
Bailey-Watts, A.E.. 1981 Loch Leven phytoplankton succession. In: *Annual Report of the Institute of Terrestrial Ecology 1980.* NERC/ITE, 88-92

Table 30. Estimated numbers (in hundreds) of the 10 commonest trees growing in Edinburgh (1972), other residential areas, burghs, of the Lothian region (1972–75) and Bangor, north Wales, (1980).

Edinburgh		Lothian burghs (excluding Edinburgh)		Bangor	
Apple, domestic	1400	Sycamore	410	Oak	265
Lilac	810	Wych elm	190	Sycamore	210
Flowering cherry	660	Hawthorn	160	Hazel	168
Sycamore	650	Elder	140	Holly	66
Rowan	560	Birch	110	Hawthorn	58
Cypresses	450	Rowan	100	Ash	54
Apple, crab	440	Oak	100	Cypresses	35
Beech	410	Flowering cherry	90	Flowering cherry	35
Laburnum	400	Ash	90	Wych elm	33
Birch	370	Apple, domestic	80	Rowan	28

NB The 10 commonest trees account for 64% of the total in Edinburgh, 66% of the total in Lothian burghs (excluding Edinburgh), and 86% of those in Bangor.

(excluding Edinburgh), although widely separated geographically, share 7 of their 10 commonest species, while the Lothian region, as a whole, and the Arfon district share only 4: being a small town in the countryside appears to have a greater bearing on the choice of trees than does its location.

Surveys may highlight problems requiring attention, such as the threat posed to hedgerow trees, not only by hedgerow removal, but also by present-day management procedures involving repeated machine maintenance. Contrary to what might be expected, species are not equally affected, regeneration of oak and elm being more severely hampered than that of beech, ash and sycamore. The strong control of apical growth in beech and sycamore, and particularly ash, enables the rapid development of a few strong shoots which may develop substantially between cuts to an extent that encourages hedgerow trimmers to leave them untouched on subsequent occasions. In contrast, oaks and elms usually produce small competing shoots which are continually at risk. For this and other reasons, there could be fundamental change in the species composition of mature hedgerow trees, unless positive measures are taken to protect oak saplings. Interestingly, where walls and hedges are about equally common, as in north Wales, populations of trees associated with walls, and hence not subject to machine trimming, contained a satisfactory distribution of size classes.

In addition to compiling inventories of amenity trees, it is important to understand their growth characteristics, which, in comparison to those of the limited range of plantation trees, are virtually unknown. Tables of life expectancies are being prepared while seeking the relations between size and age, so enabling culturists to ensure that the resource will be sustained. A start has been made with sycamore, ash and hawthorn, but preliminary results indicate that the twin influences of site diversity and intraspecific variation are responsible for a great deal of variation. Nonetheless, it is hoped, by excluding data from trees growing in extreme conditions (waterlogged soil, severe exposure, tarmacadam pavements, etc), that it will be possible to make useful generalisations, possibly with the development of 'regional' tables to accommodate major soil and climate differences.

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LOCH LEVEN PHYTOPLANKTON SUCCESSION

To obtain a better understanding of the relationships between the biota and chemical constituents of the shallow mixed Loch Leven, it has been necessary to (i) assess factors controlling seasonal, annual and long-term changes in the composition and abundance of phytoplankton assemblages, and (ii) assess and predict how these assemblages would be altered by 'natural' and man-induced factors.

The phytoplankton study was started in 1967 in collaboration with colleagues in universities and other research institutions who have been concerned with physical, geological, chemical and complementary aspects of the biology of Loch Leven. Much of the early work was summarised in the Proceedings of the Royal Society of Edinburgh (1974). More recently, algal investigations being made within ITE have been integrated within a project group including physical limnologists and others working with crustacean and rotifer zooplankton, and fish, with studies on juvenile perch development and feeding being the latest additions (Jones, see page 45 of this Report).

