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Optimizing agri-environment schemes to improve river health and conservation value

Alison E. Poole[a], David Bradley[b], Rosie Salazar[a], David W. Macdonald[a,*]

[a] Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney House, Abingdon Road, Tubney, Abingdon OX13 5QL, UK

[b] APEM Limited, Riverview, A17 Embankment Business Park, Heaton Mersey, Stockport SK4 3GN, UK

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ABSTRACT

Freshwater ecosystems deliver services that are crucial to human existence and well-being, yet, globally, their degradation has outpaced remedial management. Rivers can be subjected to a range of anthropogenic pressures and agricultural land use is one major cause of water pollution and habitat degradation in European rivers. The Water Framework Directive is a major legislative driver for good ecological status in Europe's rivers and in the UK; this has led to attempts to reduce the negative effects of agriculture on rivers through agri-environment schemes (AES). AES are funded from tax revenue and it is important that they are optimized to deliver measurable ecological improvements. The purpose of this paper is to assess the ecological effectiveness of AES in a lowland English river basin. We examined the effect of distance from river in optimizing AES for the biological heath and conservation value of rivers.

We used aquatic macroinvertebrates as indicators of river health and conservation value, to assess the effects of AES likely to improve river health (hereafter "AES river options"). This catchment in lowland England had a very high (over 80%) level of uptake of entry level AES, and facilitated a comparison between schemes that do or do not contain AES river options. The conservation value of macroinvertebrate communities and the proportion of macroinvertebrates intolerant of water pollution and sedimentation increased with high proportions of woodland within 100 m or 500 m of the river throughout the entire upstream catchment. High proportions of AES river options within the same distance were correlated with higher proportions of sediment-sensitive macroinvertebrates. We conclude that for improving biological quality or promoting the conservation value of river communities, AES will be optimized by preserving woodland within a 100–500 m buffer zone along the upstream length of the river.

1. Introduction

Freshwater ecosystems deliver services that are crucial to human existence and well-being (Oelkers et al., 2011; Pacini et al., 2012). On a global scale, however, the degradation of riverine ecosystems is increasing faster than attempts at remedial management (Gleick, 2003; Ormerod et al., 2010). The European Union has put in place the Water Framework Directive (WFD), with an aim to have all surface and groundwater bodies in Europe of "good" ecological status by 2015 (E.U., 2010). European rivers are subjected to range of anthropogenic pressures, including water pollution, flow modifications, geomorphological modifications and land use (Ormerod et al., 2010). Land use affects ecological quality through diffuse pollution and sedimentation (e.g. Allan, 2004; Foley et al., 2005), and by reducing temperature fluctuations (e.g. woodland, Franken et al., 2007). Agricultural land is a major source of diffuse water pollution in UK rivers (e.g. Davies et al., 2009), and this has led to attempts to reduce the negative effects of farming through agri-environment schemes (AES, Natural England, 2012). AES in England are administered by Natural England, the statutory nature conservation agency (Natural England, 2012). UK AES with potential effects on rivers (hereafter "river options") include buffer strips (e.g. Osborne and Kovacic, 1993), management for nitrogen run off (e.g. Withers and Lord, 2002), organic farming (e.g. Magbanua et al., 2010) and woodland conservation and restoration (Franken et al., 2007). UK AES are administered via payments to land managers and funded from tax revenue; it is, therefore, important that AES are optimized to deliver measurable ecological improvements. We believe that this cannot be determined without evaluating their effectiveness at improving the biological quality and conservation value of water bodies.

Examination of the effects of land use on rivers generally focuses on one or more of three spatial scales: reach, sub-catchment and

* Corresponding author.
E-mail addresses: david.macdonald@zoo.ox.ac.uk, bs8aep@hotmail.com (D.W. Macdonald).

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catchment. Reach scale studies (e.g. Arnaiz et al., 2011) examine the effects of land use at a local scale, immediately adjacent to a short stretch of the river. Sub-catchment scale studies (e.g. Allan et al., 1997) compare results from different sub-catchments within a catchment, while catchment level studies (e.g. Allan and Johnson, 1997) examine the effects of land use throughout the entire catchment. The effects of land use, including land uses commonly implemented as AES, have been extensively explored at the local (reach) scale. For example, Sweeney (1993) showed that woodland on a streamside in Pennsylvania, USA, greatly increased the diversity, growth rate, survivorship, adult size and fecundity of aquatic macroinvertebrates. Krutz et al. (2005) showed that vegetative filter strips can significantly reduce the amount of herbicide runoff at a local scale and Heathwaite et al. (1998) and Borin et al. (2005) showed that nitrogen, phosphorus and other pollutant runoff could be greatly reduced using grass buffer strips of varying widths. However, in order for mitigation measures to be cost-effective they must improve ecological quality at the reach and catchment scale: for this reason conservation practitioners advocate the concept of managing rivers as catchments (Verdonschot, 2000) and the WFD requires ecological status to be reported at the reach scale (E.U., 2010). It is therefore important to understand the relationship between catchment wide land use and ecological quality, in order to assess the effectiveness of current mitigation measures, such as AES. Studies incorporating two or all three scales typically do so by focussing on which factors have an influence at each spatial scale (e.g. Allan et al., 1997). At the reach scale distance from the river is often taken into account, by looking at land use a certain distance away. This is typically the riparian corridor (e.g. Arnaiz et al., 2011), or a buffer strip (e.g. Weigelhofer et al., 2012), beyond which lies agricultural land. Studies at the sub-catchment and catchment scale have typically included all land within the catchment or sub-catchment (e.g. Allan et al., 1997; Allan and Johnson, 1997; Aspinall and Pearson, 2000). One notable exception to this being Sponseller et al. (2001) who examined the influence of the river corridor in isolation from the rest of the catchment for the entire upstream catchment. Reach scale studies therefore assume that the effect of land use depends on distance. It is reasonable to assume the same assumption holds at the scale of catchments. The effect of filtration, for example, is expected to be influential at a large spatial scale (e.g. Krutz et al., 2005). Examining distance from the river has, to our knowledge, not been explored previously at the catchment scale, despite distance having been shown to be significant at the local scale.

