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Urban rivers as dispersal corridors for primarily wind-dispersed invasive tree species

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ABSTRACT

Urbanization may have a large affect on biodiversity patterns by enhancing biological invasions. Urban habitats harbour high numbers of introduced plant species and may function as starting points for invasions along urban–rural gradients. As information on underlying mechanisms is critical for managing biological invasions, we test the role of rivers as dispersal corridors for primarily wind-dispersed ornamentals. We released tagged fruits of three invasive tree species in the Spree River (Berlin, Germany) and directly observed the fate of the floating samaras. The number of floating samaras declined exponentially with distance from the release point. A quarter floated 1200 m within 3 h. Despite marked differences in fruit morphology, there were no interspecific differences in floating capacity. We showed hydrochory to be an effective dispersal agent in wind-dispersed tree species, extending wind-related transport distances by several times. In this way, rivers are expected to link urban propagule sources with natural habitats downstream. Our results suggest that planting native tree species along river corridors would help prevent invasion risks and contribute to implementing principles of ecological design in urban greenways and generally consider the importance of eradicating wind-dispersed invasive tree species in floodplains in early invasion stages to prevent further water-mediated dispersal.

1. Introduction

The major global trend toward urbanization affects biodiversity severely (Hansen et al., 2005; McKinney, 2006) and cities, as centres of trade, transport, and travel, are crucial drivers in facilitating the introduction and further spread of exotic species (Kowarik, 1995; Pyšek, 1998). Urban green spaces harbour a high number of introduced ornamentals that may escape from cultivation (Kowarik, 2005; McConnachie et al., 2008). Global warming may enhance invasions by planted ornamentals as many of them are native to warmer regions (Niinemets and Penuelas, 2008). Hence, the question of whether cities function as starting points for plant invasions into rural or natural habitats becomes increasingly important. Because a better understanding of the mechanisms underlying plant invasions along urban–rural gradients is needed to optimize prevention and management strategies (Hulme et al., 2008), we address the role of dispersal corridors that may link urban propagule sources with natural habitats in the adjacent countryside.

Transportation corridors have been recognized as important pathways for the unintentional transport of nonnative species. Vehicles can move a broad array of species (Hodkinson and Thompson, 1997; Zwaenepoel et al., 2006) and by this promote a directional transfer of species along urban–rural gradients (von der Lippe and Kowarik, 2008). In contrast to roads, the role of urban rivers as dispersal corridors has not been studied in detail. A high number of nonindigenous species in urban or suburban riparian systems (Burton et al., 2005; Maskell et al., 2006) suggests a seed influx from adjacent urban propagule sources, but as different dispersal vectors may work in concert, the role of hydrochory needs to be disentangled from other dispersal vectors.

Previous studies on the functioning of water dispersal mostly addressed rivers in near-natural settings; these revealed hydrochory as a powerful dispersal vector mostly in aquatic or wetland species (Middleton, 2000; Middleton et al., 2006) and one that enhances habitat connectivity at local to regional scales (Johansson et al., 1996; Jansson et al., 2005; Vogt et al., 2006; Gurnell et al., 2008). Moving water transports propagules of nonindigenous species that invade predominantly riparian systems (e.g., Thomas et al., 2006; Truscott et al., 2006).

Hydrochory does not require specific well-developed morphological adaptations for water dispersal (Johansson et al., 1996), and some studies have illustrated its capacity to function as a secondary dispersal mechanism in tree species that are primarily dispersed by birds (Hampe, 2004) or wind (e.g., Thébauld and Debussche, 1991; Seiwa et al., 2008). As secondary dispersal vectors can increase the spatial reach of dispersal processes significantly compared with the primary vector (Higgins et al., 2003; Nathan,

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2006), we hypothesize that rivers that link urban areas with more natural habitats downstream may play an important role in moving samaras of exotic wind-dispersed tree species, which are often planted in, or colonize, urban habitats adjacent to rivers or channels. The possible function of urban rivers as dispersal corridors has not been considered in planning, design and management approaches for urban river greenways (e.g., Baschak and Brown, 1995).

Thus, we analyze the seed dispersal of three tree species: the European *Acer platanoides* L., the North American *A. negundo* L., and the Asian *Ailanthus altissima* Mill. Swingle. All of these species frequently colonize urban habitats, are invasive in Europe or North America, and produce wind-dispersed samaras (Reinhart and Callaway, 2004; Kowarik and Säumel, 2007). Using an embanked section of the Spree River in the historic centre of Berlin, Germany, for a seed-release experiment, we address the following questions: (1) How effective is water-mediated dispersal of wind-dispersed tree species along embanked urban rivers? (2) Do differences in fruit characteristics (weight, length and width of samaras) influence the functioning of water dispersal?

2. Materials and methods

Several methods for tracking the movement of diaspores by water are well established (e.g., Thomas et al., 2006; Schneider and Sharitz, 1988). Because of methodological constraints in placing seed traps or dip nets in river sections with heavy boat traffic, we chose an experimental approach of direct, visual tracking of floating seeds that had been marked with different colours before release.

