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The role of large wood in retaining fine sediment, organic matter and plant propagules in a small, single-thread forest river

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ABSTRACT

This paper investigates associations among large wood accumulations, retained sediment, and organic matter and the establishment of a viable propagule bank within a forested reach of a lowland river, the Highland Water, UK.

A wood survey within the 2-km study reach, illustrates that the quantity of wood retained within the channel is typical of relatively unmanaged river channels bordered by deciduous woodland and that the wood accumulations (jams) that are present are well developed, typically spanning the river channel and comprised of wood that is well decayed.

Sediment samples were obtained in a stratified random design focusing on nine subreaches within which samples were aggregated from five different types of sampling location. Two of these locations were wood-associated (within and on bank faces immediately adjacent to wood jams), and the other three locations represented the broader river environment (gravel bars, bank faces, floodplain). The samples were analysed to establish their calibre, organic, and viable plant propagule content.

The gravel bar sampling locations retained significantly coarser sediment containing a lower proportion of organic matter and viable propagules than the other four sampling locations. The two wood-related sampling locations retained sediment of intermediate calibre between the gravel bar and the bank–floodplain samples but they retained significantly more organic matter and viable propagules than were found in the other three sampling locations. In particular, the jam bank samples (areas of sediment accumulation against bank faces adjacent to wood jams) contained the highest number of propagules and the largest number of propagule species.

These results suggest that retention of propagules, organic matter and relatively fine sediment in and around wood jams has the potential to support vegetation regeneration, further sediment retention, and as a consequence, landform development within woodland streams, although this process is arrested by grazing at the study site. These results also suggest that self-restoration using wood is a potentially cost-effective and far-reaching river restoration strategy but that its full effects develop gradually and require the establishment of a functioning wood budget coupled with grazing levels that are in balance with vegetation growth.

1. Introduction

Naturally functioning forested rivers typically display complex riparian vegetation structure and fluvial forms that are driven by interactions among dead and living vegetation and fluvial processes (Gurnell, 2013). These interactions are reflected in the presence of a dynamic mosaic of large wood accumulations that induce spatial and temporal variations in flow velocity and patterns; erosion, sorting, and deposition of sediments; and the formation of landforms of varying sediment calibre including lateral bars and benches, eroded banks, and side channels that strongly impact on the age structure and patchiness of the riparian forest (e.g., Gregory et al., 1991; Naiman et al., 2005; Latterell et al., 2006).

Large wood accumulations in the active river channel not only significantly influence flow hydraulics, the retention and sorting of organic and inorganic fluvial sediments, and thus the morphological characteristics of the channel (e.g., Abbe and Montgomery, 2003), but these wood structures also perform important ecological functions as they are habitats in their own right; induce the development of other habitats, such as pools, vegetated and unvegetated bars, and side channels; provide shelter for organisms from predators as well as hydraulic refugia; and are a source of food. As a result, large wood structures support many organisms and their life history stages (e.g., Anderson et al., 1984; Benke and Wallace, 2003; Dolloff and Warren, 2003; Francis et al., 2008; Schneider and Winemiller, 2008). This paper contributes to research on associations among large wood, physical habitats and living organisms by exploring the relations between wood jams, sediment patches representative of particular physical habitats, and plant propagule retention.

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Rivers are important for dispersing plant propagules across the landscape. The process of hydrochory (i.e., dispersal of diaspores by water: van der Pijl, 1982; Andersson et al., 2000) has been investigated by many researchers in relation to the colonisation of riparian zones and related influences on riparian vegetation communities (e.g., Nilsson and Grelsson, 1990; Nilsson et al., 1991; Andersson et al., 2000; Jansson et al., 2000; Gurnell et al., 2006). As well as floating freely in rivers, plant propagules can be transported within the water column in the same manner as sediment particles—and by attaching to floating objects such as small pieces of wood, logs, twigs, and leaves—and can then be stranded in large wood accumulations (Johansen and Hytteborn, 2001) and other obstructions within the channel. Indeed, deposition of relatively fine sediment in the shelter of obstacles on river bars and channel margins has been shown to be accompanied by the deposition of plentiful seeds and other plant propagules (Gurnell et al., 2007). Therefore, wood obstructions within river channels could be expected to provide important sediment and propagule retention sites. Some evidence has been published for plant propagule retention by wood. Fetherston et al. (1995) and Abbe and Montgomery (2003) noted that trees colonise the bar surfaces that aggrade in the lee of bar-apex jams, and Collins et al. (2012) placed forest regeneration at the centre of their 'large wood cycle'. Furthermore, Pettit et al. (2006) surveyed some of the 200,000 wood piles deposited along a 105-km length of the Sabie River's bedrock macrochannel following a very large flood and found that vegetation regeneration from seedlings was occurring in 28% of wood piles and that wood was sprouting in 36% of the piles. The substantial vegetated patches that are produced by these processes not only influence further vegetation colonisation and associated landform development but the resulting vegetated landforms can provide sufficient shelter from disturbance for areas of exposed sediment downstream and that seedlings can successfully initiate vegetation colonisation of these sheltered areas (Moggridge and Gurnell, 2009). However, to our knowledge, no direct assessment of seed bank development associated with wood jams has been undertaken to date. This topic forms the focus of the present paper.

