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# PHYTOPLANKTON PRODUCTION, AS ESTIMATED BY THE $C^{14}$ TECHNIQUE, AND POPULATIONS CONTRIBUTING TO PRODUCTION 1980/81/82, IN THE TURKEY LAKES, ONTARIO, WATERSHED

by

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## ABSTRACT

The Turkey Lakes calibrated watershed consists of a series of four lakes (five basins) underlain by sparingly soluble silicate bedrock. Lowest pH's and alkalinities occured in the headwater lake and increased downstream. Carbon assimilated (measured by *in situ* $C^{14}$ incubation) was greatest between one and four metres in all lakes. Production was low in winter, $<0.5$ mg C $m^{-3}h^{-1}$, and increased during summer. Carbon assimilated in the ice-free period was greatest in the shallowest lake and lower in the larger, deeper lakes of the watershed. Production followed the order imposed by lake depth. The headwater lake did not develop the bloom/crash change in phytoplankton abundance or species composition that occured in all the other lakes. Peaks in production coincided with peaks of algal abundance. Cyanophytes were consistently the dominant algal group with the species contributing to peaks in phytoplankton abundance varying from lake to lake.

Collins, R.H., J.R.M. Kelso, J.H. Lipsit, & J.E. Moore. 1983. Production de phytoplancton estimée au moyen de la méthode du $C^{14}$ et populations contribuant à la production pour 1980, 1981, et 1982 dans le bassin versant des lacs Turkey en Ontario. Can. Tech. Rep. Fish. Aquat. Sci., (1191).

## RESUME

Le bassin versant étalonné des lacs Turkey se compose d'un semble de quatre lacs (cinq bassins) et repose sur un socle rocheux silicaté faiblement soluble. Les pH et les alcalinités les plus faibles sont observés dans le lac d'amont et augmentent vers l'aval. La quantité de carbone assimilé (mesurées par incubation in sutu du $C^{14}$) était la plus grande entre un et quatre métres dans tous les lacs. La production tait faible en hiver, moins de 0.5 mg C $m^{-3}g^{-1}$, et augmentait pendant l'été. La quantité de carbone assimilé pendant la période sans glace était la plus forte dans le lac le moins profond et la plus faible dans les lacs plus grands et plus profonds du bassin versant. Le lac d'amont ne présentait pas les modifications marquées de la productivité ou la diversité des espèces caractéristiques du phytoplancton dans tous les autres lacs. Les maximums de la production coincidaient avec les périodes de plus grande abondance des algues. Les cyanophytes constituaient uniformément le groupe d'algues dominant et les espèces responsables des maximums d'abondance du phytoplancton variaient d'un lac à l'autre.

## INTRODUCTION

Acid deposition is high (20 to 70 mg $SO_4$ $m^{-2}yr^{-1}$) over much of the sensitive Canadian Shield (Harvey et al., 1981) and threatens sensitive lakes in Ontario (Kelso & Minns, 1982; Minns, 1981). Correlative observation suggests that acidification either significantly decreases phytoplankton species diversity (Kwiatkowski & Roff, 1976) or produces only a marginal influence (Kelso et al., 1982) upon community structure. Müller (1980) has also shown that changes occurred in the periphyton community of an Ontario lake during artificial acidification. The effects of acidification upon primary production is less clear (Conway & Hendrey, 1982) and the mechanisms have been surmised rather than determined experimentally (Johnson, 1982).

This paper does not deal with production changes resulting from the acidification process, but examines the change in carbon incorporation of natural phytoplankton *in situ* within a watershed which progresses from a poorly buffered first order lake downstream through progressively better buffered systems.

## LAKE DESCRIPTIONS

The watershed (Fig. 1) is situated some 50 km north of Sault Ste. Marie, Ontario, and some 25 km east of Coppermine Point on Lake Superior. No local sources of anthropogenic contamination are implicated in the chemical state of the system. The Turkey Lakes are a series of four lakes (five basins) which originate from a poorly buffered (36 μeq $l^{-1}$), low pH (5.9), first order lake. The watershed is completely underlain by sparingly soluble silicate bedrock (greenstones and granites). Alkalinity within the watershed increases to a high of about 190 μeq $l^{-1}$ in Big Turkey Lake (Table 1).

Batchawana Mountain (elevation 628 m) dominates the watershed and falls away to Turkey Lake (elevation 372 m) with an overall relief of 256 m. Individual lake elevations for each basin are, L1 - 497 m, L2 - 497 m, L3 - 388 m, L5 - 375 m, and L6 - 372 m.

Measurements to assess primary productivity in the Turkey Lakes watershed study commenced as soon as the lakes were free of ice during April-May in the spring, and continued to October-November each year. The method chosen was the $C^{14}$ technique and incubations coincided with maximum solar input at mid-day. Breaks in sampling (June, August-October, 1980) were unavoidable due to impassable road conditions, personnel change, and equipment malfunctions. Incubations were conducted on a bi-weekly basis throughout the ice-free period in all five lakes. Two teams were used so that all incubations were coincident.

A buoy with a suspension apparatus was placed in each lake as soon as the ice disappeared in the spring and left in place until freeze-up. Incubations were carried out in 125 ml reagent bottles at surface, one, two, three, and five metres with the exception of L3 where the lake was only four metres deep. Water was collected from the appropriate depth using a three-litre horizontal Van Dorn sampler. All bottles were rinsed three times with the sample water. For each depth, two bottles were filled with ambient water and one ml of water withdrawn to allow for the addition of a $C^{14}$ solution. The bottles were inoculated with 100 μl of $C^{14}$, then capped, and suspended at their appropriate depths immediately. For a background count, one extra bottle from the greatest depth was treated identically except that all light was excluded.

Incubation time was dependent on light intensity, varying from two hours on a clear sunny day to four hours on an overcast fall day. After the allotted time elapsed, samples were retrieved and incubation time was noted. Each sample was fixed with one ml of a 37 percent formaldehyde solution and capped for transport.

A 100 ml aliquot of each bottle was filtered through a 0.45 μ cellulose membrane filter at less than seven p.s.i. vacuum. Each filter was placed in a 25 ml scintillation vial and 20 ml of PCS scintillation cocktail added. All counts were made using a liquid scintillation counter.

Test incubations with water screened through a 64 μ mesh showed no significant difference in carbon incorporation from untreated water samples and screening was therefore discontinued.

Total carbon uptake for each depth was calculated using the mean of the duplicate counts and subtracting the background count determined from the dark bottle:-

$$^{12}Cu = 1{,}000 \times {}^{12}C_A \times \frac{^{14}Cu}{^{14}C_A} \times 1.06 \times \frac{1}{T} \times \frac{B}{S}$$

where $^{12}Cu$ = carbon uptake rate in mg C $m^{-3}$ $h^{-1}$

$^{12}C_A$ = total dissolved inorganic carbon (DIC) in mg $l^{-1}$ (Fig. 5)

$^{14}Cu$ = DPM uptake (count result)

$^{14}C_A$ = DPM added to bottle

T = incubation time (hours)

B = bottle volume (125 ml)

S = filtered volume (100 ml)

Phytoplankton were identified and counted using the Utermöhl inverted microscope technique (Vollenweider, 1969). Collection methods and times were similar to those described below for water.

Alkalinity and pH values were determined from tube composite samples. Total DIC was determined by comparison of DIC values to alkalinity (R. Semkin, unpublished).

