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Chapter (non-refereed)

Bailey-Watts, A.E.; Kirika, A.A.. 1986 Amount of phosphorous entering Loch Leven. In: *Annual Report of the Institute of Terrestrial Ecology 1985/86.* NERC/ITE, 79-80.

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Harriman, R, Morrison, B R S, Caines, L A, Collen, P and Watt, A W. 1987. Long term changes in fish populations of acid streams and lochs in Galloway. *Water Air and Soil Pollut*, 32, 89–112.

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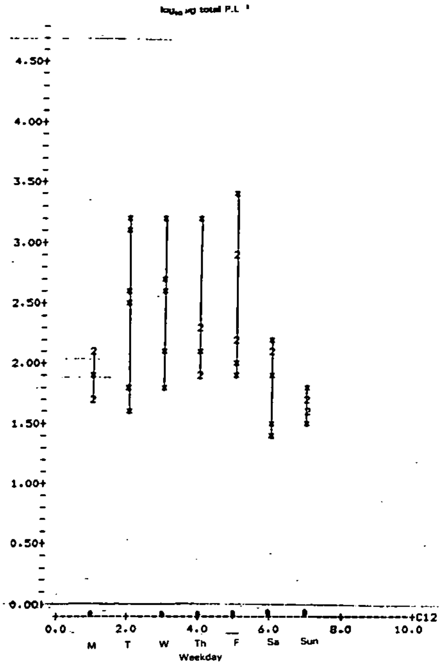

Figure 10. Total P concentrations ($\mu g\ l^{-1}$, plotted on log_{10} scale) on different days of the week from January to October 1985, in a major inflow to Loch Leven, which receives industrial effluent.

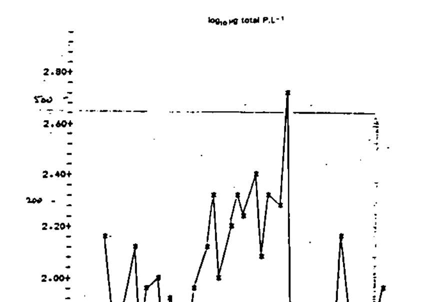

Figure 11. A comparison between total P concentrations ($\mu g\ l^{-1}$ plotted on log_{10} scale) above (Nc) and below (Na) an outfall of treated sewage on a major feeder stream to Loch Leven, January–October 1985.

Amount of Phosphorus Entering Loch Leven

Intensive ecological surveillance of Loch Leven, since the late 1960s, indicates that phosphorus (P) is of special importance in the eutrophication of the loch and to the growth of its plankton (Bailey-Watts 1979, 1981; Bailey-Watts *et al.* 1983). Recent interest in P levels has arisen because of a continuing deterioration in water quality of some of the inflows and of the loch itself. Concern over this trend has been expressed by official bodies, including the Nature Conservancy Council (NCC), which manages the loch as a National Nature Reserve, and the Forth River Purification Board (FRPB), which is responsible for water quality in the catchment of the loch, and by downstream industrial abstractors of water from the loch.

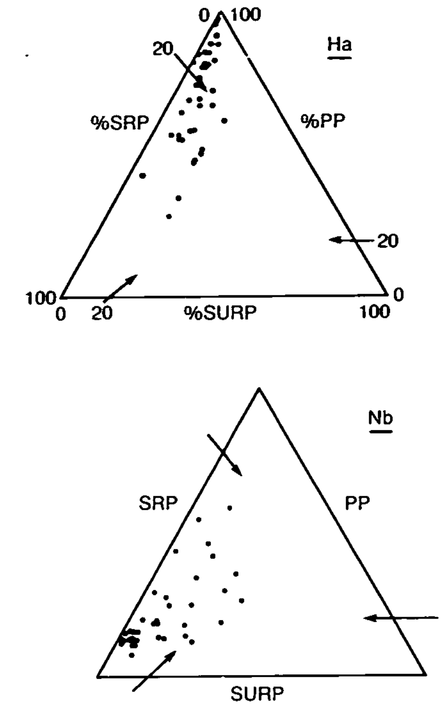

Figure 12. Triangular plots of contrasting proportions of soluble reactive P (SRP), soluble unreactive P (SURP), and particulate P (PP), in a small silty stream (Ha) and a major river affected by sewage effluent (Nb) flowing into Loch Leven.

