	–	–	r	–	–	1	–	–	–	–	–	1	–	–	r	–	–	–	1	–	–	–	–	–	–	r	r	–	1	–	–	–	–	r
Tabellaria flocculosa (Roth) Kütz.	a	A	–	r	–	r	r	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	r	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–
EUGLENOPHYTA																																						
EUGLENOPHYCEAE																																						
Euglenales																																						
Euglena (four species)	b	A	1	r	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–
Trachelomonas volvocina Ehr.	p	A	–	2	–	3	1	–	1	r	–	3	–	–	1	1	–	4	1	–	3	1	1	2	2	–	5	3	–	r	–	–	–	–	–	r	–	–
		B	–	–	1	–	r	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	r	–
Trachelomonas scabra var. *pygmaea* Playf.	a	A	–	1	–	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
PYRRHOPHYTA																																						
DINOPHYCEAE																																						
Gymnodiniales																																						
Gymnodinium helveticum Pen.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–
Gymnodinium sp.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	r	–	–	–	–	–	2	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	1	–	–	–
Peridiniales																																						
Ceratium hirundinella f. *furcoides* Schröd.	p	A	–	r	–	r	1	–	–	–	–	1	r	–	r	r	–	r	–	–	1	–	–	–	–	–	1	r	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Glenodinium borgei (Lemm.) Schill.	p	A	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	r	–	–	–	–	–	–	–	1	1	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	1	–	–	–	–	–	–	–	–
Peridinium striolatum Playf.	p	A	–	r	2	–	r	–	–	1	–	–	1	–	–	1	–	–	3	–	r	r	–	r	–	–	r	1	–	–	r	–	2	1	–	1	1	–
		B	–	4	5	–	5	–	–	2	–	–	2	–	–	r	–	–	1	–	–	–	–	–	–	–	4	4	–	5	3	–	–	5	1	5	5	1
Dinococcales																																						
Cystodinium cornifax (Schillg.) Klebs.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	r	–	–
		B	–	r	–	–	r	–	–	–	–	–	r	–	–	–	–	–	r	–	–	–	–	–	–	–	r	–	–	1	–	–	–	r	–	1	r	–
CRYPTOPHYCEAE																																						
Cryptomonas ovata Ehr.	p	A	–	–	3	–	–	–	–	1	–	–	1	–	–	1	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	r	–
		B	–	–	–	–	1	–	–	–	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–		–	–	–	–	–	r	–	–	–	–

	COM-MU-NITY	LAKE	MAY			JUNE			JULY			AUG.			SEPT			OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.		
			66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	66	67	68	67	68	69	67	68	69	67	68	69	67	68	69
CYANOPHYTA																																						
MYXOPHYCEAE																																						
Chroococcales																																						
Chroococcus limneticus	p	A	–	–	–	–	1	–	–	1	–	–	1	–	–	–	–	–	–	–	–	1	–	1	–	–	1	5	–	r	–	–	1	–	–	r	1	–
Lemm.		B	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	r	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	1	–	–	–
Coelosphaerium kuetzingianum	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2	–	–	–	–	r	–	–
Nag.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gloeocapsa sp.	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Merismopedia elegans var.	a	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	2	–	–	r	–	–	–	–	–	r	1	–	–	–	–
major G. M. Smith		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Microcystis aeruginosa Kütz.	p	A	1	2	–	–	2	–	–	1	–	–	1	–	–	–	–	–	1	–	–	1	–	–	–	–	–	1	–	1	1	1	–	–	r	3	r	–
(= *Anacystis cyanea* Drouet & Daily)		B	–	r	–	–	1	–	–	1	–	–	1	–	–	1	–	–	4	–	–	–	–	–	–	–	4	r	–	1	–	–	–	5	3	–	r	–
Microcystis flos-aquae	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Wittr.) Kirchn.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hormogonales																																						
Anabaena circinalis	p	A	2	–	5	2	–	–	3	r	2	–	3	r	–	1	–	2	2	1	1	1	1	2	5	1	5	1	3	1	1	–	–	1	1	–	–	–
Rabenh.		B	–	–	1	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	1	–	–	–	–
Anabaena flos-aquae (Lyng.)	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bréb.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	2	–	–	r	–	–	–	r	–	–	r	–
Anabaena miniata Skuja	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–
Arthrospira platensis	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Nordst.) Gom.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lyngbya birgei G. M.	a	A	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Smith		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lyngbya hieronymusii	a	A	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lemm.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nodularia spumigena	b	A	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mertens		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Oscillatoria limnetica	p	A	–	r	–	1	–	–	–	r	1	–	1	–	1	–	–	–	–	–	–	1	–	1	–	–	r	–	–	–	r	–	–	r	–	r	1	–
Lemm.		B	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	r	–	r	–	–	–	1
Oscillatoria limosa (Roth)	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C. A. Ag.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
Oscillatoria princeps	b	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	5
Vaucher		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
Oscillatoria rubescens	p	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
De Candolle		B	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oscillatoria tenuis	b	A	–	r	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
C. A. Ag.		B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5

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