Ecological Engineering 70 (2014) 102–113

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Effects of flooding on the seed bank and soil properties in a conservation area on the Han River, South Korea

Hyohyemi Lee[a,c,*], Josu G. Alday[b], Kang-Hyun Cho[d], Eun Ju Lee[c], Rob H. Marrs[b,*]

[a] Bureau of Ecological Conservation Research, National Institute of Ecology, Seocheon 325-813, South Korea
[b] School of Environmental Sciences, University of Liverpool, Liverpool L69 3GP, UK
[c] School of Biological Sciences, Seoul National University, Seoul 151-742, South Korea
[d] Department of Biological Science, Inha University, Incheon, 402-751, South Korea

ARTICLE INFO

Article history:
Received 30 October 2013
Received in revised form 20 March 2014
Accepted 19 April 2014

Keywords:
Soil physico-chemical properties
Seed bank
Flooding
Multivariate analysis
Conservation
Restoration

ABSTRACT

Flooding can have a major impact on riverside plant communities, and this is likely to be especially important in monsoonal climates, where large floods occur after heavy rain. In urban areas where riparian vegetation remnants are the only vegetation of conservation interest remaining, understanding the impacts that floods have on these ecosystems is needed to inform their future conservation. Accordingly, we assessed the impact of a flood caused by Typhoon "Ewiniar" on the soil seed bank of five plant communities of the only remaining fragment of high-quality riverine habitat within the Seoul city stretch of the Han River (South Korea). We surveyed the seed bank composition of the five dominant plant communities before and after the flood. We also measured selected soil physico-chemical properties in each community. We used univariate and multivariate methods to examine the effect of the flood on both seed bank and soil physico-chemical properties. Flooding resulted in variable deposition of sediment within the plant communities; four communities varied from 14.6 to 18.8 cm but the fifth (dominated by *Miscanthus sacchariflorus*) had much less sediment (4.8 cm). The physico-chemical properties of the surface soil also changed after the flood, with the sediment particle size being the most affected. The species richness and composition of the seed bank suffered significant changes after the flood. In both cases there was a homogenization process, with was also impinged on species with different life-forms (annuals and perennials). Our results suggest that an extreme flood can affect the riparian vegetation seed bank by removing wetland plant species and allowing common and ruderal species to establish. There may also be different interactions between the different plant communities in terms of sediment capture and this translates into altered soil conditions and seed banks. These results are of use to conservation policy-makers aiming to conserve a native flora within severely modified urban rivers, and these remnant areas can provide an important seed source of wetland plants to aid restoration of riparian ecosystems.

1. Introduction

Natural river landscapes of the temperate regions can harbour a high biodiversity due to their high habitat heterogeneity and both lateral and longitudinal river connectivity (Naiman et al., 1993; Van Looy et al., 2009). The longitudinal exchange via water flow, creates areas of geo-diversity within river landscapes through the erosion, transportation and deposition of sediment (Stromberg et al., 2011). Flooding is also a major factor in controlling biological community structure (Alves Pagotto et al., 2011), often moderating the relationships between the hydrological regime, soil structure (sediment), flora and fauna.

Riverine systems usually include the land within a water catchment, a network of streams which drain it, and its component flora and fauna (FISRWG, 1998). Riverine systems are, therefore, important landscape components from a holistic conservation perspective, being under great threat, especially those parts of the river flowing through urban areas (Gergel et al., 2002; Karr and Chu, 2000; Paul and Meyer, 2008). The remnant vegetation within urban river systems is usually highly-fragmented, degraded and susceptible to human disturbance. Many parts of the riverine system are subject to environmental pressures which affect both the chemical and physical environment, being some parts disturbed

* Corresponding author at: University of Liverpool, Liverpool L69 3GP, UK. Tel.: +44 979 108321/+44 1517955172; fax: +44 979 108440.
E-mail addresses: ejlee@snu.ac.kr (H. Lee), calluna@liverpool.ac.uk (R.H. Marrs).

http://dx.doi.org/10.1016/j.ecoleng.2014.04.014
0925-8574/

on a regular basis by flooding which varies in extent and duration (Abernethy and Willby, 1999; Amiaud and Touzard, 2004; Capon and Brock, 2006; Cho and Cho, 2005; Hölzel and Otte, 2001; Jutila, 2001). When flooding occurs there is a large flow of water, usually resulting from heavy rain within the upstream catchment, and the effects can be severe, changing the river topography (Alves Pagotto et al., 2011; Schmidt et al., 2001; Stromberg et al., 2011; Yarie et al., 1998). However, in less severe cases, there is often sediment transport within the water flow which is deposited downstream (Hayashi et al., 2012). In these cases, the flood-deposited sediment provides an incoming source of both mineral and organic material, each containing nutrients, and of course plant propagules, i.e. seeds and vegetative fragments (Cockel and Gurnell, 2012; Riis and Baattrup-Pedersen, 2011). The role of seed banks in riverine restoration has recently been emphasized by Cui et al. (2013) who described species densities variations between river positions, sediment depth and pollutant loads. Flooding can have direct negative effects through both the erosion of plants and soils (Capon and Brock, 2006; Eldridge and Lunt, 2010), and through the physical deposition of flood-borne sediments (Chang, 2005; van derValk et al., 1983); the latter killing newly-emergent seedlings and preventing seedling emergence as the surface soil is buried. Recovery after flooding can also be affected by the sediment deposition as it impinges on both soil physico-chemical characteristics and the seed bank, both of which could alter successional recovery. Here, therefore, we examine the impact of deposited sediment on the vegetation and soil seed bank in the floodplain of a refuge of semi-natural vegetation of conservation interest within a highly-modified river.

