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Seed germination from deposited sediments during high winter flow in riparian areas

Tenna Riis[a,*], Annette Baattrup-Pedersen[b], Jane B. Poulsen[b], Brian Kronvang[b]

[a] Department of Bioscience, Aarhus University, Ole Worms Allé, 8000 Aarhus C, Denmark
[b] Department of Bioscience, Aarhus University, Vejlsøvej, 8600 Silkeborg, Denmark

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ABSTRACT

In this study we examine how seed richness, diversity and composition from winter deposited sediment vary at increasing distances from a river channel. The objectives were to (1) describe the abundance, diversity, species composition and indicator species of seed deposited in a riparian wetland at different distances from the stream, (2) determine the range of variability in seed deposition at two spatial scales namely within distances and between distances from the river, and (3) determine the temporal patterns in seed germination at different distances from the river. A transect was established perpendicular to the river channel extending 101 m into the river valley. Samples of winter deposited sediment were collected in early spring in 20 cm × 20 cm plots with three replicates positioned 2 m, 16 m, 23 m, 41 m, 70 m and 101 m from the river. Germination from the sediment seed pool was followed for six weeks under, respectively, moist and wet conditions in a greenhouse with a natural light regime and a mean temperature of 20 °C. Overall, we found that winter high flow deposited a substantial amount of viable seeds in the inundated area. Germination was most successful under moist conditions where the number of seedlings ranged from 1050 to 3817 m^{-2}. Species richness (10.7 ± 1.5 species), Shannon diversity (2.13 ± 0.13) and evenness (0.90 ± 0.03) peaked in samples taken 16 m from the river channel. Variation in vegetation parameters was very high between samples, and 36% of the observations showed higher variation within replicates from the same distance than between distances reflecting high variability on a small spatial scale. The higher diversity of seedlings 16 m from the river coincided with a confluence zone emerging within the floodplain due to the complex flow arising during inundations, causing higher sediment deposition. Most seeds and most species germinated within the first three weeks, indicating that species commonly deposited with winter high flow in riparian wetlands show early germination, giving them a competitive advantage when vegetation establishes in early spring.

1. Introduction

Understanding the mechanisms generating and maintaining species diversity in riparian wetlands is a necessity to successfully restore impacted systems. Generally, it is believed that the presence of strong gradients over the land-water ecotone and the function of streams as migration corridors for a wide range of species are important for the high diversity that can be observed in stream ecosystems, including their floodplains (e.g. Ward et al., 1999). Hydrochory and inundation of wetlands have long been recognized as important factors structuring vegetation in riparian areas (Schneider and Sharitz, 1986; Johansson and Nilsson, 1993; Amoros and Bornette, 2002). Gurnell et al. (2006) found that hydrochory from upstream reaches was important for colonization of banks in newly cut river reaches in the River Cole in England. Jansson et al. (2000) documented that free-flowing rivers in northern Sweden where inundation of riparian areas occurs regularly had higher species diversity and plant cover than regulated rivers.

Inundation of riparian areas occurs at high river flow and leads to sediment transport and deposition of seeds in riparian areas (Nilsson et al., 2010). Seeds transported by the river to the wetlands are stored in more or less transient river seed pools (Nilsson et al., 2010; Riis and Baattrup-Pedersen, 2011). In many temperate regions high flows and riparian inundation occur in late winter and spring (Poff et al., 2006; Kronvang et al., 2009). The study of seed deposition in floodplains as part of winter/spring high flows is vastly interesting, as large sediment deposition allows seedlings to significantly influence the composition of the vegetation in the subsequent growing season due to lowered influence by existing vegetation (Riis and Baattrup-Pedersen, 2011). It is likely that the

* Corresponding author. Tel.: +45 8942 4725; fax: +45 8942 4747.
E-mail address: tenna.riis@biology.au.dk (T. Riis).

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ability to germinate early in spring is an important life history trait as it may control the impact of deposited species on the composition of the vegetation in the inundated area after flood recession. Early germination may increase the chance of plants to avoid early competition with other species on the bare deposited sediment. Only few studies exist of seed germination in winter deposited sediments; however, Goodson et al. (2003) analyzed winter deposited seeds at three elevations in a British river, and their results suggested that sediment and seed deposition by rivers are closely related processes.

