
Bailey-Watts, A.E.; Kirika, A.A.. 1984 Eutropication of Loch Leven. In: Annual Report of the Institute of Terrestrial Ecology 1983. NERC/ITE, 19-21.

Eutrophication of Loch Leven

Fresh waters commonly become increasingly enriched with mineral nutrients, and lakes and rivers are each subject to this eutrophication process (Vollenweider 1968). The substances of most concern in this context are nitrogen and phosphorus, as both are essential for plant growth, and it is commonly the growth response by plants to the enrichment that causes problems. Thus, in standing waters in particular, the enrichment is shown by dense algal populations which may (directly or indirectly) affect man's use of the water for potable and industrial supply, as well as fishing and other leisure activities. Depending on the particular species of alga present, the growths may form the surface 'blooms' characteristic of many lakes on calm and especially warm days.

Records of algae collected from Loch Leven in south-east Scotland at the turn of the century (Bachmann 1906, 1907) suggest that this large shallow lake (4 m mean depth, 13 km^2 surface area) has been eutrophic for a long time. Moreover, dense blooms of blue-green algae in the loch were noted in 1937, when they were associated with poor trout angling returns (Rosenberg 1938), and on occasions during the 1950s and 1960s (Brook 1957, 1958, 1965). Fluctuations in the Loch Leven phytoplankton—monitored especially closely since 1968 (Bailey-Watts 1974, 1978, 1982)—show that the loch has remained eutrophic. However, it is only since the late 1960s that detailed chemical analyses have been made of Loch Leven water. Our understanding of the relationships between phytoplankton performance and nutrient concentrations in this loch has thus been developed from the analysis of the last 15 years' records.

Since 1968, it has been established that the major source of nitrogen to the loch is surrounding agricultural land (Holden & Caines 1974; Holden 1976). To increase the yields of improved grass for cattle and of grain crops, much of the catchment of the loch (70% of a total area of 145 km^2—Smith 1974) has been heavily fertilized since the late 1950s. Runoff from the agricultural land has resulted in increases in nitrate concentrations in the inflowing streams. These increases have led to a rise of approximately 1 mg N l^{-1} over the period 1970–1980 in the recorded winter (January–March) maximum concentrations in the loch itself (Figure 9).

Contrasting with nitrogen supplies, which enter the loch in a diffuse manner, most of the phosphorus reaches the loch at well-defined points (Plate 7). During the late 1960s, and up until 1972, some 65–70% of the total loading (>1·25 g P m^{-2} yr^{-1}) was associated with a single point source, ie an outfall of woollen mill effluent (Holden 1976). By 1976, a considerable reduction in total phosphorus loading

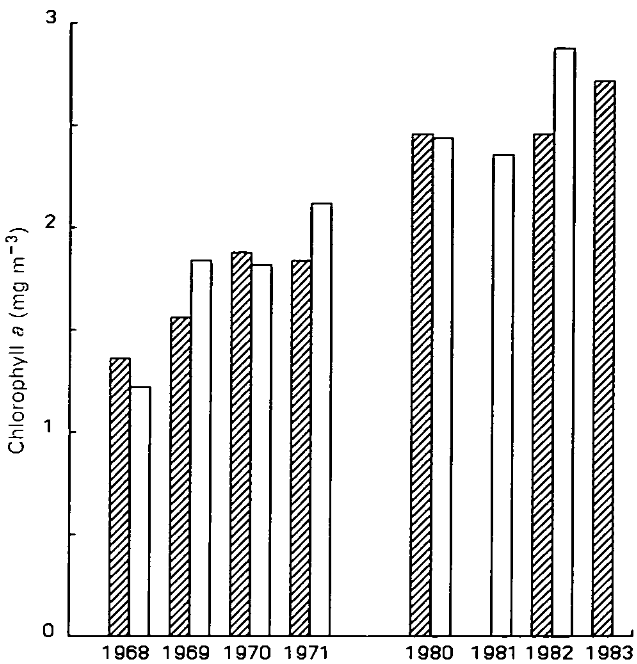

Figure 9 Contrasts in the winter maximum nitrate concentrations in Loch Leven between the periods 1968–71 and 1980–83 (1968–71 data from Holden & Caines 1974). Shaded columns refer to a sampling station near the outflow and unshaded columns to an open water site

was effected by a change in the policy of the wool manufacturers for the disposal of their effluent. Thus, by 1976, the estimated total loading had been reduced to 0·7 g P m^{-2} yr^{-1} (values calculated from Holden & Caines 1974).

