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Chlorophyll-*a* in the rivers of eastern England

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Abstract

Chlorophyll-*a* concentration variations are described for two major river basins in England, the Humber and the Thames and related to catchment characteristics and nutrient concentrations across a range of rural, agricultural and urban/industrial settings. For all the rivers there are strong seasonal variations, with concentrations peaking in the spring and summer time when biological activity is at its highest. However, there are large variations in the magnitude of the seasonal effects across the rivers. For the spring–summer low-flow periods, average concentrations of chlorophyll-*a* correlate with soluble reactive phosphorus (SRP). Chlorophyll-*a* is also correlated with particulate nitrogen (PN), organic carbon (POC) and suspended sediments. However, the strongest relationships are with catchment area and flow, where two straight line relationships are observed. The results indicate the importance of residence times for determining planktonic growth within the rivers. This is also indicated by the lack of chlorophyll-*a* response to lowering of SRP concentrations in several of the rivers in the area due to phosphorus stripping of effluents at major sewage treatment works. A key control on chlorophyll-*a* concentration may be the input of canal and reservoir waters during the growing period: this too relates to issues of residence times. However, there may well be a complex series of factors influencing residence time across the catchments due to features such as inhomogeneous flow within the catchments, a fractal distribution of stream channels that leads to a distribution of residence times and differences in planktonic inoculation sources. Industrial pollution on the Aire and Calder seems to have affected the relationship of chlorophyll-*a* with PN and POC. The results are discussed in relation to the Water Framework Directive.

Keywords: Chlorophyll; Rivers; Nutrients; Nitrate; Particulate nitrogen; Organic carbon; Phosphate; Silica; Sediments; Aire; Calder; Don; Humber; Kennet; Lambourn; Pang; Thames; Trent; LOCAR; LOIS; RELU; Water framework directive

1. Introduction

In the UK, rivers are of major importance in relation to social, economic and environmental factors. The larger UK rivers, especially within the lowland areas, often have catchments with high urban populations and intensive agriculture. Urban and agricultural pollution by nitrogen and phosphorus (nitrate and phosphate in particular) is of major concern for lowland UK rivers (and lakes) with regards to eutrophication (Defra, 2004; Withers and Lord, 2002; Mainstone and Parr, 2002). The issue of eutrophication represents a major challenge to the environmental management of lowland UK rivers. This challenge is set across Europe within the context of the wide ranging Water Framework Directive (WFD: Council of European Communities, 2000) with its emphasis on improving the ecological status of European surface waters. The WFD entered into force in 2000 with a series of goals targeted to 2015 with

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requirements to meet the environmental objectives of "good ecological status" and "good chemical status", covering a wide range of chemicals harmful to the aquatic environment. The issue of reducing nutrient pollution in lowland UK rivers has implications not just in terms of maintaining and improving riverine ecology, but there are major socio-economic constraints (Dwyer et al., 2002; Pretty et al., 2003). The aims of the WFD are wider than those simply relating to eutrophication, but the issues are interactive within the context of improving our aquatic environment.

There has been good foundational work on the hydroecology of river plankton (Reynolds, 2000) and the importance of residence time has been demonstrated (Søballe and Kimmel, 1987). Phytoplankton concentrations are not only controlled by residence times but also other factors such as channel retention, aggregation of dead zones and the distribution and timing of discharge velocities and channel length are important (Reynolds, 2000). However, as Reynolds (2000) points out 'Whereas the ecology of lacustrine plankton has absorbed the investigative energies of aquatic biologists for more than a century, its fluvial counterpart (potamoplankton) has received only sporadic attention'. Recently, Hilton et al. (2006-this volume) hypothesised that, short-retention-time rivers respond to increasing nutrients by increased growth of benthic and epiphytic algae, whereas long-retention-time rivers are dominated by phytoplankton. As a result they concluded that in UK lowland rivers, which are generally saturated with nutrients, the growth of phytoplankton will be controlled by the size of the phytoplankton inoculum in the upper reaches of the river and the time of travel (retention time) to reach a particular sampling point in a catchment (cf. review by Hilton et al., 2006-this volume).

In this paper, information on chlorophyll-*a* in rivers forming part of two major basins in eastern England is examined to test this hypothesised relationship between phytoplankton inoculum size, retention time and phytoplankton biomass in rivers. One of these basins, the Humber, provides a major source of UK contaminants to the economically important but ecologically vulnerable North Sea (Jarvie et al., 1997). The other basin, the Thames, covers one of the major lowland agricultural areas of the UK. For the Thames Basin, population density is high and there are major social pressures for urban redistribution and 'invasion' of green belt areas. These pressures can lead to substantial issues of the maintenance of good river water quality in response to pressures for increased water use (abstractions) and increased pollution from additional sewage burdens (Evans et al., 2003). The work brings together substantial material collected as part of the Land Ocean Interaction Study (LOIS: Leeks and Jarvie, 1998) and studies by the Centre of Ecology and Hydrology for the upper Thames area (Neal and Jarvie, 2005). A key feature of the work is that it deals with a national system of critical catchment typologies (rural, agricultural and urban/industrial systems) that are interlinked over a relatively small area compared, for example, to global river systems. The UK river systems in many cases have lake/reservoirs that are important in maintaining base flows. In other cases there is an interchange of waters between rivers and nearby canals. These features are important because the lake/reservoir/canal sources of water are of particular significance during low flow periods when dilution potential of nutrients is lowest, biological activity is at its highest and eutrophication risk is at its greatest. The combination of important typologies over a small area, the different types of water sourcing during low flows and a good and extensive water quality database for UK rivers, provides a case study of relevance not just to the UK but to the wider international research community and contributes to the assessment of the key factors and processes controlling water chemistry in the freshwaters of Europe (Wade, 2006-this volume). Further, there are key issues of nutrient limitation for many of the rivers dealt with in this study (Jarvie et al., 1998, 2002). The research is also of importance to the issues of sustainability of UK farming within the Rural Economy Land Use programme (RELU: www.relu.ac.uk) and to the development of environmental science for UK rivers within a socioeconomic framework.

2. Study area and data resource

The study area comprises the rivers and their tributaries of two major UK basins, the Humber in the north-east and the upper Thames in the south-east of England (Fig. 1). The locations, general water quality, land use, geology and monitoring duration for these two basins have been covered in numerous earlier publications (cf. summaries of Neal and Robson, 2000; Neal and Jarvie, 2005), and here only the salient features need description. The data comprises research within the LOIS programme of 1993–1997 (Leeks and Jarvie, 1998) and the CEH Wallingford lowland research programme 1997 to present (Neal and Jarvie, 2005) including studies within the UK Lowland Catchment Research programme (LOCAR; Neal et al., 2004). Davies and Neal (2004, in press) consider nutrient distributions within a GIS framework and with linkages