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The early impact of large wood introduction on the morphology and sediment characteristics of a lowland river

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ABSTRACT

Habitat degradation in river ecosystems has considerably increased over the past decades, resulting in detrimental effects on aquatic and riparian communities. During the last two decades, the value of large wood as a resource for river restoration and recovery has been increasingly documented. However, post-project appraisal of the associations between restored large wood, morphological complexity and river ecology as a result of river restoration is extremely rare and thus scientific knowledge is essential. To investigate restored wood-induced morphological response and sediment complexity in an overwidened reach along a low gradient lowland river (River Bure, UK), two sub-reaches containing 12 jams initiated by wood emplacement in 2008 and 2010 and a sub-reach free of wood were studied. Wood surveys recording the dimensions and number of wood pieces in jams, geomorphological mapping of the reach illustrating the spatial distribution of features in and around the jams and in a section free of wood, and sediment sampling (analysed for particle size, organic content and plant propagule abundance) of five recurring patch types surrounding each jam (two wood-related patches and three representing the broader river environment) were performed. Wood jams partially spanned the river channel and contained large pieces of wood that created more open structures than naturally-formed wood jams. Where no wood was introduced, the channel remains wide and the gravel bed is buried by sand and finer sediment. In the restored reaches, fine sediment has accumulated in and around the wood jams and has been stabilised by vegetation colonisation, enhancing flow velocities in the narrowed channel sufficiently to mobilise fine sediment and expose the gravel bed. Sediment analysis reveals sediment fining with time since wood emplacement, largely achieved within the two wood-related patch types. Fine sediment retained around the wood shows a relatively higher plant propagule content than other patch types, suitable for sustaining plant succession as the vegetated side bars aggrade. Although channel narrowing and morphological adjustment has occurred surprisingly rapidly in this low energy, over-widened reach following wood introduction (2–4 years), sustaining the recovery in the longer term to suitably support flora and fauna communities depends on the continued delivery of wood by ensuring a natural supply of sufficiently large wood pieces from riparian trees both upstream and within the reach.

1. Introduction

Rivers worldwide are subject to anthropogenic influences that degrade habitat conditions and threaten biodiversity (Malmqvist and Rundle, 2002). Widespread among these impacts are a variety of physical alterations, including straightening, embanking, widening, and dredging, and the removal of large wood. These actions homogenise the geomorphological and hydraulic features of the channel and degrade river ecosystems, reducing their capacity to recover to a fully functioning state that is important for river and floodplain morphology and ecology (Hobbs and Norton, 2006; Palmer et al., 2010).

Since the 1980s, there have been increasing efforts to actively restore the form and ecological function of degraded rivers (e.g. Roper et al., 1997; Harrison et al., 2004; Lepori et al., 2005; Palmer et al., 2010). Key techniques that have been used include the introduction of a more sinuous planform, soft engineering of river banks, introduction of boulders and planting schemes, the construction of artificial riffles and pools, and the installation of protective fencing material (see Roni et al., 2008; RRC, 2013). More recently, large wood has been introduced into river systems as a restoration tool (Palmer et al., 2010; RRC, 2013).

The presence of large wood in relatively unimpacted river systems is known to be important for increasing hydraulic complexity

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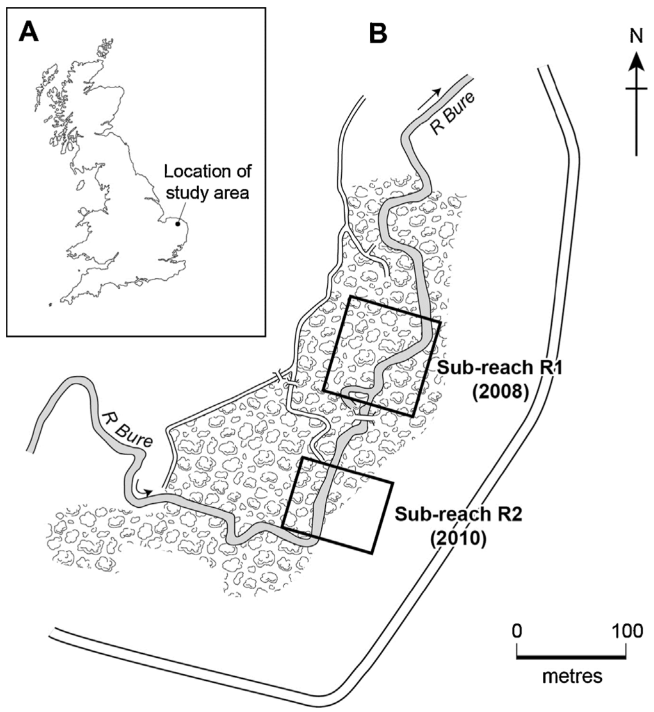