Surface temperatures were obtained from an electronic bathythermograph (R. Semkin, unpublished).

Light intensity measurements were obtained from a solarimeter and are expressed in Langleys per hour.

## RESULTS AND DISCUSSION

In the five basins of the watershed, lowest pH's (Fig. 2) were consistently found in L1 and increased downstream where the highest pH's were consistently found in L6 (Table 1). A regular progressive downstream increase of at least one unit of pH is apparent. In 1981, pH's were highest in late summer and lowest in May. In 1980, pH's were highest in early summer and lowest in May. In summers of both years, pH's were similar.

Temperatures varied only slightly among the lakes and followed the expected annual cycle for lakes in this latitude (Fig. 3). Maximum temperature (26 to 27°C) occurred in mid-July in 1981 and in June in 1980. Minimum temperatures occurred, of course, during the winter. Ice formed during the period late October to early November in both years and disappeared in the first week in May. The shallowest lake, L3, was always slightly warmer than other lakes in the system.

Solar radiation (Fig. 4) varied between 150 and 600 Langleys during both years. Minimum values occurred in the fall during these incubation series.

Data in Fig. 5 were from all lakes and no apparent difference in the DIC-alkalinity relationship is apparent. Dissolved inorganic carbon was linearly related to alkalinity and the correlation coefficient was high ($r = 0.85$) and significant at $P = < .05$.

All basins within the Turkey Lakes system were poorly buffered, having alkalinities of $<200$ µeq $l^{-1}$. By comparison with other lakes on the Canadian

Shield, these lakes are similar to those typically found on resistant substrate but are among the most poorly buffered systems (Kelso et al., 1982). This type of lake reflects those which typically undergo large seasonal shifts in pH and alkalinity resulting from spring freshets (Jeffries et al., 1979).

Carbon assimilation varied with depth in each lake with maximum production consistently between one and four metres (Table 2). For comparative purposes among the lakes, only the maximum production ($P_{max}$) was used, regardless of the depth at which it occurred. Carbon assimilation by the phytoplankton assemblage was extremely limited, $<0.5$ mg $m^{-3}$ $h^{-1}$, both under ice cover and in early spring (Fig. 6) in all lakes.

Production increased during summer (Fig. 6) and although the increase was irregular in nature, the peaks are apparent. The magnitude of the peaks in production was greatest in L3. Carbon assimilated was also greatest in L3 with large, well-defined peaks in plankton production apparent. Conversely, production was usually lower in the larger and deeper L6, with the exception of some observed periods of low production in L1 and L2 during 1981.

Production followed the order imposed by lake depth (L3 L2 L1 L5 L6). No nutrient data is available at this time for this system and thus the influence of nutrient availability on phytoplankton production cannot be examined.

During 1980, Cyanophytes were the dominant contributors to the number of species in all lakes (Figs. 7 to 11). *Merismopedia punctata* Meyen was the major blue-green in L1 and L2 and became the sole Cyanophyte species during the summer peak period of production and thus was the dominant algae. These lakes (L1 and L2) never developed the bloom/crash change in abundance or species that occurred in the other lakes. In L3 the same species was significant but blooms were coincident with species dominance changes and blooms of *Microcystis flos-aquae*

(Wittrock) Kirchn. in early August. In late September, blooms were associated with increased numbers of a wider variety of species such as Aphanothece clathrata West & G.S. West, Chroococcus dispersus (Keissl.) Lemm. and Anabaena solitaria Kleb. Species shifts within L5 also accounted for the peaks in algal abundance. Chroococcus were always a major contributor, but the peaks were coincident with increased number of Aphanothece clathrata in July, Microcystis in August and mid-September, and Coelosphaerium minutissimum Lemm. at the end of September. Several species contributed to the community in L6 with Chroococcus dispersus playing a major role in the summer bloom along with Aphanothece clathrata. The fall bloom was produced by Merismopedia punctata.

When production is low during the colder months, no major species are dominant and the total number of cells, $<$ 1,000 cells per ml, is composed of Chrysophyceae, Bacillariophyceae, Chlorophyta, Pyrrhophyta, and Cyanophyta. Since the collections of Kelso et al. (1982) were made in the colder months, the species discussed there are typical of low production periods.

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This work was initiated by R.J. Love in 1980. A number of persons assisted with field work over the years including particularly K. Thomas, M.-A. Miltenberg, D. Prescott, G. Reider, and J. Kraft. Much of the background lake characteristics were provided by R. Semkin, National Water Research Institute, Environment Canada.

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## List of Tables

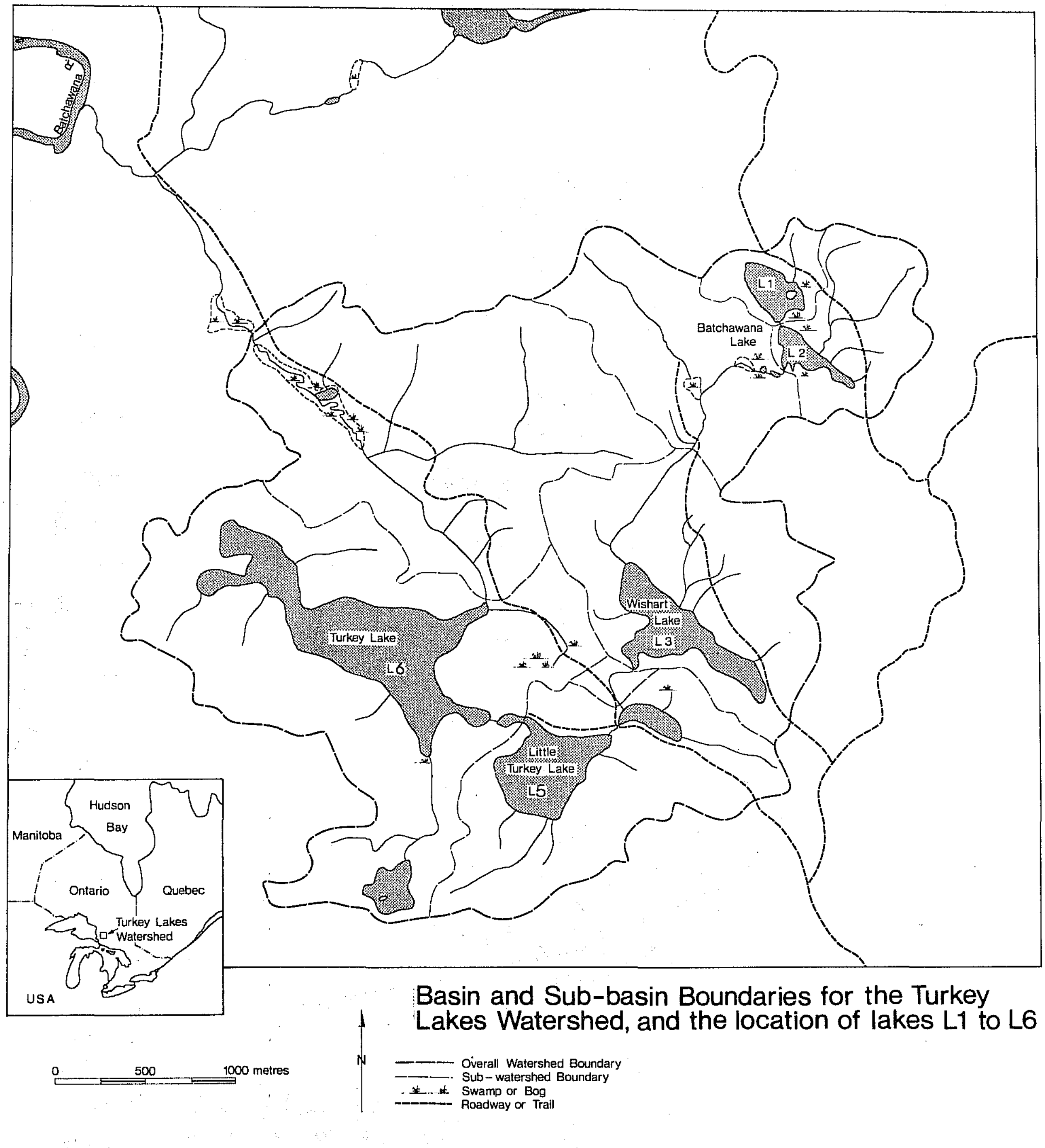
Table 1. Lake morphometric and chemical characteristics (annual mean values) of lakes in the Turkey Lakes Watershed (Jeffries and Semkin, 1982).