Phytoplankton samples have been taken at more or less weekly intervals in the period 1968–80 to assess (a) crop density (volumes and weights, also amounts of chlorophyll *a*) and (b) species diversity, abundance and chemical (N, P, C. and SiO_2) content (Bailey-Watts 1974, 1978). Additionally, the interactions between population fluctuations and water chemistry have been considered (Bailey-Watts 1976*a*, *b*), as have the effects of grazing zooplankton on the abundance of phytoplankton (Bailey-Watts & Lund 1973; Bailey-Watts 1974), the latter recently becoming the focus of experimental studies.

The seasonal patterns of phytoplankton growth have, in recent years, differed markedly from those in earlier years (Bailey-Watts in press). In particular, large algae, eg *Anabaena* (Cyanophyceae), produced the largest biomass in 1979, whereas in 1968 *Synechococcus* n sp (Cyanophyceae) – a very small species – predominated. As a consequence, and because annual mean concentrations of chlorophyll *a* have decreased, total numbers of individuals are now much smaller (Table 31).

Many factors control the structure of freshwater phytoplankton communities (Lund 1965; Hutchinson 1967), but it is thought that long-term changes in Loch Leven are mainly attributable to changes in water chemistry and zooplankton.

Table 31. Features of the phytoplankton that developed in Loch Leven in 1968 and 1979.

	1968	1979	
I *Chlorophyll a concentrations* (mg m^{-3}			
Annual mean	94	41	
Means Jan – June	120	35	
Means July – Dec	63	46	
Annual maximum and date of occurrence	188 (June)	160 (Mar) 350 (Oct)	
Annual minimum and date of occurrence	35 (Aug)	2 (Jan & Dec)	
Index of variation – number of times the temporal graph plot crosses (in either direction) the annual mean value	4	12	
II *Species composition*			
Major classes (by volume)	Bacillariophyceae (B) and Cyanophyceae (C)	Bacillariophyceae (B) and Cyanophyceae (C)	
Temporal distribution of important genera			
Jan – Mar	Unicellular Centrales (B) *Asterionella* (B)	Unicellular Centrales (B)	
Apr – June	As for Jan – Mar plus *Diatoma* (B) and *Synechococcus* (C)	As for Jan – Mar plus *Asterionella* (B)	
July – Sept	* *Dictyosphaerium* Unicellular Centrales (B) *Synechococcus* (C)	*Anabaena* (C) *Microcystis* (C)	
Oct – Dec	Unicellular Centrales (B) *Synechococcus* (C)	*Anabaena* (C)	
Species producing largest population (by volume)	*Synechococcus* n sp	Unicellular Centrales	*Anabaena*
Mean volume of individuals of species producing largest volume (μm^3)	10·6	120	200
Peak numbers of individuals of species producing largest volume (ml^{-1})	4·4 × 10^6	1·7 × 10^5	9·8 × 10^3
Peak numbers of phytoplankton individuals (ml^{-1})	5·0 × 10^6	1·91 × 10^5	

* *Dictoyosphaerium* is a genus within the Chlorophyceae.

i. *Water chemistry*

The annual loadings of phosphorus to Loch Leven from 1968 to 1972 were 1·5 g m^{-2}, but, with industrial (woollen mill) effluents being subsequently lessened, these loadings had decreased to <0·5 g m^{-2} by 1975 (Holden & Caines 1974; Holden 1976). In contrast, amounts of nitrogen have tended to increase, with winter maximum concentrations of nitrate in 1980 being nearly double those detected 12 or more years ago. As a result of these changes, the N:P ratio is likely to have increased.

ii. *Crustacean zooplankton*

When comparing zooplankton development in Loch Leven in 1969 and 1972, Johnston & Walker (1974) found that the copepod *Cyclops* occurred in almost pure stands in the earlier year, whereas the cladoceran *Daphnia*, which was initially absent, occurred in appreciable numbers in 1972. Subsequently, many observers have recorded annual maxima of 80 *Daphnia* per litre, while recent populations of *Cyclops* are about one sixth the size of those recorded in 1969. Field and laboratory investigations (Fryer 1957; Miss E. W. Rutkowski pers. comm.) indicate that *Cyclops* feeds on algae, rotifers and Crustacea, including its own young; contrastingly, *Daphnia* is herbivorous with a preference for small algae. Nonetheless, the removal of small algae by *Cyclops* should not be discounted, as its early life stages may take food of this sort.

