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Phosphates in freshwater

Standards for nature conservation

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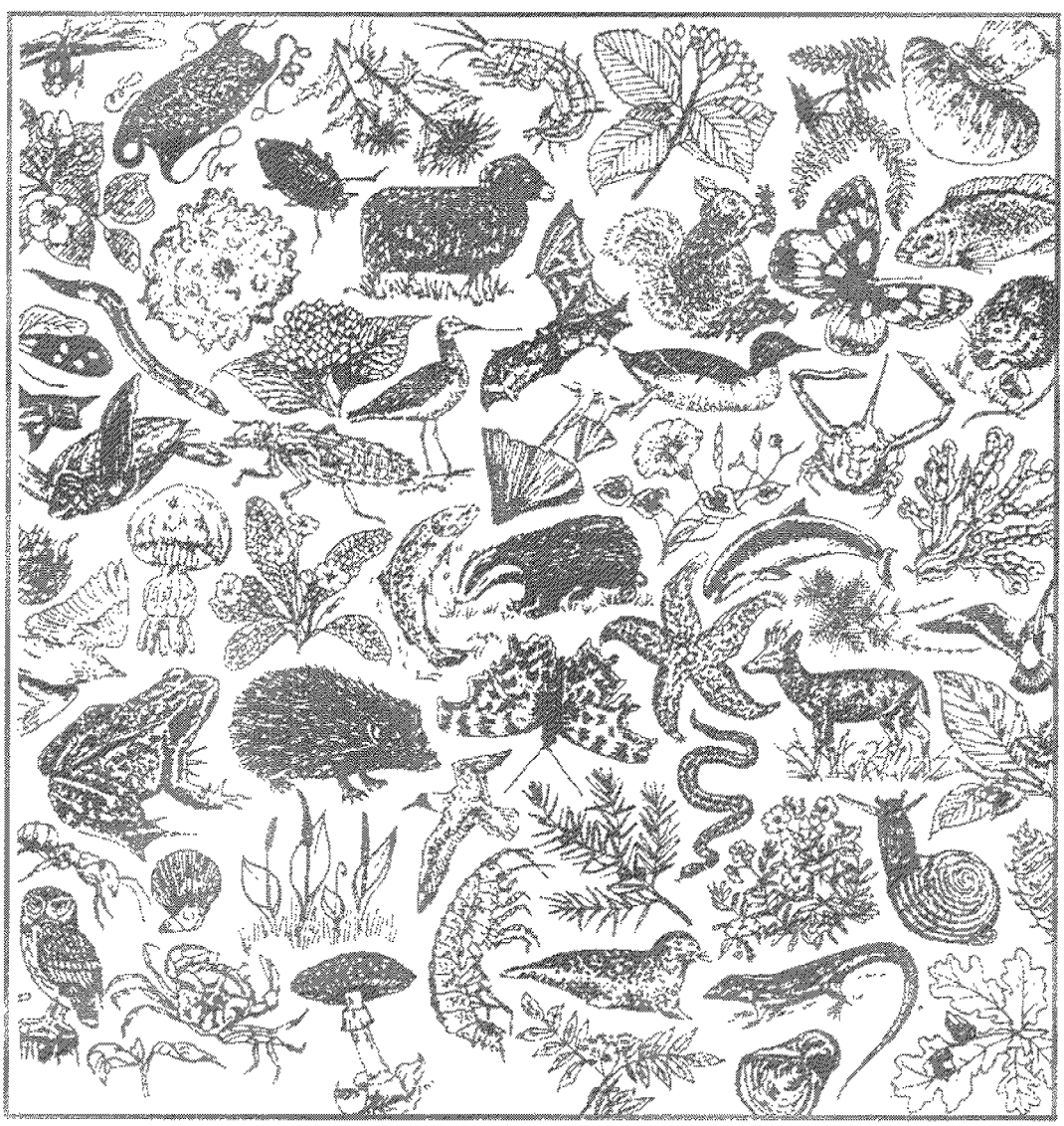

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No 73

Phosphates in Freshwater

Standards for Nature Conservation

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EXECUTIVE SUMMARY

The Department of the Environment is in the process of drawing up Statutory Water Quality Objectives and compliance measures for controlled waters in England and Wales, under Sections 82 and 83 of the Water Resources Act 1991. Six Use-Related Classes have been identified, including a Special Ecosystem Use Class that would aim to maintain or improve the quality of rivers or riverine sites of the highest ecological importance (including Sites of Special Scientific Interest). English Nature has produced proposals for a series of water quality criteria based upon a range of values of orthophosphate and ammonia concentrations and Biochemical Oxygen Demand, for the Special Ecosystem Use Class. It is envisaged that these criteria would be applied on a case-by-case basis to protect the specific nature of the river and its ecology, over and above the protection to be afforded by the Fisheries Ecosystem Use Class. WRc was commissioned to investigate the technical evidence that would support the application of the proposed phosphorus criteria, specifically in relation to riverine macrophyte interest, and to identify any further research required.