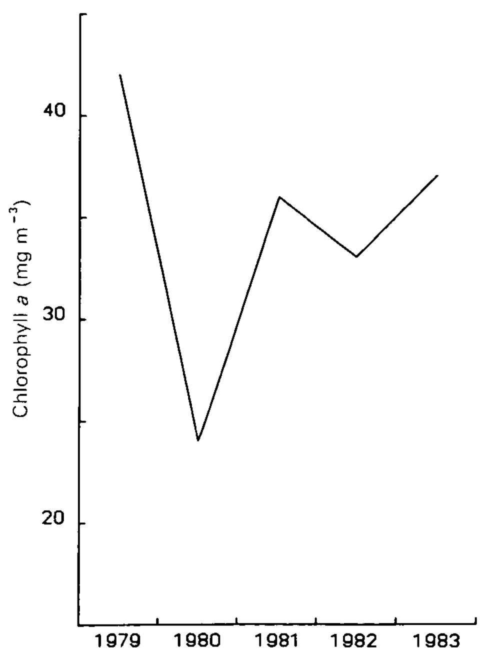

Figure 10 Mean phytoplankton biomass levels (expressed as concentrations of chlorophyll a) in Loch Leven 1979–83

Table 3. Algae dominating the phytoplankton of Loch Leven at the times of various biomass maxima, 1979–82

Season	Year 1979	1980	1981	1982
January–April	Unicellular centric diatoms	Unicellular centric diatoms	Unicellular centric diatoms	Unicellular centric diatoms
May–August	Cryptomonads and chrysoflagellates	Chrysoflagellates	Pennate diatoms, chrysoflagellates, unicellular and colonial green algae	Colonial blue-green algae and cryptomonads
September–December	Filamentous blue-green algae	Filamentous blue-green algae	Unicellular green algae, chrysoflagellates and unicellular centric diatoms	Unicellular and colonial green algae and colonial blue-green algae

The eutrophication of Loch Leven over recent times can, therefore, be summarized as an overall increase in nitrogen loading and a general decrease in phosphorus loading. A desk study (Bailey-Watts 1983) suggests that the current total loading of phosphorus has changed little since 1976, and, at 0·8 g m^{-2} yr^{-1}, reflects an increase attributable mainly to the contribution in treated sewage as a result of population increases in the catchment area (see also Cuttle 1982).

Mean algal biomass had approximately halved over the period 1968–1976, during which time the loading changes referred to above took place, and annual mean chlorophyll concentrations of 36, 32 and 41 mg m^{-3} were obtained for the years 1977, 1978 and 1979 respectively (Bailey-Watts 1982). As Figure 10 shows, the pigment levels have remained fairly low since 1979. However, changes in algal species composition have continued throughout the period under review (Bailey-Watts 1974, 1978, 1982, unpublished data); Table 3 illustrates the range of dominant species recorded at the times of major crop maxima during 1979–1983 – the period of relative stability in terms of mean annual biomass.

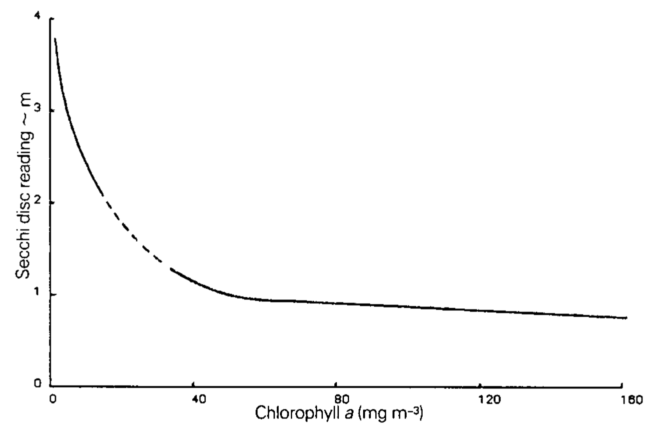

Figure 11 Line illustrating relationship between water transparency (expressed as Secchi disc reading) and phytoplankton biomass (expressed as chlorophyll a *concentration) in Loch Leven for 1980–83 (n = 130); dashed portion corresponds to the predicted decrease in pigment concentration if the phosphorus loading is reduced (see text)*