In parallel with the broader literature on the physical effects of large wood in rivers, three decades of research within the Highland Water (where the present research was conducted) has focused on the distribution and dynamics of large wood accumulations and their interactions with channel geomorphology (e.g., Gregory et al., 1985, 1994; Gregory and Davis, 1992; Gurnell and Sweet, 1998). Research on the geomorphological role of large wood has concentrated on studying the varying physical properties of wood accumulations, the stability of pool–riffle sequences, and the number and size of pools associated with large wood accumulations (Piégay and Gurnell, 1997; Gurnell and Sweet, 1998; Gurnell et al., 2002; Millington and Sear, 2007). Research has also investigated how large wood accumulations influence floodplain sedimentation (Jeffries et al., 2003; Sear et al., 2010), focusing on the impact of wood retention on the frequency and duration of overbank and floodplain deposition, the formation of multichannel patterns, and the formation and maintenance of floodplain surfaces. Biological research on the Highland Water has been limited. Recently, some research has been conducted on the significance of wood for fish populations (e.g., Langford et al., 2012). In addition, Sear et al. (2010) inferred that depositional features such as large wood accumulations along the Highland Water may be important germination sites for trees and shrubs. Nonetheless, no formal research has been done to investigate the possible relationships between large wood accumulations and plant propagule retention in the Highland Water.

This paper investigates associations between wood, sediment, and plant propagule retention along a 2-km reach of the Highland Water. The study first explores the type and distribution of wood accumulations within the reach and then considers the properties of sediment retained within five recurring types of sampling sites within the river, two of which are wood-associated. The research addresses the following research questions:

- What are the types and characteristics of large wood accumulations present within the studied river channel?
- What are the characteristics of sediments and associated plant propagules retained in the river channel in sampling locations within, near, and between the wood accumulations?
- Are any significant associations evident between sediment and plant propagule characteristics and the types of sampling location in which they are found?

2. Study area

This study was conducted along a reach of the Highland Water, flowing through the New Forest, Hampshire, UK (Fig. 1). The 2-km study reach has an average slope of 0.006 $m \cdot m^{-1}$ and the relatively shallow active channel (~1 m to bankfull level) extends to an average width of ~4 m (Gurnell and Sweet, 1998). The size of the bed material within the active channel is highly variable, ranging from local cobble–pebble deposits to more widespread coarse gravel deposits with frequent patches of sand and silt. The banks are composed mainly of sand-, silt- and clay-sized particles with gravel lenses.

The study reach is bordered by old, mainly deciduous woodland, including alder (*Alnus glutinosa (L.) Gaertn*), ash (*Fraxinus excelsior L.*), birch (*Betula pubescens Ehrh.*), beech (*Fagus sylvatica L.*), holly (*Ilex aquifolium L.*), oak (*Quercus petraea (Mattuschaka.) Leibel.*) and several species of willow (*Salix* spp.). The woodland is largely unmanaged, although grazing of the ground vegetation and lower branches by ponies, deer, and cattle is intense. The river channel is also essentially unmanaged and follows a sinuous course through the woodland with large wood and other tree-related features such as exposed tree roots forming important structures and geomorphic features within the channel bed and banks. Despite the heavy grazing, the lack of management of large wood and riparian woodland make the Highland Water one of a very small number of sites in England suitable for this study, as the majority of English rivers have been subject to riparian tree management and wood removal over many decades—even centuries. This paper focuses on sediment retained by wood accumulations (hereafter called jams) and associated geomorphic units and considers the calibre and organic content of the sediment and its associated seed bank.

3. Methods

3.1. Field methods

The ~2-km-long study reach was divided into nine contiguous 200-m subreaches (Fig. 1). Two types of data or samples were collected from all nine subreaches: (i) all large wood jams were located and their characteristics were recorded; and (ii) sediment samples were collected to provide data on sediment calibre, organic content, and the plant propagule bank.

3.1.1. Large wood jam survey

Although many definitions of 'large wood' have been used (Hassan et al., 2005), large wood was defined for the present study as wood pieces exceeding 1 m in length and 0.1 m in diameter. All large wood jams that spanned at least 20% of the channel width were surveyed between 9 and 12 May 2011 to record the properties listed in Table 1.

Each jam was characterised according to its position, type (following the classification of Gregory et al., 1995), and decay status (Table 1). Position was categorised with respect to the nearest river bend; type was categorised on the basis of the way the jam interacted with flow; and a simple three-fold categorisation of decay status reflected the predominant level of decay of the large wood pieces as an indicator of jam age and stability. The outer dimensions (length, width, and height)