In this study, we examined the biological quality and conservation value of riverine communities in the upper River Thames catchment in southern England, in areas with varying amounts of AES implementation. The study focussed on organic farming, deciduous woodland and other options such as those designed to reduce run-off as candidate “AES river options”, as these were thought to be the most likely to have a positive effect on ecological quality (e.g. Sweeney, 1993; Krutz et al., 2005; Weigelhofer et al., 2012; Natural England, 2012). For a full list of “AES river options” see Table 1. We used multiple aquatic macroinvertebrate indices to quantify the effects of different stressors on biological quality (organic pollution, sedimentation and flow modifications) and to measure conservation value of riverine communities. The upper River Thames catchment has a very high (over 80%) level of uptake of entry level AES, with some schemes containing river options and some not (Natural England, 2012), making it a good model in which to test the effects of implementing river options, over and above other AES, on ecological quality and river ecology.

Specifically, we asked which of the AES river options implemented at the catchment scale are likely to optimize the conservation value and biological quality of riverine communities, and what is the optimal distance from the river for AES? Our key objective was to evaluate which AES river options will optimize the biological quality and conservation value of rivers.

Table 1
English agri-environment schemes designed to promote river health (river options), different codes denote e.g. width of buffer and adjacent land use. Taken from Environmental stewardship handbooks available from Natural England, codes are those used by NE.

River option	Description
EJ5, OJ5, HJ5, OHJ5	Grassed areas to prevent run off
EE9, EJ9, OE9, OJ9, HJ9, OHE9, OHJ9, EE10, OE10, OHE10	Buffer strips next to water courses
EJ10, HJ10	Enhanced maize crop management to prevent run-off
EJ11, OJ11, HJ11, OHJ11	Watercourse fencing

2. Methods

2.1. Study area

The study area comprised the Upper Thames and its tributaries, southern England, encompassing the rivers Thames, Windrush, Evenlode, Cherwell, Oxon Ray and Thame, stretching from Kemble, Gloucestershire, 1°26′W 51°40′N, to Cheddington, Buckinghamshire 0°39′W 51°50′N, and from Woodford Hasle, Northamptonshire 1°12′W 52°10′N to Wallingford, Oxfordshire, 1°07′W 51°36′N (see Fig. 1).

The depth of the Upper Thames is generally >1 m with width varying between 2 m and 30 m although the depth at our sampling sites varied between 0.1 m and 0.7 m and the width varied between 3 m and 35 m. Riparian vegetation included trees ranging in height from 1 m to more than 20 m, forbs, shrubs and grass. Some of the tree species found in the riparian zone included willow *Salix fragilis*, alder *Alnus glutinosa*, and ash *Fraxinus excelsior*. Shrubs and other vegetation like nettles *Urtica dioica* and bramble *Rubus fruticosus* were also present with the common reed *Phragmites australis* and reedsweet grass *Glyceria maxima* common emergent vegetation. Much of the catchment was either arable agriculture land or rough pasture, with only a small part being built up residential area. Overall agri-environment scheme (AES) uptake was very high (over 80%), with a lower uptake of river options (i.e. not all AES contained a water option), making it an ideal catchment to evaluate their effects, over and above the effect of standard AES.

2.2. GIS analysis

We investigated the effects of three land cover types: woodland, organic farming and agri-environment schemes (AES) with options likely to affect river health (river options, see Table 1). Taken together we term these conservation priority habitats. We considered woodland whether or not it was implemented or maintained as part of an AES. River options included options such as a buffer strip next to a waterway, farming for reduced run-off and organic farming (such that organic land was a subset of AES). For the full list of “river options” see Table 1. GIS base layers were downloaded from the Ordnance Survey (Great Britain) website (www.ordnancesurvey.co.uk/oswebsite/opendata/).ArcMap 10 (ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute) was used in all analyses. Landcover data were obtained from Ordnance Survey (OS) (woodland), Natural England (AES Schemes, including organic farming) and the Environment Agency (rivers). Catchments for each site were calculated using a Digital Terrain Model (DTM) available from OS. Catchments averaged around 200 km^2 and ranged from 3 km^2 to 2150 km^2, typically catchments were less than 300 km^2