Although current algal biomass levels are low compared to those recorded a decade ago, the general problems commonly associated with algal developments induced by eutrophication persist. At Loch Leven, these include (i) unsightly scums and odour associated with the collapse of occasional dense blooms of blue-green algae, (ii) poor water clarity, (iii) problems in treating water for downstream industrial purposes (paper making), (iv) limited coverage by submerged rooted vegetation, and (v) poor fishing. The recent desk study to assess the feasibility of further control of phosphorus inputs to the loch suggested that removal of phosphorus from sewage and trade effluent should be seriously considered; phosphorus in these effluents currently appears to represent over 60% of the total loading. Other work (Bailey-Watts – unpublished observations) suggests that some of the current densest phytoplankton crops are prevented from increasing further because of phosphorus shortages. The application to Loch Leven data of the findings of an OECD programme on chlorophyll–phosphorus relationships (Anon 1982) indicates that a further reduction in mean chlorophyll levels to about 15 mg m^{-3} might be expected. If this were the case, a marked increase in water clarity could result, even though no significant increase in water transparency has been found since mean chlorophyll levels were reduced from the earlier values of 1000 mg m^{-3}. The relationship between water transparency and pigment levels is complex (Figure 11), but a marked change in water transparency is observed over that part of the range of pigment concentrations of interest here.

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Acid rain effects on river catchments in north-west England

There is increasing concern that acid precipitation may have deleterious effects on some fresh waters in Britain. In England, the Lake District region in the north-west is receiving much attention. Here, the rainfall is high (1000–4000 mm yr^{-1}) and its pH is low – the mean value for 1978–79 was 4·4 (Nicholson *et al.* 1980). The geology of much of the area is dominated by volcanic rocks with low calcium buffering capacities. Consequently, fresh waters tend to be acidic and often contain high concentrations of aluminium – a metal which is toxic to fish (Driscoll *et al.* 1980).

The North West Water Authority (NWWA) is investigating the chemistry and biology at approximately 100 river and lake-side sampling points throughout the Lake District. About 50 of these points are on the Rivers Esk and Duddon or their tributaries (Plate 5). NWWA has already reported some of its findings (Prigg 1983). It has noted the absence of fish from stretches of river where it had expected to find some, and is also concerned about fish mortalities which have occurred in the Rivers Esk and Duddon in recent years, usually after periods of heavy rain.

The Freshwater Biological Association (FBA) is also studying the area (NERC 1983). Its studies of a number of freshwater tarns and lakes and of rainfall (Sutcliffe *et al.* 1982) have led it to conclude that there has been no evidence for acidification of the waters studied over recent years. Nevertheless, the FBA is continuing its studies, concentrating on high altitude lakes and tarns, which are more likely to be affected by acidification, and on the chemistry of aluminium and its complexes, which are particularly relevant to the toxic effects on fish.

A research project has been started, in collaboration with the above organizations and others working on similar topics in the UK, to explore several related avenues of research.

1. Water samples are being collected from many of the NWWA sampling points along the Rivers Esk and Duddon, with the assistance of NWWA staff. Analysing the samples for different soluble aluminium compounds will give some indication of the possible toxic effects of this metal on fish in these rivers, as some aluminium compounds are much more toxic to fish than others (Driscoll *et al.* 1980).

2. The acidity of precipitation is being studied, using rain collectors, with the aim of identifying acid deposition 'episodes' (Fowler & Cape in press) and relating these to the continuous pH monitoring records of the NWWA from the Rivers Esk and Duddon.

3. Sediments collected from tributaries of the Esk and Duddon are being analysed for a range of toxic metals, to determine if metals other than aluminium may affect the biology of these rivers.

4. Using computing methods previously applied to land classification studies in ITE (Bunce 1979), an attempt is being made to classify catchments, currently sampled by the NWWA, into different