| Lake | Elevation (m) | Lake Area (ha) | Drainage Basin Area (ha) | Alkalinity ($\mu eq\ l^{-1}$) | | pH | | Conductivity | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1980 | 1981 | 1980 | 1981 | 1980 | 1981 |
| Batchawana N. Basin (L1) | 497 | 5.88 | 24.0 | 38 | 35 | 6.33 | 5.47 | 27.47 | 31.53 |
| Batchawana S. Basin (L2) | 497 | 5.82 | 61.7 | 61 | 46 | 6.33 | 5.47 | 31.61 | 33.86 |
| Wishart (L3) | 388 | 19.2 | 337 | 107 | 99 | 6.83 | 6.18 | 39.34 | 45.09 |
| Little Turkey (L5) | 375 | 19.2 | 491 | 156 | 128 | 7.02 | 6.39 | 45.04 | 48.46 |
| Turkey (L6) | 372 | 52.0 | 803 | 188 | 167 | 7.07 | 6.55 | 47.79 | 53.01 |

Table 2. Carbon incorporation measured *in situ* in the Turkey Lakes watershed on three representative dates June 9, August 11, and September 8, 1982.

| Incubation depth | Batchawana L. | | | | | | Wishart L. | | | Little Turkey L. | | | Big Turkey L. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June 9/82 | Aug. 11/82 | Sept. 8/82 | June 9/82 | Aug. 11/82 | Sept. 8/82 | June 9/82 | Aug. 11/82 | Sept. 8/82 | June 9/82 | Aug. 11/82 | Sept. 8/82 | June 9/82 | Aug. 11/82 | Sept. 8/82 |
| 0 | 1.5 | 1.1 | 3.4 | 1.6 | 4.9 | 4.9 | 2.0 | 1.6 | 4.2 | 0.8 | 1.4 | 1.5 | 0.9 | 1.4 | 1.7 |
| 1 | 2.2 | 2.0 | 3.7 | 1.5 | 4.8 | 4.6 | 2.4 | 4.6 | 4.1 | 0.9 | 2.7 | 2.0 | 1.4 | 1.7 | 2.2 |
| 2 | 2.6 | 3.2 | 2.8 | 1.5 | 4.5 | 4.1 | 2.9 | 7.1 | 4.0 | 1.1 | 3.8 | 2.9 | 1.6 | 2.2 | 2.9 |
| 3 | 2.1 | 3.0 | 3.0 | 1.3 | 4.5 | 3.1 | 3.4 | 6.7 | 3.1 | 1.3 | 3.4 | 3.4 | 1.4 | 2.5 | 2.7 |
| 4 | 1.4 | 2.5 | 2.5 | 0.7 | 4.1 | 2.1 | 1.8 | 3.5 | 1.7 | 1.5 | 2.8 | 3.2 | 1.3 | 2.5 | 2.5 |
| 5 | 1.0 | 2.2 | 0.6 | 0.5 | 2.8 | 1.9 | | | | 1.6 | 2.4 | 3.1 | 1.5 | 2.4 | 2.6 |

## List of Figures




Basin and Sub-basin Boundaries for the Turkey Lakes Watershed, and the location of lakes L1 to L6

Fig. 1.

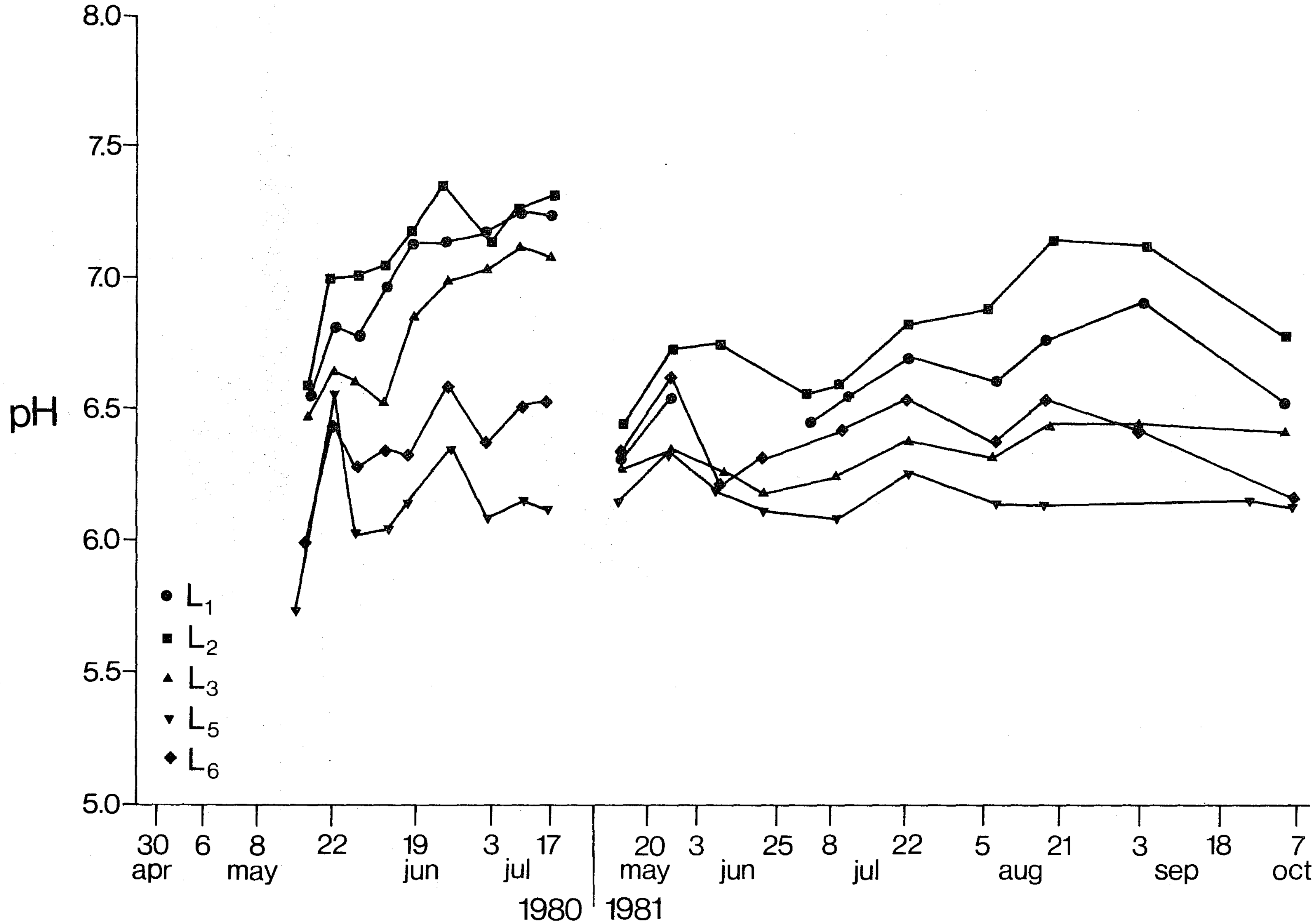



Fig. 2. pH levels during incubation times for 1980 and 1981 in the Turkey Lakes watershed.