The long-term as well as seasonally varying importance of grazing pressures, relative to the effects of changed chemistry, remains to be resolved. However, changes in species, and their population densities, seem to be of cardinal importance. But how should these changes be represented? By plotting numbers of species and 2 indices of diversity (the Shannon-Wiener, and equitability), it was found that species diversity decreased when amounts of chlorophyll greatly increased as in February/March and October (Figure 55). Seasonal differences were also found when the size frequency distributions of different algal crops were examined (Bailey-Watts & Kirika in press) (Figure 56). The sharply defined peaks for February, March and June 1979 contrast with the distribution in September, when cells ranging widely in length were more equally abundant.

How are populations of phytoplankton and rotifer and crustacean zooplankton interrelated? Changes in phytoplankton density in laboratory systems containing collections of natural phytoplankton/zooplankton assemblages were compared with concurrent changes in similar systems from which the larger (crustacean) zooplankton elements were removed by net (Figure 57). From series of week-long experiments done at fortnightly intervals throughout most of 1978, it seems that the removal of zooplankton, especially in the middle of the year when the filter-feeding *Daphnia* is most abundant, results in smaller decreases in algal abundance when the crop is declining and greater increases when the crop is increasing. These experiments will be continued to further our understanding of zooplankton grazing on the populations of different algae.

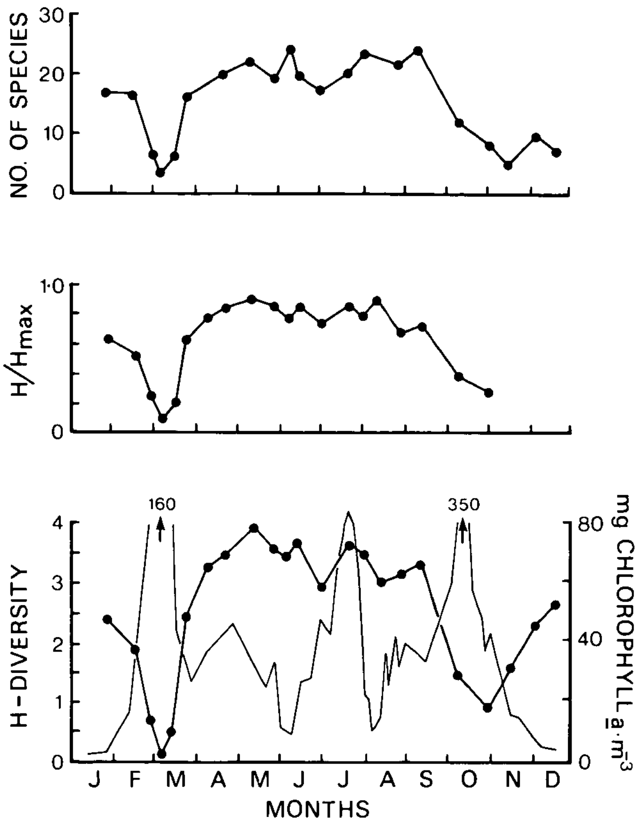

Figure 55 Changes of concentrations of chlorophyll a (lower graph, thin line) in Loch Leven during 1979 related to changes in the diversity of species of algae plotted as (i) numbers of species (upper graph), (ii) Shannon-Wiener diversity index (H—lower graph •——•), and (iii) equitability index (H/H_{max}—middle graph).

Despite decreased supplies of phosphorus to Loch Leven, the incidence of bloom-forming blue-green algae, of the *Anabaena* type, has increased: this change is associated with an increase in the relative frequency of larger species of algae, possibly because the smaller species are grazed by *Daphnia*. Reynolds and Walsby (1975) associate large populations of *Anabaena*—because it can fix molecular nitrogen—with waters having relatively small amounts of nitrogen compared with those of phosphorus. Because of the changes in nutrient loading, the average N:P ratio in Loch Leven would be expected to be higher than heretofore. However, examination of the data indicates that the N:P ratios are very low in late summer. (Figure 58).

