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A spatial and seasonal assessment of river water chemistry across North West England

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ABSTRACT

This paper presents information on the spatial and seasonal patterns of river water chemistry at approximately 800 sites in North West England based on data from the Environment Agency regional monitoring programme. Within a GIS framework, the linkages between average water chemistry (pH, sulphate, base cations, nutrients and metals) catchment characteristics (topography, land cover, soil hydrology, base flow index and geology), rainfall, deposition chemistry and geo-spatial information on discharge consents (point sources) are examined. Water quality maps reveal that there is a clear distinction between the uplands and lowlands. Upland waters are acidic and have low concentrations of base cations, explained by background geological sources and land cover. Localised high concentrations of metals occur in areas of the Cumbrian Fells which are subjected to mining effluent inputs. Nutrient concentrations are low in the uplands with the exception sites receiving effluent inputs from rural point sources. In the lowlands, both past and present human activities have a major impact on river water chemistry, especially in the urban and industrial heartlands of Greater Manchester, south Lancashire and Merseyside. Over 40% of the sites have average orthophosphate concentrations >0.1 mg-P l^{-1}. Results suggest that the dominant control on orthophosphate concentrations is point source contributions from sewage effluent inputs. Diffuse agricultural sources are also important, although this influence is masked by the impact of point sources. Average nitrate concentrations are linked to the coverage of arable land, although sewage effluent inputs have a significant effect on nitrate concentrations. Metal concentrations in the lowlands are linked to diffuse and point sources. The study demonstrates that point sources, as well as diffuse sources, need to be considered when targeting measures for the effective reduction in river nutrient concentrations. This issue is clearly important with regards to the European Union Water Framework Directive, eutrophication and river water quality.

1. Introduction

River water chemistry is determined by the interactions between soils and underlying geology, topographic features, rainfall and atmospheric inputs, anthropogenic sources (e.g. agricultural runoff and effluent discharges) and catchment hydrology (Billett et al., 1996; Robson and Neal, 1997; Smart et al., 1998; Cooper et al., 2000; Jarvie et al., 2002; Daly et al., 2002; Buck et al., 2004). Within a Geographical Information System (GIS) framework, spatial datasets, such as land use and geology, have been used to explore the controls on river water quality in a variety of environments and across a range of scales. The catchment characteristic approach has been used within the context of surface water acidification (e.g. Kernan et al., 1998; Thornton and Dise, 1998; Cooper et al., 2004; Cresser et al., 2006; Evans et al., 2006), nutrient transfers through river basins (Ekholm et al., 2000; Ferrier et al., 2001; Daly et al., 2002; Donohue et al., 2005; Jarvie et al., 2002; Davies and Neal, 2004, 2007; Evans et al., 2006; Meynendonckx et al., 2006; Helliwell et al., 2007) and sediment dynamics in fluvial systems (e.g. Siakeu et al., 2004; Takagi et al., 2007; Hashimoto et al., 2008).

Understanding the relationships between catchment characteristics and river water chemistry provides a base for determining how future changes in land use and climate will impact on river water quality and functioning (Robson and Neal, 1997; Jarvie et al., 2002). Therefore, it is important to determine the processes that regulate stream water chemistry in landscapes under increasing pressure from human population, whether from urbanisation or more intensive food production. This understanding will help underpin environmental management, especially in the context of meeting the hydrochemical and ecological goals of the European Union Water Framework Directive (WFD) (European Community, 2000).

Within the UK, considerable amounts of water quality data have been and are continuing to be collected by environmental regulatory bodies, such as the Environment Agency of England and Wales and the

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Scottish Environment Protection Agency. Water quality datasets held by these bodies have been used to explore controls on stream water chemistry for some major UK river basins, such as the Humber and the Tweed (e.g. Neal et al., 1997; Robson and Neal, 1997; Jarvie et al., 2000; Oguchi et al., 2000; Jarvie et al., 2002). However, there is paucity of information on the variability in river water chemistry in relation to catchment characteristics for many UK rivers.

Here we examine one critical area based on the industrial and urban conurbations/heartlands of the North West of England and the major rivers draining this area entering the Irish Sea. The rivers of this region are subjected to numerous pressures including point and diffuse pollution. The importance of this area is recognised for example with the River Ribble which provided a key typology for a European Union river basin network designed to test the WFD implementation guidelines (Fox et al., 2004; EA, 2009a). This paper builds upon the water quality mapping approaches used by Robson and Neal (1997) and Oguchi et al. (2000) to explore the spatial distribution of river water chemistry across the North West region using Environment Agency water quality data. The methods employed by Thornton and Dise (1998), Jarvie et al. (2002) and Davies and Neal (2004, 2007) are used to explore empirical relationships between a wide range of catchment characteristics and average river water chemistry (acidity and base cations, nutrients and metals). This is extended by GIS-based analysis of geo-spatial information on Environment Agency consented discharges from point sources and examination of seasonal water chemistry data. We address three key questions in this paper:

1. Are there regional patterns in river water chemistry?
2. Are there linkages between river water chemistry and catchment characteristics?
3. What are the major sources of acidity, base cations, nutrients and metals?