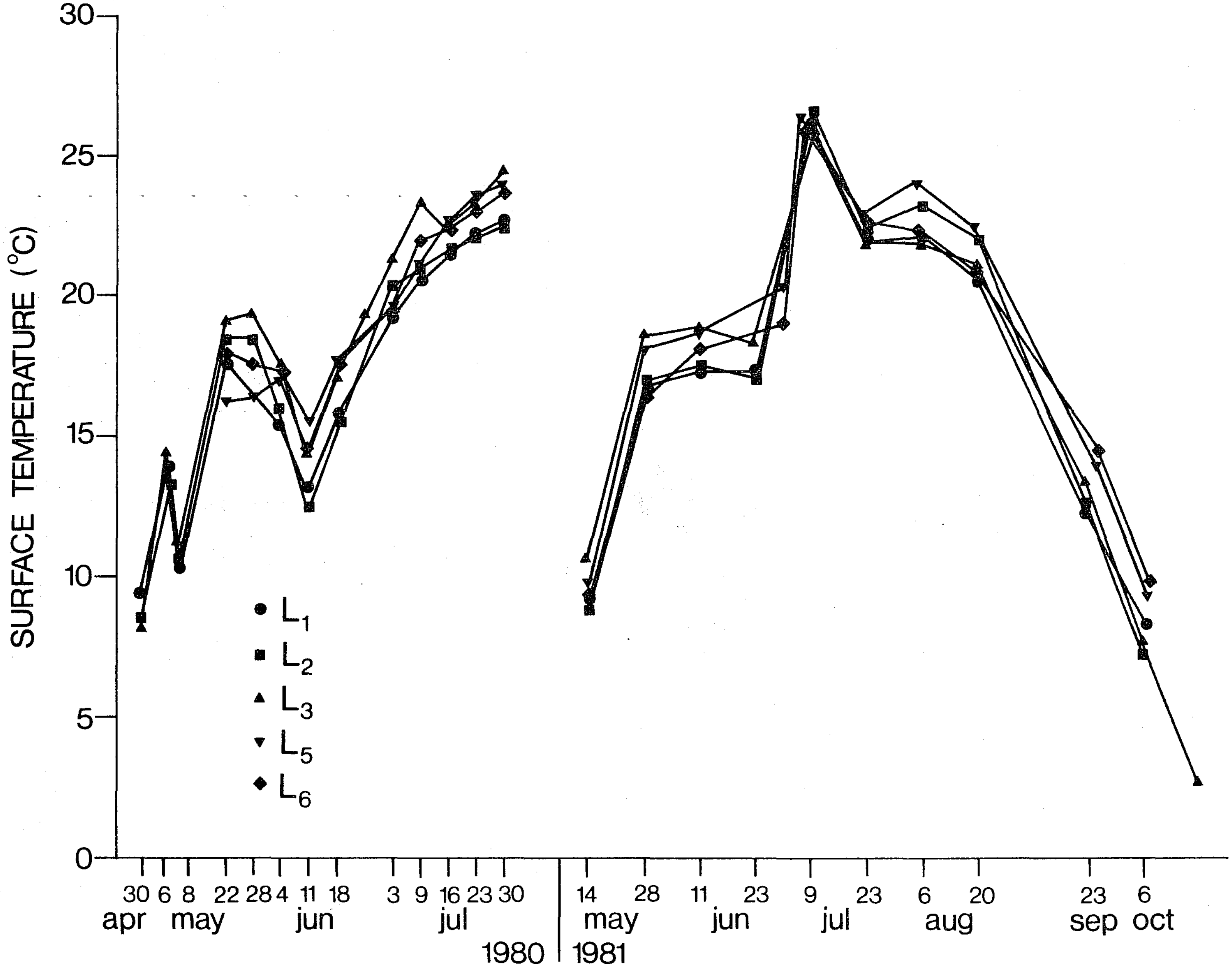



Fig. 3. Surface temperatures during incubation times for 1980 and 1981 in the Turkey Lakes Watershed.