More attention than hitherto will be given to the possibly major and long-lasting effects of relatively short-term changes of physical (weather) conditions on the chemistry and biology of Loch Leven.

Ideally, ecological investigations should be supported by critical taxonomic studies. Scanning electron

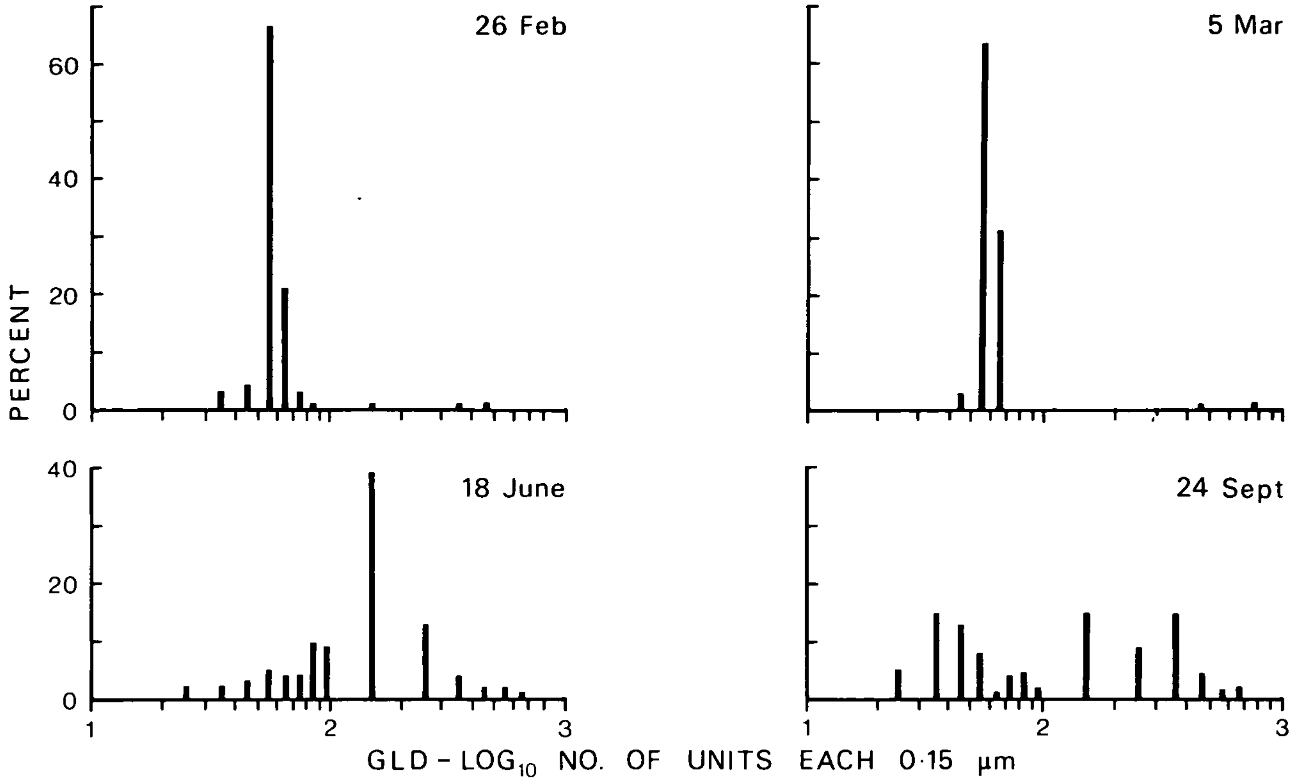

Figure 56 Size class distributions of phytoplankton algae in Loch Leven on selected dates during 1979. GLD is the greatest linear dimension.