2. Study area

The North West of England (Fig. 1A) is one of the UK's most varied regions, with the rural upland landscapes of the north, to the populated lowland centres of the south (Fig. 1B). The region has a variety of land use types including intensive agriculture on the Lancashire plain, open moorland in Cumbria and heavily urbanised and industrial areas of

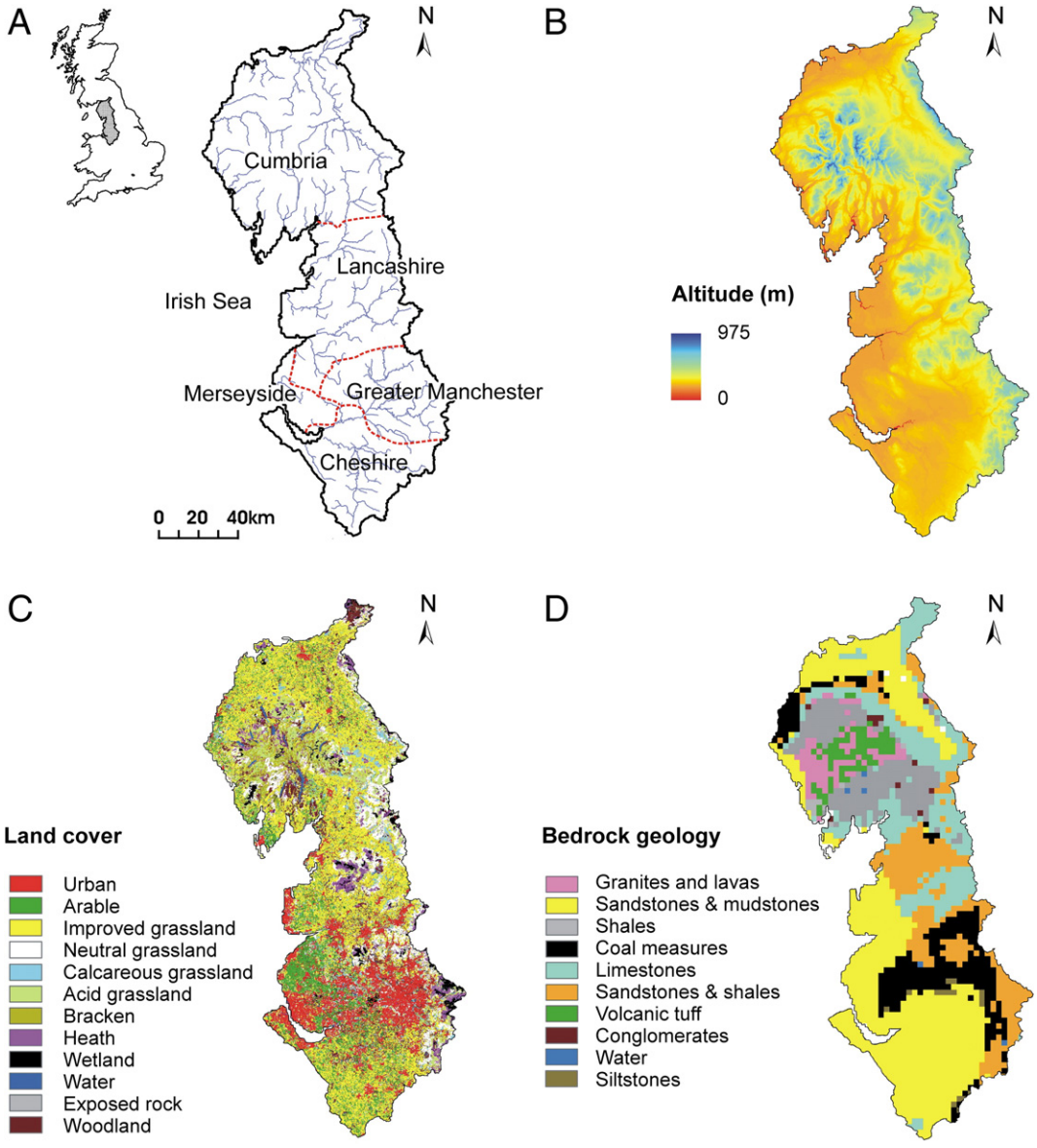

Fig. 1. North West study area showing major rivers (A); altitude (B); land cover (C); bedrock geology (D).