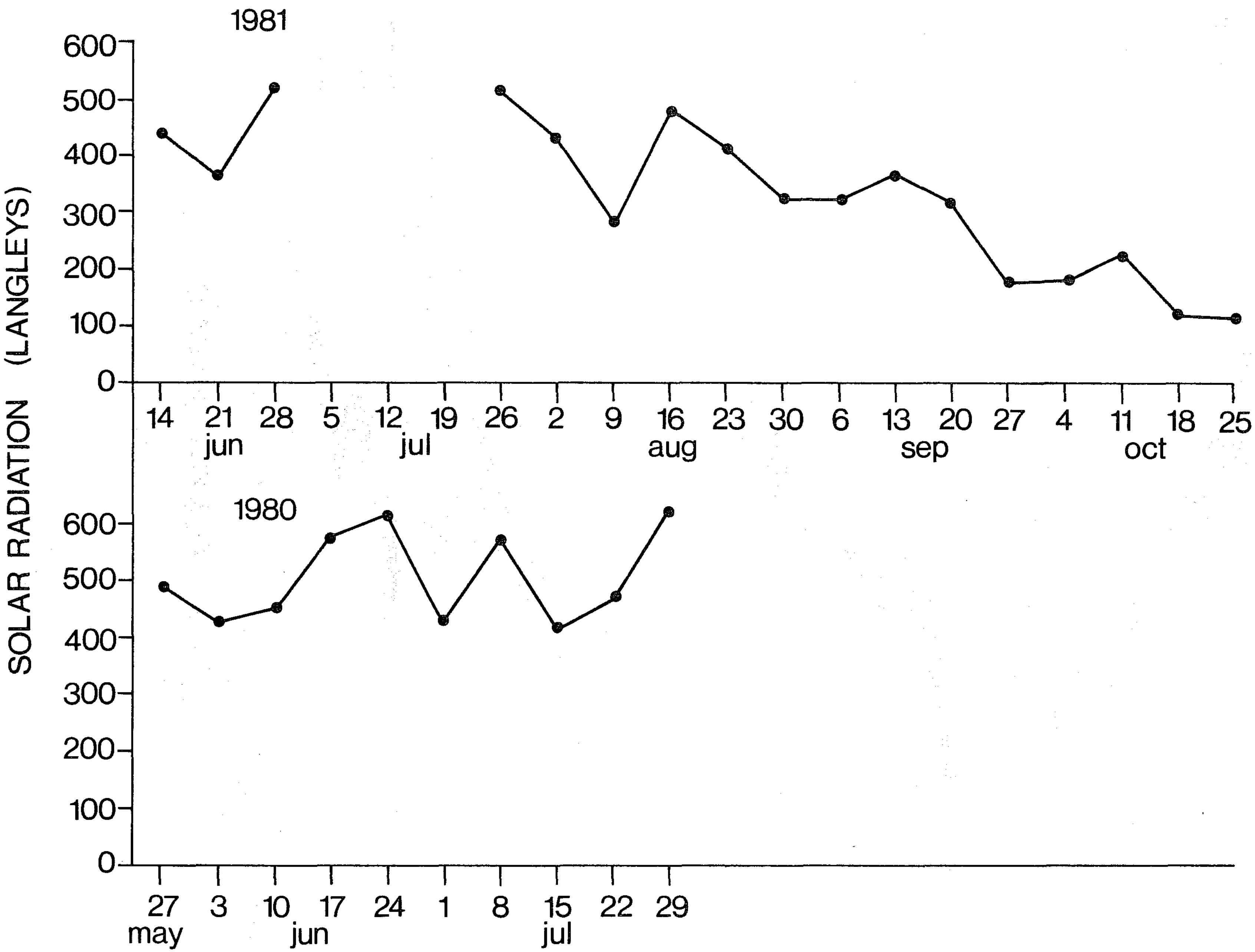



Fig. 4. Solar radiation during incubation times for 1980 and 1981 in the Turkey Lakes watershed.

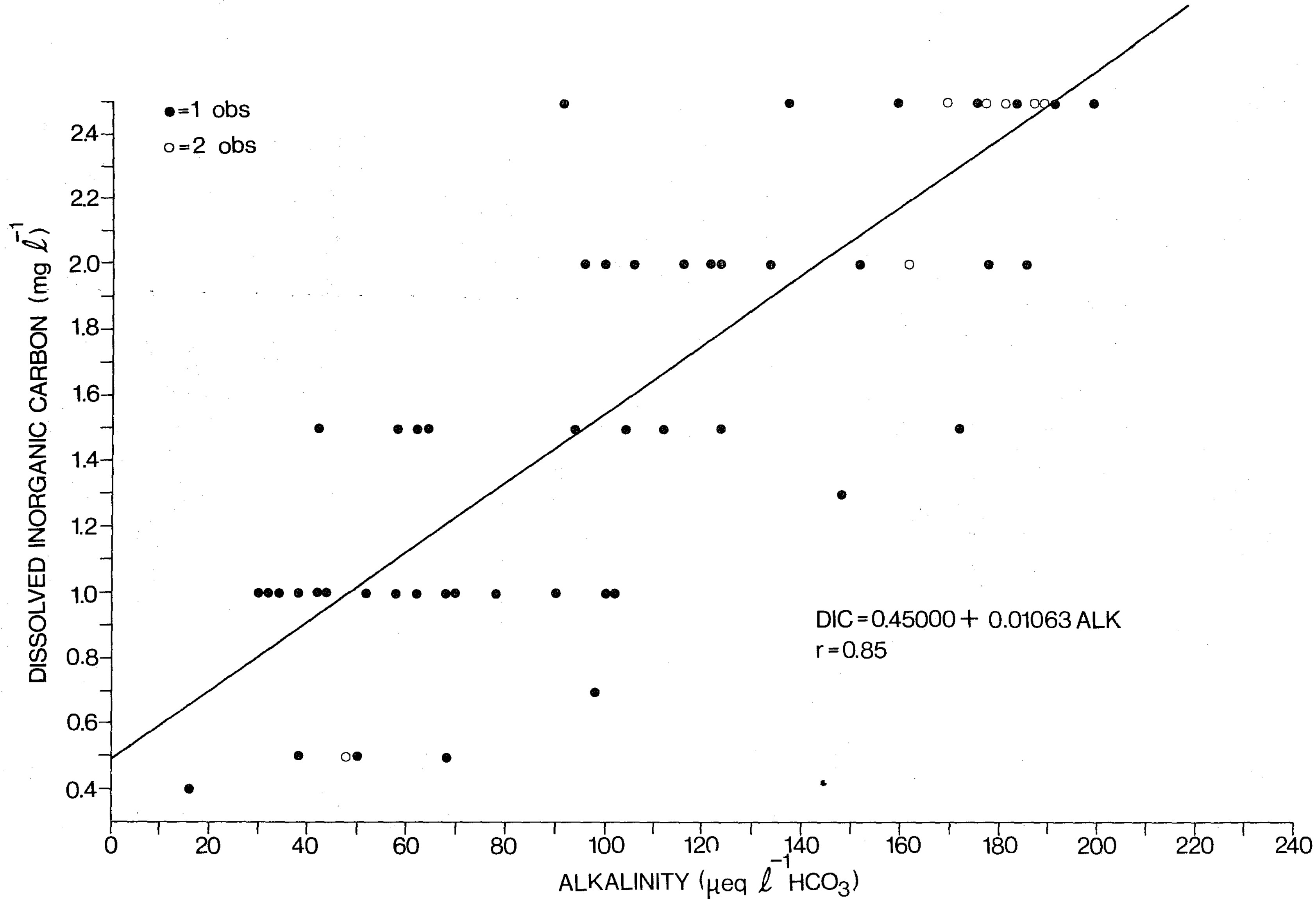



Fig. 5. Turkey Lakes Data, Dissolved Inorganic Carbon versus Alkalinity, tube samples only