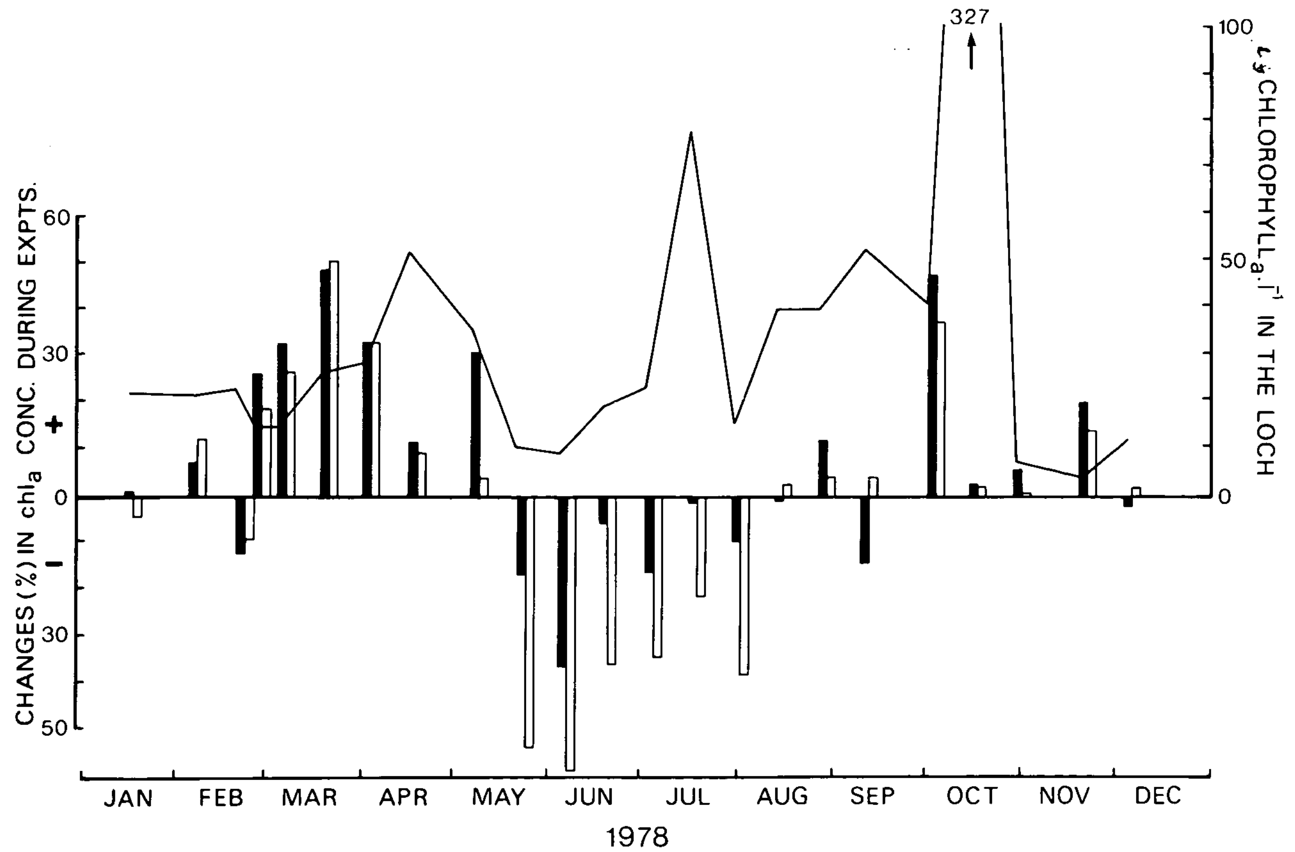

Figure 57 Increases (+) and decreases (−) in Loch Leven phytoplankton density (as chlorophyll a) expressed as percentages of the initial densities in experimental containers with control (natural—open columns) and treated (Crustacean zooplankton removed—solid columns) collections of plankton. Right-hand axis refers to algal abundance in the bay sample used for the experiments (solid line).