It has been concluded that the single most suitable phosphorus parameter for water quality criteria in this context is orthophosphate, in the form of Soluble Reactive Phosphorus (SRP). SRP criteria should be applied as a "growing season" mean and an annual mean, and failure to comply with either should constitute non-compliance.

A review of relevant literature revealed that few comprehensive studies have been undertaken to link macrophyte community status to specific riverine levels of phosphorus. However, the findings of a number of studies would support the imposition of criteria of the order of the Class 1 (annual mean of 0.02 mg l^{-1} SRP) and Class 2 (0.06 mg l-1 SRP) values proposed by English Nature. Some work suggests that a more stringent criterion of 0.01 mg l^{-1} SRP may be appropriate for ultra-oligotrophic rivers. It is suggested that the Class 3 criterion (0.11 mg l^{-1} SRP) is brought into line with the DoE definition of "sensitive waters" under the EC Urban Waste Water Treatment Directive (0.1 mg l^{-1} SRP). No changes are suggested to the Class 4 (0.2 mg l^{-1} SRP) and Class 5 (1.0 mg l^{-1} SRP) critera proposed, as there is little ecological information available to support or refute their position; however, they can be supported on the basis that they provide useful "stepping stones" on the way to a desirable trophic status for highly enriched "Special Ecosystem" rivers.

An analysis of historical data revealed a large amount of spatial and temporal incompatibility between macrophyte data collected by English Nature and a database of SRP data collated from National Rivers Authority archives. The exercise highlighted the need for a coordinated approach to monitoring in order to maximise the benefits to both parties. Temporal and spatial comparisons worthy of further examination have been identified and the required information outlined.

It is recommended that, owing to the limited information available on the effect of phosphorus on specific riverine macrophyte communities and species, the proposed SRP criteria are applied to SSSIs and pSSSIs on the basis of water quality history, with a view to maintaining concentrations at, or restoring them to, natural or pre-cultural levels. Implicit in this approach is that

macrophyte interest exists in riverine SSSIs and pSSSIs with greatly elevated phosphorus levels **despite** the hypereutrophic conditions, not because of them. It is not known whether the special interest at such sites is sustainable in the long term at such high nutrient concentrations, or whether effects as yet undocumented are occurring, within either the macrophyte community or the ecosystem as a whole. Such a precautionary approach can be justified on the basis that the waters in question are of high ecological importance and represent only a small proportion of the total river length.

Trend analysis of historical water quality data should be undertaken for the rivers in question, in order to identify where increases in SRP concentrations have occurred. Where a significant positive trend in SRP is detected, the water quality criteria should be set to coincide with the SRP concentration at the beginning of the time series. Indirect evidence for increases in phosphorus concentrations should also be considered, in order to try and identify background phosphorus levels. Methods that could possibly be used include: the derivation of empirical relationships between catchment characteristics and phosphorus loadings/concentrations; comparison of nutrient concentrations between similar rivers; estimation of historical catchment loadings; and sedimentary diatom frustule analysis. However, it is recognised that such methods are likely to require further development. Where no increase in SRP concentrations can be detected and none is suspected, the criteria should be set to coincide with current SRP levels (allowing for between-year variability).

For SSSI and pSSSI rivers with mean SRP concentrations greater than 0.2 mg l^{-1}, it is recommended that the target level should be at least Class 4 (0.2 mg l^{-1}). Class 4 still represents a trophic state above that likely to be natural for any UK river, and is therefore not unreasonable as a minimum target for sites of special conservation interest. Such a move is likely to increase the diversity of the macrophyte community through the reduced competitiveness of species that tend to dominate at elevated phosphorus levels. Where large reductions in SRP are required, intermediate "milestones" may be necessary to show progress towards the target level.