We collected fruits of our three model species from randomly chosen trees in Berlin during the period of natural seed abscission and measured dry weight [DW], maximum wing length [*L*], and maximum wing width [*W*] (means ± SD for $N = 50$) with the following results for *Ailanthus altissima* (DW = 52 ± 8 mg, $L = 46 \pm 3$ mm, $W = 11 \pm 1$ mm), *Acer negundo* (DW = 48 ± 10 mg, $L = 32 \pm 2$ mm, $W = 10 \pm 1$ mm), and *Acer platanoides* (177 ± 26 mg, $L = 53 \pm 4$ mm, $W = 19 \pm 2$ mm). Then we tagged samaras with different colours of spray paint (Aero Decor Colour-Spray, Union Chemie Berlin, Germany). To test whether the colour affected the floating ability we floated 50 coloured and noncoloured samaras per species in water basins (70 cm × 120 cm × 30 cm), disturbed the water surface by

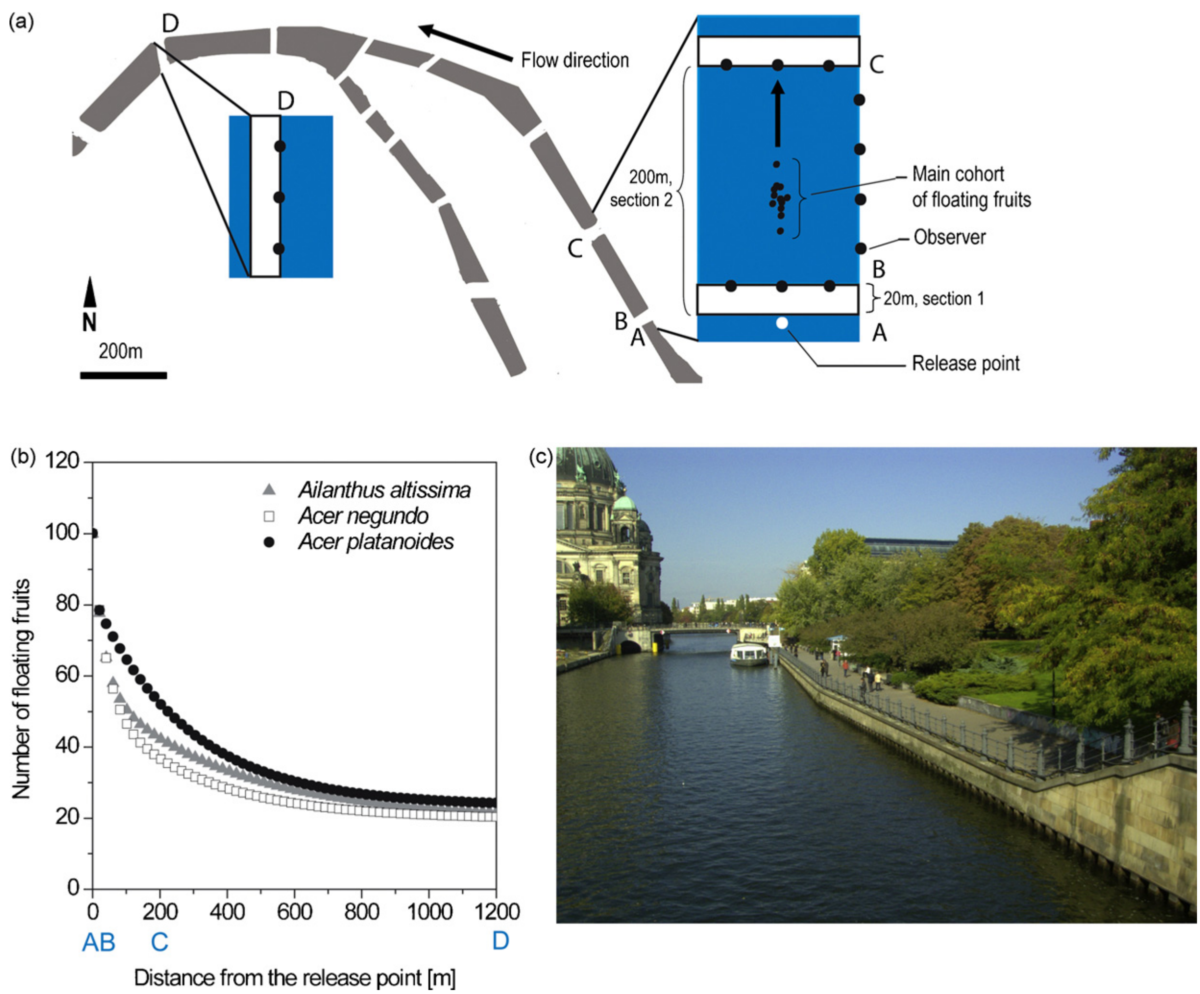

Fig. 1. (a) The Spree River in the historical center of Berlin. White gaps indicate bridges. (A) Point of release of fruit cohorts (upstream side of Rathausbrücke, 52°31′1.6″N, 13°24′14.6″E). Size and time of arrival of fruit cohorts were measured at (B) downstream side of Rathausbrücke after floating 20 m, (C) upstream side of Liebknechtbrücke after floating 200 m, and (D) upstream side of Weidendammbrücke after floating 1200 m (52°31′20″N, 13°23′17″E). Black points indicate observation points along the river embankments between (B) and (C) and on the three bridges. (b) Number of floating fruits of the studied species along the observed transect along the Spree River (five replications, number of released seeds per replication was 100). Second order exponential decay fits of the number of floating seeds at different distances from the release point are shown for the observed distances. Fitting parameters for the second order exponential decay fit ($y = y_0 + A_1 e^{-x/t1} + A_2 e^{-x/t2}$) are given with SD: *Ailanthus altissima* ($R^2 = 0.98$; χ^2/df = 24.3), *Acer negundo* ($R^2 = 0.95$; χ^2/df = 57.7) and *Acer platanoides* ($R^2 = 0.92$; χ^2/df = 381.3). The upper case letters A, B, C and D indicate location as in (a). (c) Photograph of the study site in the historical center of Berlin taken on Rathausbrücke (B) to Liebknechtbrücke (C).