Fig. 1. (A) Location of the River Bure in Eastern England; (B) the Blickling Hall estate near Aylsham showing the study reach, which includes sub-reaches affected by reintroduction of wood in November 2008 (sub-reach R1) and November 2010 (sub-reach R2).
Source: Modified from RRC (2013).

and, as a consequence, mobilising, retaining, and sorting sediments. These processes result in morphologically complex river channels containing many distinctive wood-related landforms that support the life cycles of a variety of plants, insects and fish (e.g. Abbe and Montgomery, 1996; Tank and Winterbourn, 1996; Benke and Wallace, 2003; Francis et al., 2008). The inferred importance of wood for fluvial geomorphology and aquatic organisms has also led to experimental and field research on the benefits of large wood introduction and the disadvantages of large wood removal for fluvial ecosystems (e.g. Sundbaum and Naeslund, 1998; Abbe et al., 2003; Harrison et al., 2004; Kail et al., 2007; Lester and Boulton, 2008).

This paper presents some preliminary findings from research being undertaken on a reach of a single-thread, lowland river, the River Bure, Norfolk, UK, where felled trees have been introduced into the river channel as a restoration tool. This paper investigates the early response of a river to wood emplacement in 2008 and 2010 following sampling in May 2012. This paper addresses the following questions:

1. What are the characteristics of the wood jams at this early stage following their emplacement?
2. What are the morphological responses to wood emplacement?
3. What are the characteristics of sediments retained within patches/landforms directly associated with the introduced wood in comparison with other patch types within the study reach?

2. Study site

This study was conducted along a reach of the River Bure, Norfolk, UK (Fig. 1). The River Bure catchment covers an area of 164.7 km^2. The 240 m study reach (Fig. 1B) is located on the Blickling Hall estate, near Aylsham (Grid Ref. TG161301). The river is bordered by farmland, parkland and relatively open, mixed deciduous woodland. Riparian trees growing along the river margin are dominated by alder (*Alnus glutinosa* (L.) Gaertn).

The study reach has an average slope of 0.005 m m^{-1} and the active channel extends to an average width of approximately 7.6 m. The river banks are composed mainly of sand, silt and clay with occasional gravel lenses, whereas the bed material is gravel which is mainly overlain by a layer of finer sediment, predominantly sand and silt. The layer of sand and finer sediment on the river bed results from a combination of sediment delivery to the channel from the floodplain, particularly from cultivated land and historical widening of the channel which has led to a reduction in flow velocities (RRC, 2013).

Flow records from the River Bure at Ingworth (TG1921429614), which is the nearest gauging station to the study site, shows a mean annual discharge of 3.2 m^3 s^{-1}. The hydrological regime of the river is characterised by low summer flows with winter high flows averaging less than double the summer flows (Fig. 2). Winter flows and floods (average discharge 4.3 m^3 s^{-1}) occur between January and March from heavy rains, sometimes superimposed on snowmelt runoff, while summer flows (average discharge 2.4 m^3 s^{-1}) occur between July and September (Whitehead, 2006). The varying water levels associated with the river's flashy flow regime during winter and spring disturb sediments and vegetation within the active channel leading to widespread erosion of bars and also deposition of sediment.

Large wood had previously been removed from the reach to improve access for angling and to mitigate against flood risk. Following concerns raised by the local angling club regarding habitat quality for wild trout, and a desire to improve the conservation value of the reach, the National Trust site manager designed and implemented a river restoration scheme involving reintroduction of large wood (whole trees and logs; see RRC (2013) for full details). The wood was reintroduced into the study reach in two phases: within sub-reach R1 in November 2008, and sub-reach R2 in November 2010 (Fig. 1B). Data presented in this paper were collected in May 2012, allowing examination of sediment properties and propagule abundance four and two years following restoration of sub-reaches R1 and R2, respectively. The large size of the wood pieces, their orientation, and the fact that artificial anchoring was rarely used gives them a semi-natural appearance and potentially natural function, providing an opportunity to observe early channel adjustments induced by the introduction of large wood.

3. Methods

3.1. Experimental design

The study focused on 12 wood jams within the 240 m study reach, five in the 100 m long sub-reach R1, and seven in the 80 m long sub-reach R2 (Fig. 3Ai). Three types of data were collected: (i) the geomorphological characteristics of the river channel were mapped for the entire study reach; (ii) the position and characteristics of all large wood pieces and jams were recorded; (iii) sediment samples were obtained and subsequently analysed for their particle size, organic matter and plant propagule content.

3.2. Channel morphology

The geomorphological characteristics of the study reach were mapped under low flow conditions. The survey focused on the active river channel and mapped the location and extent of channel bed features (e.g. pools and bars), substrate types (gravel, sand, fine sediment (silt + clay)), large wood and vegetated areas. Dominant plant species in vegetated areas were identified. Since morphological adjustment depends on a combination of direct human