A minimum sampling regime should be agreed with the NRA for monitoring phosphorus within designated (SSSIs and pSSSIs) river stretches. This should formalise both the temporal and spatial sampling frequency and the Limit of Detection. It is recommended that a frequency of at least one sample per month is specified, with a Limit of Detection of 0.002 mg l^{-1} that may be relaxed outside of Class 1 (ie target level of 0.02 mg l^{-1}) waters. In rivers where a major reduction in SRP is deemed to be required, occasional monitoring of sedimentary phosphorus (interstitial water and sediment-bound fractions) should also be undertaken to assess changes in sediment quality. It is recommended that a regular (annual or biennial) joint review of water quality status, trends and compliance within SSSIs and pSSSIs is undertaken by English Nature and the NRA.

A programme of focused and planned field monitoring should be undertaken to relate changes in macrophyte communities, on both temporal and spatial bases, to differences in environmental phosphorus levels (in both the water column and the sediment). Collaboration between English Nature and the NRA should be

maximised so that duplication of effort is avoided. A standardised macrophyte survey methodology aimed at detecting the effects of phosphorus should be agreed in order to maximise the compatibility of survey data.

A number of research areas have been identified, including: analysis of data arising out of the monitoring programme proposed above; investigations into techniques to determine background riverine SRP levels; further collation and analysis of historical data; modelling of phosphorus dynamics in rivers; the development of sedimentary phosphorus standards; and a review of Michaelis-Menten half-saturation coefficients for nuisance riverine plant species.

1. INTRODUCTION

The Water Act 1989 provided the Secretary of State with powers to introduce a water quality classification and to set Water Quality Objectives (WQOs) for controlled waters. These powers are now contained in Sections 82 and 83 of the Water Resources Act 1991. During the passage of the original legislation through parliament, the Government undertook to include nature conservation criteria in the classification.

The Nature Conservancy Council and others have expressed concern in recent years about the damage caused to aquatic ecosystems by artificially raised nutrient levels. The sixteenth report of the Royal Commission on Environmental Pollution on Freshwater Quality (RCEP 1992) highlights the problems of eutrophication. It recommends that the long-term target for nutrient levels in flowing and standing waters should be the trophic state prior to significant enrichment from human activities, where this can be identified. It also states that the enrichment of nutrient-poor waters of conservation value should be avoided.

English Nature commissioned an analysis of water quality data on 90 rivers, covering the period 1980-1990 (Garland 1991). Of 13 parameters analysed, orthophosphate showed a significant upward trend at 39% of monitoring stations. English Nature has undertaken a further analysis of water quality data for 1990 and 1991 on designated and proposed riverine Sites of Special Scientific Interest. From this a classification has been developed for rivers, in consultation with the Countryside Council of Wales and the Joint Nature Conservation Committee, using target orthophosphate levels.

The National Rivers Authority has proposed a framework for monitoring the quality of controlled waters, involving a system of 6 Use Classifications, relating to 6 Use-Related Classes (URCs), and a General Quality Assessment scheme (NRA 1992). It is intended that the Use Classifications are used to assess compliance with Water Quality Objectives (which will vary between sites), whilst the General Quality Assessment will provide an absolute measure of quality that is comparable between sites. Of the 6 URCs, a Fisheries Ecosystem Class would probably apply to all rivers, whilst a Special Ecosystem Class would apply to SSSIs and perhaps other rivers or river stretches of high conservation value. English Nature has produced proposals for the Special Ecosystem Class covering Biochemical Oxygen Demand, ammoniacal nitrogen and orthophosphate (as Soluble Reactive Phosphate, SRP), as outlined in Table 1.1.

In parallel with the introduction of WQOs, the EC Directive on Waste Water Treatment (CEC 1991) is being implemented. The aim of the directive is to control the input of nutrients to freshwaters, estuaries and coastal waters. In the UK, the requirement for secondary treatment on all major sewage discharges will have a great effect on coastal sewage discharges, of which many receive little or no treatment. In addition to this requirement, there are provisions for the removal of phosphates and/or nitrates from sewage discharges affecting "sensitive areas". The target levels for these areas are set on the discharge (2 mg l^{-1} for Total Phosphorus) rather than the receiving water. English Nature has identified 102 SSSIs subject to eutrophication. However, it is unlikely that many of these will be listed as "sensitive areas", because of the exclusion of sewage treatment works serving less than 10,000 people.

A Government discussion document (DoE/MAFF/WO 1992) considered factors which should be taken into account when identifying areas subject to eutrophication under the directive. A tentative guide level of 0.1 mg l^{-1} orthophosphate (as SRP) as an annual average was put forward for rivers, and 0.05 mg l^{-1} Total Phosphorus for lakes. English Nature commented that a single guide level for each was not appropriate, since undesirable changes in plant and animal communities could occur at lower levels in naturally nutrient-poor waters. Equally, levels in lowland rivers with certain substrates could be higher than 0.1 mg l^{-1} without apparent adverse effects on plant communities.