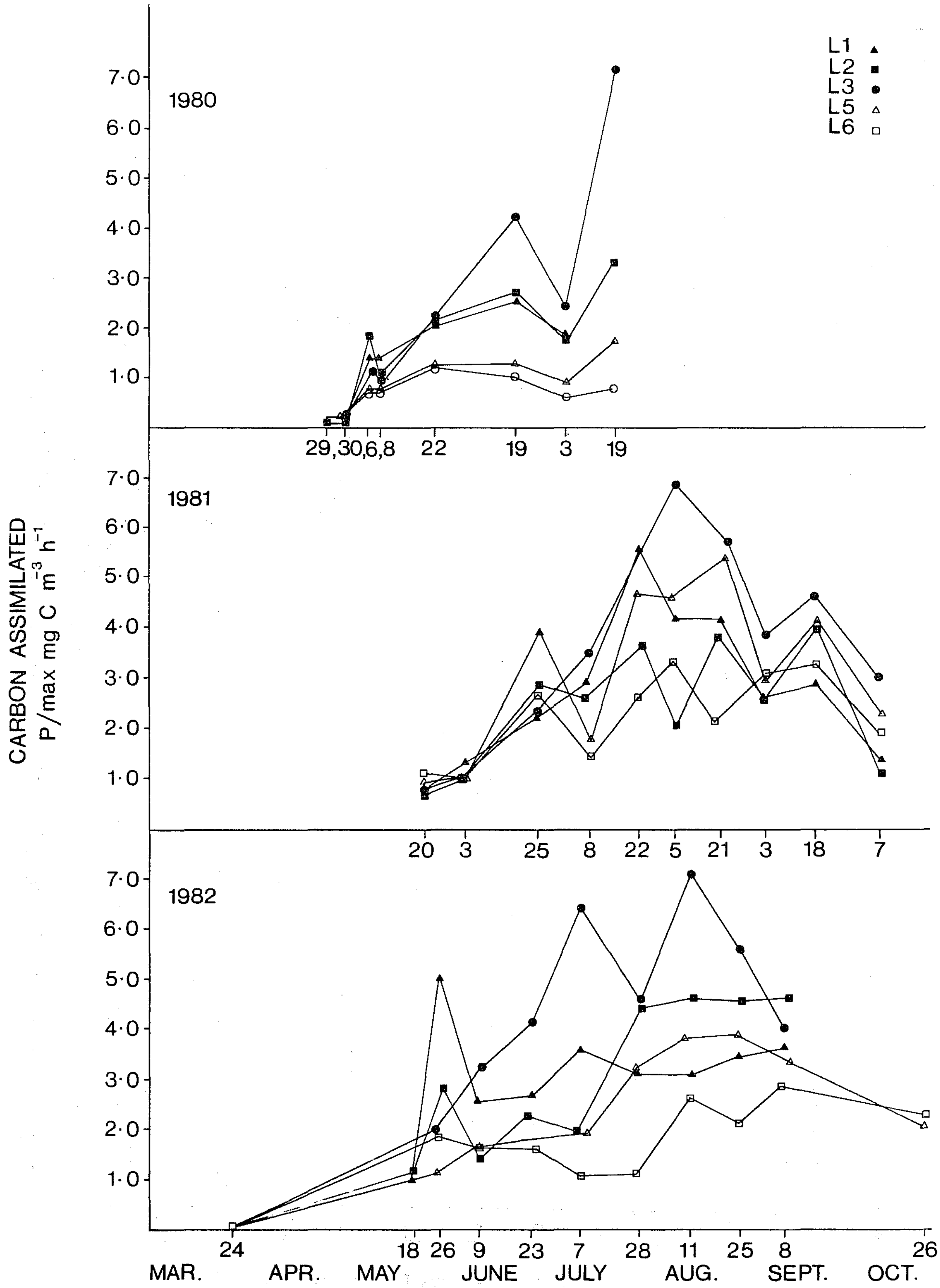



Fig. 6. Carbon assimilated (mg $m^{-3}$ $h^{-1}$ per lake) for 1980, 1981, and 1982 as determined from $C_{14}$ in situ incubations.