As summarized by Bailey-Watts and Kirika (1984), the interest led to a desk study commissioned by NCC to assess (i) the likely current (then 1982–83) loading of P to the loch, (ii) the various contributions to the total input, and (iii) implications for their control. The study took account of analytical results from an earlier loading assessment made by the Department of Agriculture and Fisheries for Scotland (DAFS) (Holden 1976; Holden & Caines 1974, unpublished data to 1978), and information on nutrient content, obtained by ITE between 1980 and 1983. The exercise concluded that, whilst point sources continued to contribute the major part of the total loading (as found by the earlier study), new measurements were necessary to establish the actual quantities currently involved. First, the sewer-served population in the loch catchment had increased, giving a higher input from sewage treatment works. Second, recent analyses of a major feeder stream receiving P-rich industrial effluent indicated that the input from this source had increased considerably since the late 1970s. Third, P inputs in rain falling directly on the loch surface were likely to be lower than originally thought. Fourth, more data were needed to estimate the more diffuse sources of P, such as in runoff from agricultural land and in wildfowl faeces. Each of these aspects is now being studied in a new project funded by DAFS, NCC, the Scottish Development Department and the Tayside Regional Council (with a grant from the Commission of European Communities). The major part of the work involves sampling all inflows to the loch, as well as the loch itself, at 8-day intervals throughout a calendar year (Bailey-Watts & Kirika 1987). An 8-day schedule was adopted because it was suspected that some water courses receive effluent whose chemistry varies with day of the week. This suspicion is justified by results from a major inflow receiving industrial P waste (Figure 10); concentrations of P were considerably higher on Tuesdays to Fridays than on other days, especially Sundays. The impact of effluent from sewage treatment works on P levels in another river was also considerable. Figure 11 shows that, despite dilution of effluent by the river, the concentrations downstream of the discharge were very much greater than 'background' levels upstream.

The above examples refer to total P, but our analyses also take account of the particulate and dissolved fractions. The proportions of particulate P, soluble reactive P, and soluble unreactive P vary seasonally within a stream and between different streams. Figure 12 contrasts a small stream (Ha), rich in particulates from road drainage, with a larger river (Nb), which is relatively richer in dissolved P from treated sewage.

Although P is the main focus of the study, water from the mouths of various streams was also analyzed for levels of nitrate and dissolved silica. The programme is integrated with FRPB work defining the height-discharge characteristics of the inflows, so that nutrient concentrations can be converted to loadings (ie the products of flow and concentration) by relating continuous and spot recordings of river heights to chemical concentrations. As well as the seasonal surveillance, a number of intensive 24-hour studies are being made to assess variations between night and day. Other sub-projects focus on external inputs of P in (i) rainwater, (ii) wildfowl faeces, and

(iii) selected agricultural areas, and on internal source P, namely that derived by recycling of the nutrient from the sediments of the loch itself.

A E Bailey-Watts and A Kirika

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Rehabilitation of Disturbed Ecosystems

Creating Attractive Grasslands

(This work is supported by Nature Conservancy Council funds)

Much of the stimulus for research on the creation of plant communities has come from the need to restore or revegetate areas of derelict land left by mining and quarrying industries in the developed countries, notably in Britain, America and Australia. A recent review (Bradshaw & Chadwick 1980) gives an account of progress in this particular area of research, where special problems, such as extremes of temperature, acidity and alkalinity, high salinity and metal toxicities, or shortage of water and nutrients, have been encountered. Much less attention has been given to establishing grasslands which contain a range of colourful forbs on land where extremes of soil and water conditions do not prevail.