In this paper, we studied the flooding impacts within a refuge of semi-natural vegetation on the banks of the Han River within Seoul City (South Korea). The Han River is subject to annual flooding during the heavy monsoonal rainfall with exceptional peaks every 3–5 years. To minimize this flooding, water flows are managed in two ways: first, there are three large dams upstream from Seoul (Soyang, Chungju and Paldang dams; Kim, 2008), and second in Seoul, the river was channelized and embanked in the mid-1960s, providing public parks, roads, and car parks along the river banks (Woo, 2010). As a result, the previous ecological functions derived from the natural riparian vegetation have been lost within the urban reaches of the Han River. However, there are four refuge areas within the confines of the Seoul city where natural vegetation remains. Lee et al. (2011) described the plant communities and seed banks of these four refuges; though, three of these had suffered recent disturbance, and one, the Amsa wetland was shown to be the only remaining fragment of relatively-undisturbed, semi-natural riverine vegetation within the city reaches. Therefore, the Amsa refuge area is extremely important from a conservation view point as it retains some vegetation along with a bank of propagules in the soil which could assist in future river restoration strategies (Jeon et al., 2008; Kim and Ju, 2005; Lee et al., 2011).

More precisely, we studied the impact of the severe 2006 flood on the seed banks and soils of five plant communities types along a transect from the river through to the landward end within the Amsa wetland. This flood was generated as a result of exceptionally heavy, seasonal rainfall (typhoon 'Ewiniar') which produced one of the highest floods in the last 25 years. The effect of this flood on the riverine communities within the Amsa wetland was analyzed by measuring change before and after the flood in (1) a range of soil physico-chemical variables, and (2) the soil seed banks of the five dominant plant communities (Lee, 2010; Lee et al., 2011). It was hoped that this information would provide a preliminary assessment to help inform conservation planning of riverbank vegetation in protected areas.

2. Methods

2.1. Study site and flood event

The Han River is a major river in South Korea; it is 470 km long with a watershed area of 26,200 km^2 and flows through the capital Seoul through to the Yellow Sea (Fig. 1). Within the catchment, the average annual precipitation is 1294 mm, with 65% occurring between July and September. The Han River is subject to annual flooding during the heavy monsoonal rainfall with exceptional peaks every 3–5 years. The studied flood was generated as a result of exceptionally heavy, seasonal rainfall (typhoon 'Ewiniar') which produced one of the highest floods in the last 25 years (Fig. 2). Since 1984, the South Korean flood forecasting system has issued 13 flood alerts under two categories ('Flood advisory' and 'Flood warning'). The 2006 event was classified as "Flood advisory", and produced the 9th highest recorded water level at the Hang River Bridge monitoring station since 1920; indeed the monitoring station was itself flooded for 24 h.

Lee et al. (2011) described the plant communities and seed banks of the four refuges on the Han River; three of these had suffered recent disturbance, and one, the Amsa wetland (0.1 km^2, N37 33′ 5.72″, W127 7′ 15.3″, Fig. 1), was shown to be the only remaining fragment of relatively-undisturbed, semi-natural riverine vegetation within the city reaches. This site was designated an "Ecological Landscape Protected Area" to conserve this habitat in 2002, and has been fenced to prevent human access. Five plant communities were described at this site (Lee, 2010; Lee et al., 2011) forming a zonation from the river bank side to the land-side as follows (Fig. 1; Nomenclature follows Lee, 1999), i.e. Waterfront (Wf), Bankside (Bn), and communities dominated by *Salix* sp. (Ss), *Phragmites australis* (Pa), and *Miscanthus saccariflorus* (Ms). The Amsa wetland, therefore, contains a mosaic of habitats which would otherwise be absent from the urban reaches of the Han River, providing aesthetic and educational services as well as a semi-natural habitat much valued for migratory birds (Yoo and Choi, 2007).

2.2. Soil/sediment sampling for seed bank assessment and chemical analysis

The pre-flood soil physico-chemical conditions and seed bank characteristics were assessed in spring (March) of 2005 and 2006, respectively; there was a small flood in 2005. On both sampling occasions, five replicate 1 m^2 quadrats were located randomly within each of the five plant communities. At each of these quadrats, five soil cores were taken using a soil corer (Eijkelkamp BV, Netherlands; corer dimensions = 5 cm diameter, 5 cm deep, 500 ml volume in total per sample). Seed bank assessment was performed in March because at this time all seeds available for germination over the summer would be present.

The post-flood conditions were measured on the site after the deposition of flood-derived sediments. In order to measure sedimentation rates, five replicate soil traps (plastic square plates, 25 × 25 cm) were placed in the each of the five communities 14 d before the flood. Immediately after the flood these were re-visited, depth and the total mass of sediment were measured in each trap, thereafter the sample were collected and moved to lab. Using the same corer of pre-flood samples, four cores were sampled from each soil trap for the seed bank analysis (400 ml volume in total per sample), and rest of the sample used for soil physico-chemical analysis.