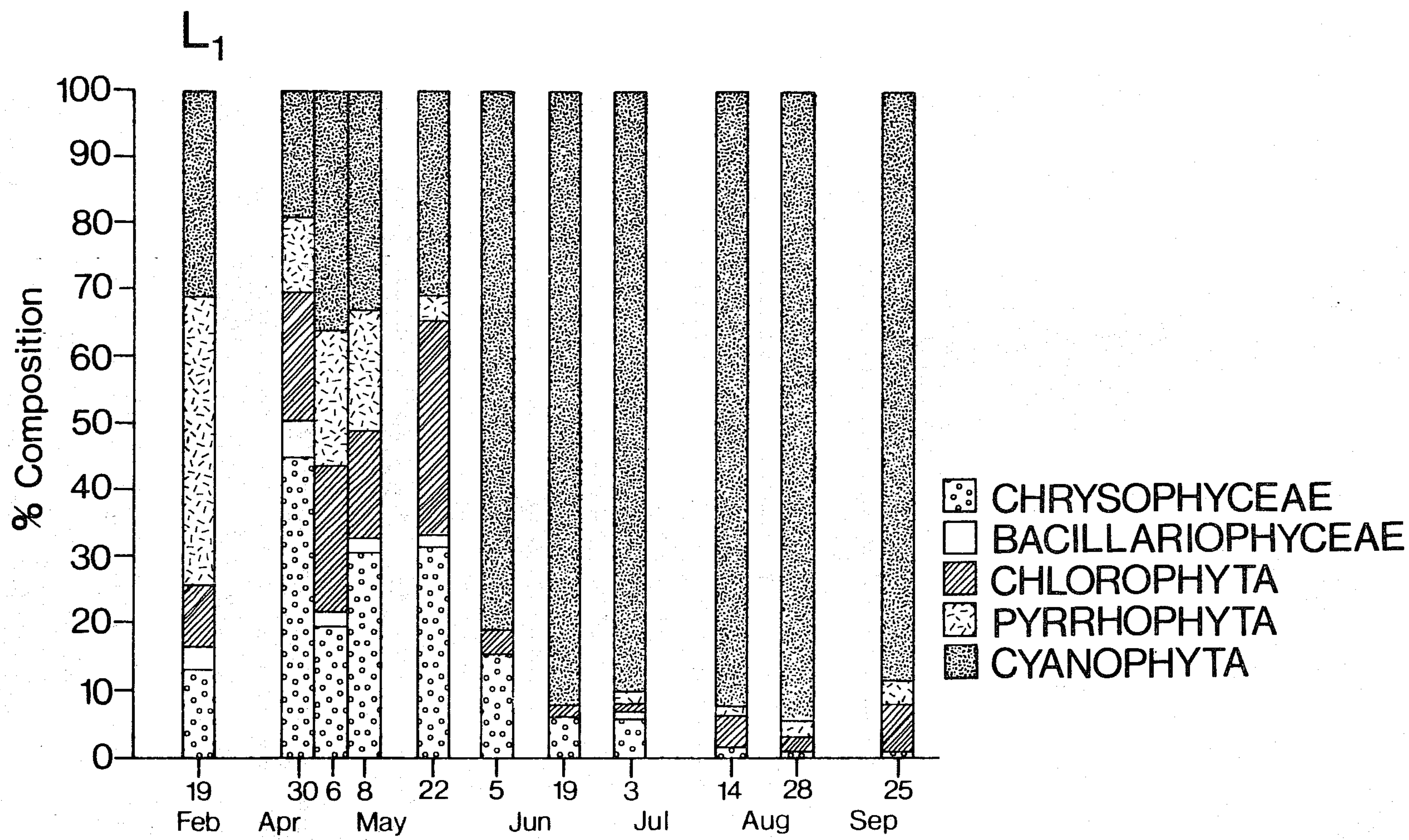



Fig. 7. Seasonal changes in phytoplankton composition for Lake L1, 1980

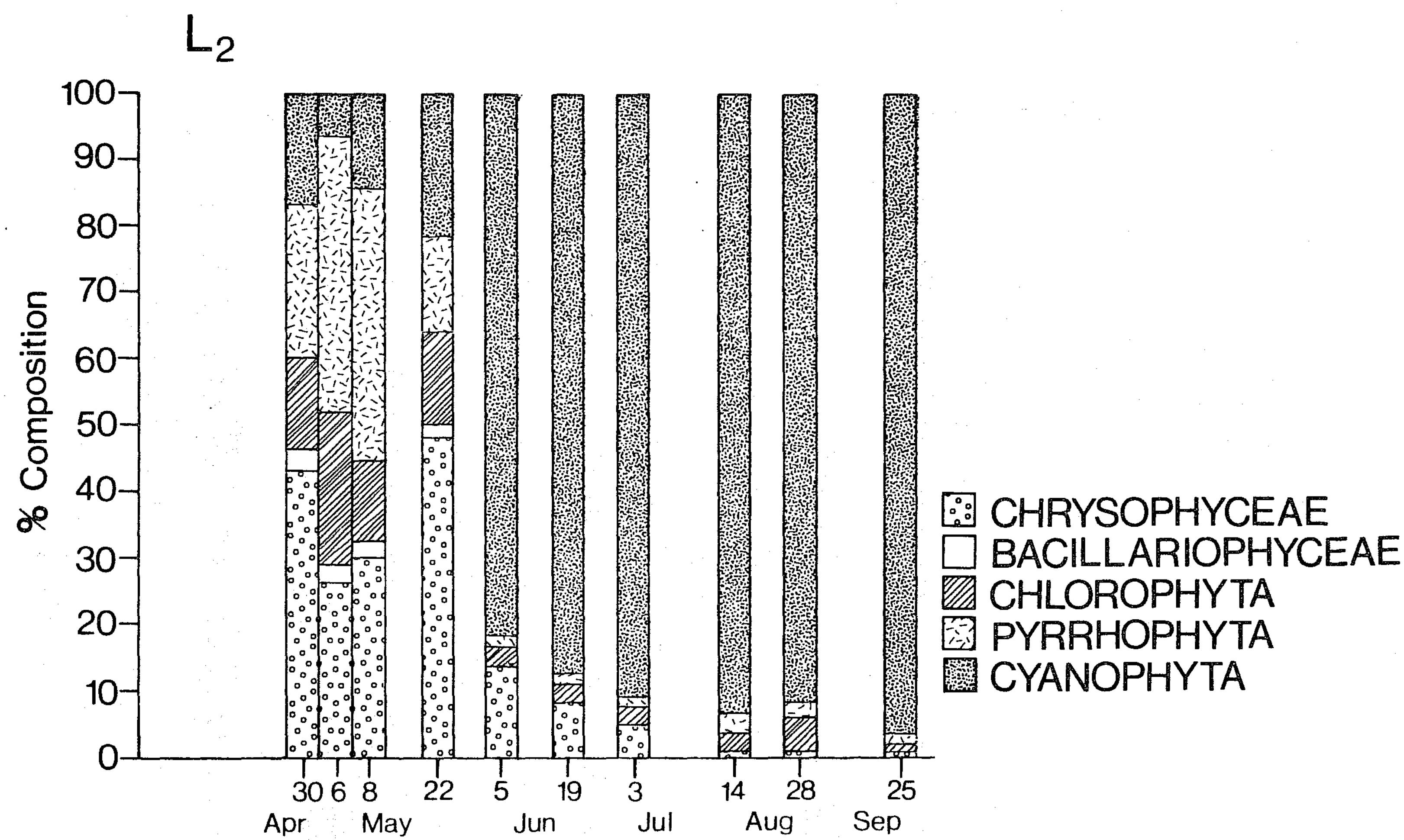



Fig. 8. Seasonal changes in phytoplankton composition for Lake L2, 1980

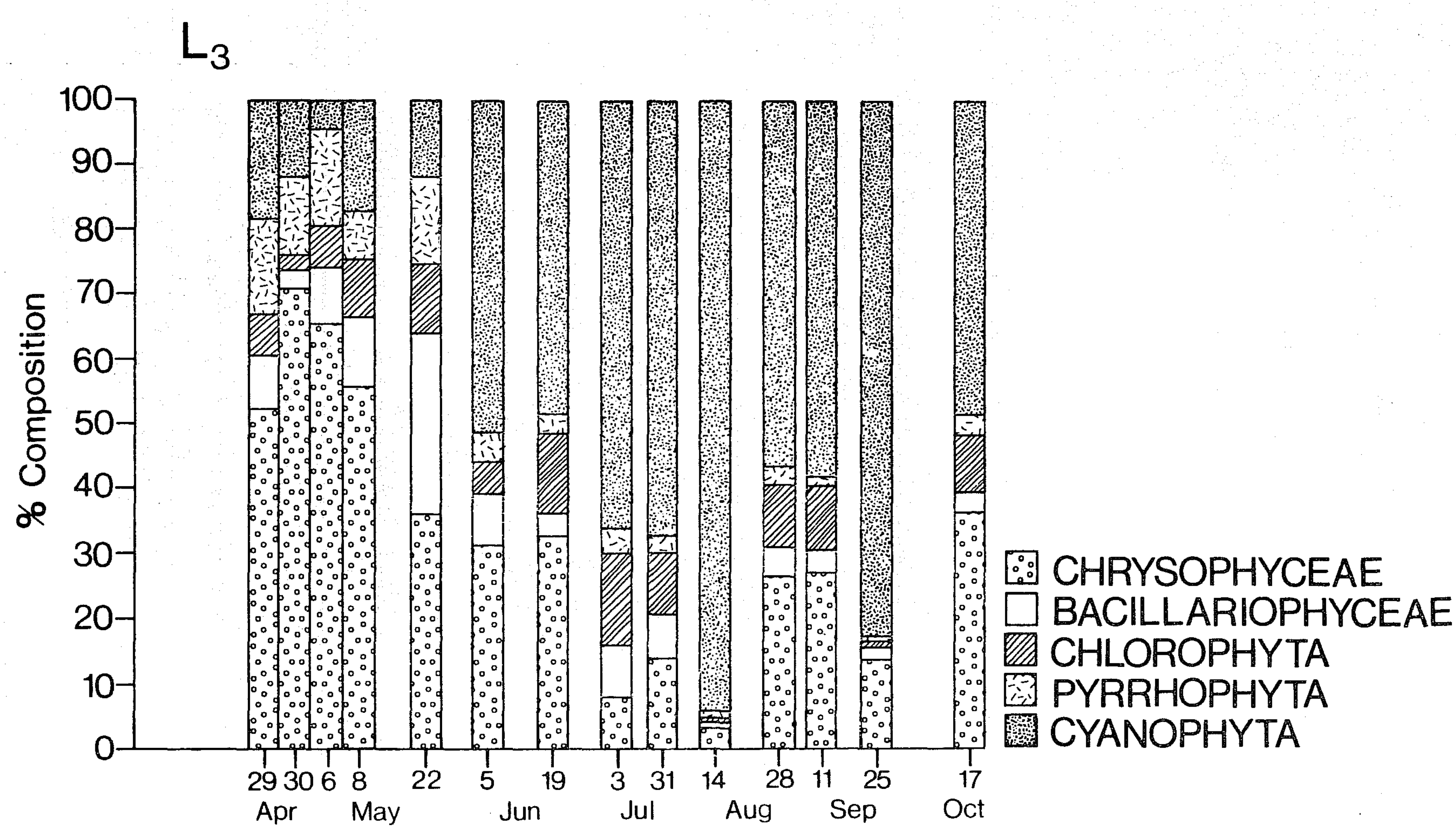