The present study was commissioned in order to review the current state of knowledge on the relationship between phosphorus and aquatic plants under different environmental conditions, with particular reference to flowing waters. This was intended to provide a better basis for judging the suitability of any proposed standards, including the target levels proposed by English Nature. A further aim of the study was to identify shortcomings in current knowledge in this area and suggest how improvements in water quality could be expected to influence macrophyte communities. This latter information would be helpful in evaluating the benefits of reduced phosphorus levels and in the design of subsequent monitoring programmes.

The five objectives of the project were as follows:

i) to briefly review the forms of phosphate in freshwater and their availability for water plant growth;

ii) to carry out a review of published data for information on the effects of phosphate forms on freshwater macrophyte species and communities;

iii) to consider the nature of the relationship between water quality from the 28 existing or proposed river SSSIs and the known macrophyte distribution;

iv) to use the information produced in (i) and (ii) above to indicate if EN's proposal could be strengthened or if any major modification is required;

v) to indicate the levels of the three key determinands (phosphate, ammonia and BOD) which could lead to improvement or deterioration of particular macrophyte communities.

This report describes all work undertaken during the project and discusses the implications of the findings in the context of setting phosphorus standards to protect macrophyte interest.

The levels of nutrients in the substrate and water column are only two of a variety of often interrelated factors that influence the distribution of plants in rivers and lakes. Pearsall (1920) regarded substrate and depth to be the most important factors controlling macrophytes in the Lake District. Other authors (Spence 1967, Seddon 1972) considered water chemistry to be important and discussed the significance of alkalinity, pH, conductivity and the ratio of certain determinands (calcium and magnesium to sodium and potassium) in influencing macrophyte distribution. In studies of soft-water and often

Table 1.1 Water quality criteria proposed by English Nature for the Special Ecosystem Use Class.

Class	BOD (ATU) mgl^{-1} as 90%ile	Total ammonia mgl^{-1} as 90%ile	Orthosphate mgl^{-1} SRP as annual mean	Class description
1	1.5	0.06	0.02	Unpolluted oligotrophic rivers with plant communities dominated by lower plants (mosses and liverworts). Characteristic higher plants include shoreweed, bog pondweed, bulbous rush and floating club-rush.
2	2.0	0.13	0.06	Oligotrophic/mesotrophic rivers on hard substrate. Typical mosses and liverwort are *Rhynchostegium riparíodes* and *Chilyschisus polyanthos*, but there are increasing numbers of higher plants, including water horsetail and alternate water milfoil. Unpolluted chalk and limestone rivers, where plant communities are often dominated by river crowfoot, also fall into this category.
3	2.5	0.20	0.11	Chalk and sandstone rivers, where higher plants are dominant. These will includ crowfoots, water cress, broad-leaved and shining pondweeds.
4	3.2	0.34	0.20	Lowland rivers on clay, larger sandstone rivers and alluvial sections of chalk rivers. Plant communities have greater numbers of emergent species, such as branched bur-reed, narrow-leaved water parsnip and pondweeds (fennel-leaved and perfoliate).
5	4.0	0.60	1.00	Polluted lowland rivers, often alluvial, with an enriched substrate. Emergent species, such as common club-rush, great reedmace, reed sweet-grass and common reed are more dominant, with floating plants such as curled pondweed and yellow water lily. Blanketweeds and duckweeds are often invasive. On more grossly enriched rivers, above 1.5 mgl^{-1} orthophosphate (as SRP), blanketweeds are a major component of a community dominated by pollution-tolerant species such as horned pondweed.

acidified streams, the pH of river water was found to strongly influence assemblages of plants (Ormerod *et al.* 1987). Holmes and Newbold (1984) concluded that river plant communities reflect both substrate and water chemistry. Irradiance has also been found to be a major factor in determining the natural distribution of submerged aquatic plant species (eg Dawson and Kern-Hansen 1979, Chambers and Kalff 1987). An important point to remember is that conclusions about keys factors in any study will depend upon the range of values encountered in the study area for each influencing variable. Only when other influencing environmental variables change minimally are the true effects of phosphorus likely to be discerned with reasonable certainty.

Macrophytes can be defined as any plant form above and including filamentous algae. In this review, the macrophytes considered include mosses but only algal species of possible (positive) conservation interest; this being the case, nuisance algal species such as *Cladophora* and *Enteromorpha* are largely omitted from discussions, except where their growth is likely to interfere with macrophytes of conservation importance through competitive interactions.