It has been estimated by the Nature Conservancy Council (Anon 1984) that 95% of all lowland herb-rich grassland and about 80% of lowland chalk and limestone grasslands have been destroyed since 1949, largely by conversion to arable land. While the defence of the best remaining areas of grassland is clearly a primary objective of nature conservation, it is nonetheless now appreciated that grasslands and meadows created by sowing mixtures of grasses and dicotyledons may have an important role in conserving wildlife in the countryside as a whole.

Opportunities for creating attractive grasslands are widespread. They occur when new verges are made on motorways or trunk roads; in urban areas in new towns, such as Milton Keynes, Peterborough and Warrington; in newly created Country Parks; in the grounds of schools and colleges, where the functional use of grass may be combined with an educative role; on the banks and surrounds of public reservoirs and on newly made farm reservoirs; on farms and estates where the owners or tenants wish to create a more attractive environment and to encourage wildlife.

Methods Available for Establishing Attractive Grasslands

In theory, there are 5 ways in which grasslands can be established incorporating wild flowers and native grasses:

1. by natural colonization of bare soil from local or nearby seed sources;
2. by spreading top soil containing the seed of grassland species;
3. by transplanting turf from species-rich grassland which overlies areas that are to be destroyed by quarrying or road-making;
4. by sowing grass/herb mixtures into prepared seed beds;
5. by diversifying established swards, using either the slot-seeding technique, or inserting pot-grown plants with a bulb planter.

In practice, methods (1), (2) and (3) have a number of undesirable features which ensure that they are rarely used, or considered for use, except in special circumstances. Natural colonization depends on the ability of propagules to reach a site. As semi-natural habitats become increasingly fragmented and dispersed, the probability of seed arriving at a site becomes low, even for those species with an effective means of dispersal, seeds of many grassland species have no dispersal mechanism and are shed within one metre of the mother plants, so the probability of their reaching sites miles away is very small. Natural colonization is a slow process, and the engineer and landscape architect often require a vegetation cover quickly. Spreading top soil in the hope that it contains the seeds of grassland species is not acceptable, as experience has shown that the seed bank consists mostly of weeds of arable land, particularly members of the Polygonaceae, Cruciferae and Compositae. Furthermore, top soil is a variable commodity, and it is extremely difficult to determine or predict the type of vegetation that will result when it is spread and not seeded.

Turf transplants, obtained by stripping the turf from areas before they are quarried, have been used successfully to revegetate restored land after quarrying (Gilbert & Wathern 1980). This method does not increase the area of grassland, but does save a valuable resource and is to be encouraged, although the area of land involved is very small.

The principal means of establishing grass/wild flower mixtures is either by sowing seed mixtures into prepared seed beds, or by diversifying existing grasslands. Some results from experiments to investigate these methods in more detail are discussed below.

Establishment of Grass/Herb Mixtures From Seed

The following are the main requirements for successful establishment from seed.

i) **Careful selection of species suitable for the ecological conditions of the site.** The mixtures suggested by Wells *et al.* (1981) for clay, chalk and alluvial soils provide a guide as to the most suitable species for those soil types. Criteria used in selecting species for inclusion in these mixtures are given in Table 4.

ii) **A weed-free seed bed.** It is essential that perennial weeds such as common couch (*Agropyron repens*), docks (*Rumex*, spp.) and common nettle (*Urtica dioica*) are killed before sowing by using a herbicide, such as glyphosate, according to the manufacturer's instructions.

Table 4. Some criteria used for selecting species for inclusion in wild flower seed mixtures

1. Ecologically suitable for particular soil/water conditions
2. Common grassland species
3. Not rare or locally distributed
4. Preferably perennial and long-lived
5. With colourful and attractive flowers
6. Attractive to insects as nectar or pollen sources
7. Not highly competitive or invasive
8. Seed germinates easily over a range of temperatures