Fig. 9. Seasonal changes in phytoplankton composition for Lake L3, 1980

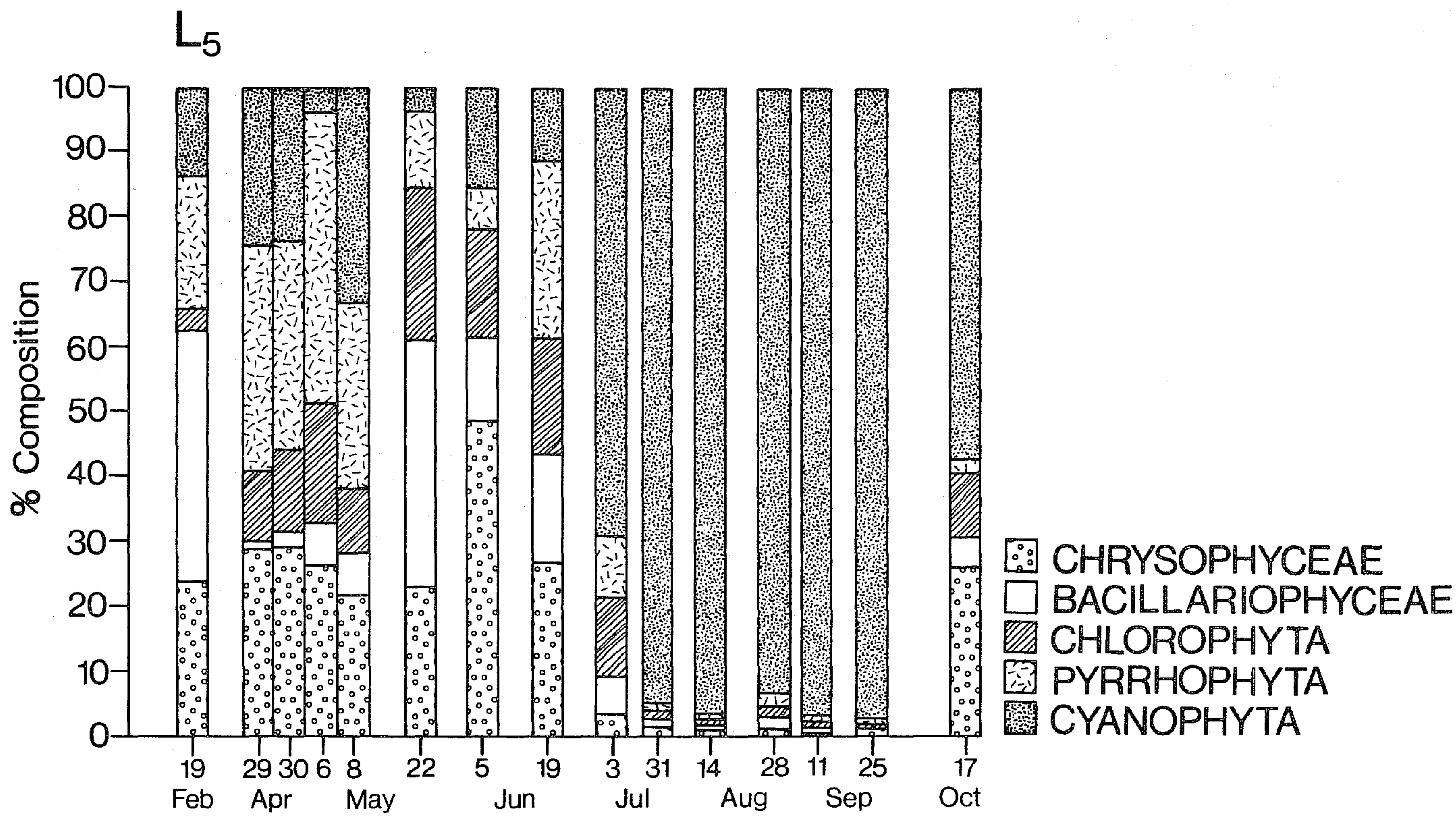



Fig. 10. Seasonal changes in phytoplankton composition for Lake L5, 1980

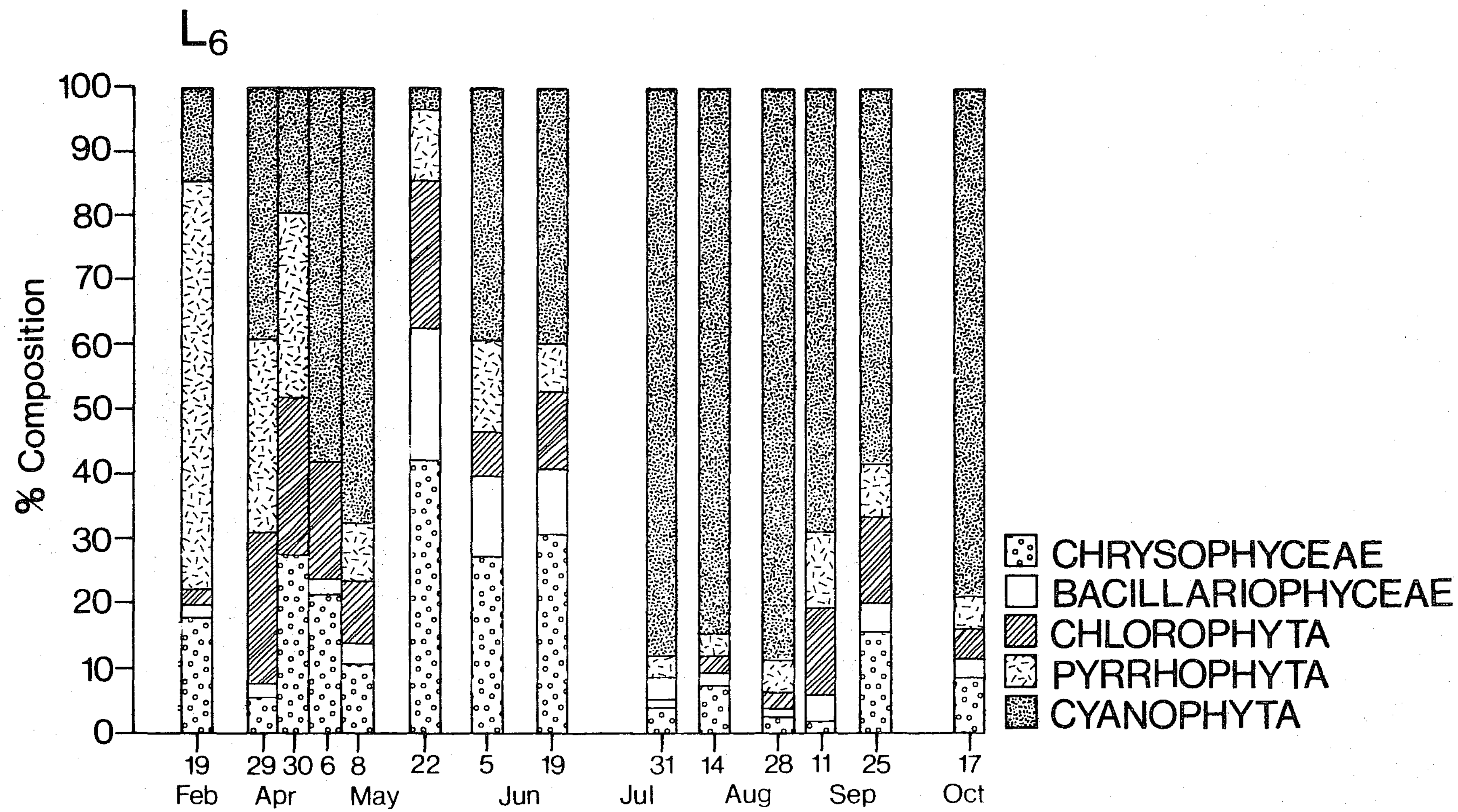



Fig. 11. Seasonal changes in phytoplankton composition for Lake L6, 1980