The objectives of this study were to (1) describe the abundance, diversity, species composition and indicator species of seed deposited in a riparian wetland at different distances from the stream, (2) determine the range of variability in seed deposition at two spatial scales, namely within distances and between distances from the river, and (3) determine the temporal scale in seed germination at different distances from the river. We expect that high variation in water levels results in high deposition of seeds and in more species because the water level variation allows a broader range of flow conditions over time, leading to higher variability in deposition of seed sizes. Moreover, high water level variation results in a combination of transport and deposition of seeds. This is inferred by the fact that drift deposits are often concentrated in distinct bands containing a large number of seeds along the high-water line (Schneider and Sharitz, 1986; Andersson et al., 2000; Andersson and Nilsson, 2002). This also implies that microtopographic variation in the wetland is an important physical factor; it increases the potential of a higher frequency of fluctuating dry and wet conditions and thus leads to higher abundance of deposited seeds. Toogood et al. (2008) also found that small alterations in the water regime can prompt rapid vegetation changes, including abundance and diversity, in riparian wetlands. With this study we aim to increase our knowledge of the effect of stream flooding on riparian vegetation composition and of how this may change with distance from the river within an inundated floodplain. This knowledge is useful for predicting the influence of natural seed dispersal on the riparian areas in the planning of stream restoration projects aiming to increase the hydrological connectivity between rivers and their floodplains.

2. Methods

2.1. Study site description and sediment sampling

Sediment samples used for the experiment were collected in a large floodplain at the River Odense located between Brobyværk and Hillerslev Bro on the island of Funen, Denmark (55°13′ N, 10°15′ W). The sediment sampling site was situated in a flat part of the valley with an overall slope of only 0.3 cm m^{-1} (Fig. 1). Sediment sampling was conducted by installing three replicate 20 cm × 20 cm artificial grass mats (Astroturf) along a transect running perpendicular from the river bank to 101 m into the riparian area at six positions: 2 m, 16 m, 23 m, 41 m, 70 m, and 101 m (Fig. 1). The grass mats were positioned at increasing distances from the main river in order to capture the expected logarithmic pattern of decreasing deposition at increasing distance from the channel. The grass mat furthest away from the channel (101 m) was only inundated during the highest floods. The grass mats were deployed on 15th November 2007 and retrieved on 7th March 2008 just after the winter high flow that left the sampling area exposed. Additionally, an analysis of net deposition of sediment and organic matter and of grain size distribution at each grass mat location was carried out by Poulsen et al. (2014).

A hydrograph was calculated for the main river using the stage-discharge method (Herschy, 2009) in order to determine the number and duration of inundations of the riparian area during the study period. It was estimated that a minimum discharge of 5200 L s^{-1} (corresponding to a water stage of 24.42 m.a.s.l.) in the main river was required for the entire sampling transect to be inundated. This estimation was based on water stage in the river and floodplain topography. During this period the experimental site was flooded for a total of 30 days through seven major storm flow events. Average flow velocities at each grass mat location were estimated for the winter 2007/2008 based on a 2D numerical model of water flow on the floodplain by Poulsen et al. (2014).

2.2. Sediment treatment in seedling experiments

Winter deposited sediment was washed off the mats from each distance and was transported in closed containers to the greenhouse where the seedling experiment was conducted. Sediment samples were processed largely following the procedures described in van der Valk and Davis (1978). First, each sample was thoroughly mixed to ensure consistency. The 2 m, 16 m and 23 m samples were divided in two and subjected to one of the following two treatments: moist and air exposed sediment (moist) or submerged sediment covered with 4 cm water (submerged). These two treatments were applied to ensure germination of both seeds requiring emerged conditions and of seeds requiring submerged conditions. For three distances, 41 m, 70 m and 101 m, only the moist treatment was applied as the sample size was too small to allow two treatments. The seeds in the sediment samples can be viewed as an integrated sample over time and space in that the sediments are delivered to and transported in the river from upstream reaches during high flows (Kronvang et al., 2012); consequently, the samples represent a mixture of seeds of different origin and age.

In the greenhouse, sediment samples were spread evenly in a tray (25 cm × 35 cm) on a growth carpet (Vatex). In the moist treatment, the Vatex was placed over 3 cm growth medium (Sphagnum Substrate number 1) and in the submerged treatment over 3 cm washed sand to simulate natural conditions. These conditions were kept unaltered throughout the duration of the experiment. The trays were placed in a greenhouse with daylight and a mean temperature of 20 °C.

Once every week the trays were monitored for new emerged seedlings. All new seedlings were marked with a colored pin using one particular color for each week. Once a plant individual was identified to species, it was removed to avoid effects of competition within the trays. The experiment lasted 10 weeks in spring 2007. After 6 weeks no additional seeds germinated and the data analysis was therefore restricted to the first 6 weeks.

2.3. Data analysis

Seedling emergence was determined as the number of individuals, number of species, Shannon diversity and evenness (Shannon, 1948). Number of seedlings was determined per m^{-2} based on the sediment sampling area (0.04 m^2) and was calculated as the amount of deposited sediment divided by the mean number of seedlings at each distance (Table 1). To evaluate abundance and diversity in terms of functionality, species were allocated to one of two groups: riparian or non-riparian, on the basis of Ellenberg's indicator value for moisture preference (Ellenberg et al., 1992). Species with moisture indicator values > 6 were considered riparian and species with indicator values < 6 were considered non-riparian. Overall richness and abundance were calculated for these two species groups.