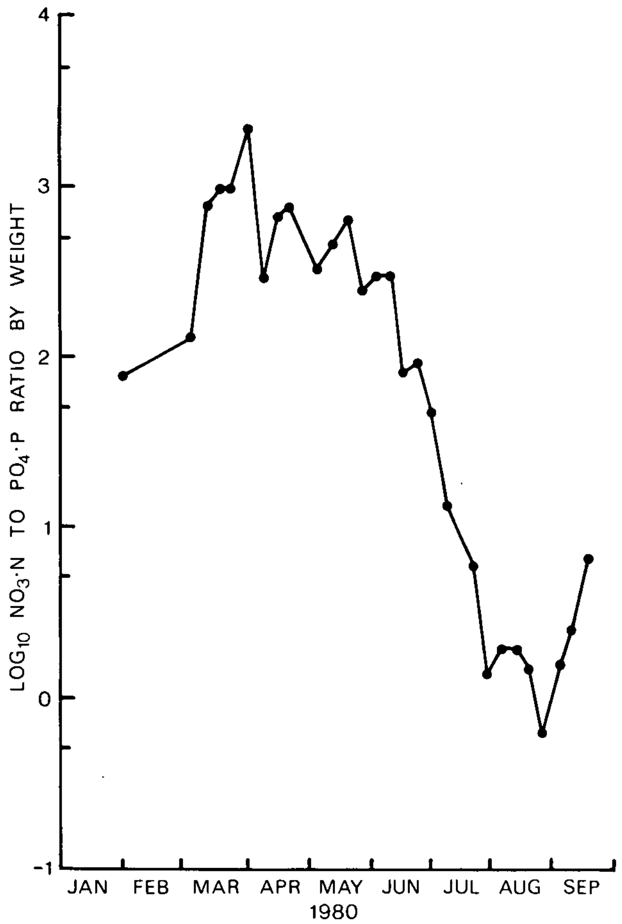

Figure 58 Seasonal changes during 1980 in the ratios, by weight, of dissolved nitrate-N: dissolved inorganic phosphate-P, found in Loch Leven.

microscopy is being used to show the detailed architecture of species of small unicellular diatoms, eg *Staphanodiscus* spp (Plate 26), which still occur in Loch Leven in large numbers (1 to 2 × 10^5 cells ml^{-1}, equivalent to between 5 and 10 mg silicate silica (SiO_2) l^{-1}) in early spring, before numbers of zooplankton increase.

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SULPHUR AIR POLLUTION

Research in ITE on air pollution has been in progress for 5 years. Initially, there were few details of the atmospheric pollutants in rural environments either in the gaseous form, or in precipitation causing the phenomena known as 'acid rain'. Interest, therefore, has been centred, though not exclusively, upon the distribution of gaseous and particulate substances derived from emissions of sulphur compounds, and their impacts on tree growth and forest ecosystems.

Effects of air pollutants on crops and other plants are usually grouped for convenience into *direct* effects, eg those attributable to the impact of gaseous compounds or polluted rain on leaves and their functions, and *indirect* effects, eg those arising from influences on soil properties. Taking into account the diverse character of pollutant impacts, it was considered essential to adopt, initially, a broad approach (i) describing the chemical characteristics of precipitation and the nature of gaseous pollutants and their changing concentrations, (ii) quantifying the 'sulphur' inputs in *dry deposition* and *wet deposition* to forests, and (iii) characterising the 'pathways' of sulphur derivatives through vegetation to soil.

The environment— gaseous pollutants and acid rain

Analyses of monthly samples of precipitation, collected during 1978 and 1979 in 18 rain collectors distributed between the English Lake District and the north coast of Scotland, have shown that precipitation is usually more acid in the east than in the west (Figure 59).

Using the Mg/SO_4 ratio method, it was found that amounts of 'excess' sulphate (ie sulphate attributable to the activities of man) were largest in south-east Scotland and the central highlands (80%) and least in the north-west (20%). Although concentrations of hydrogen ions and excess sulphate were positively correlated, nitric and hydrochloric acids contributed to acidity at some sites. If precipitation were unpolluted,