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Biodiversity functions of urban cemeteries: Evidence from one of the largest Jewish cemeteries in Europe

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ABSTRACT

As the world becomes more urbanized, urban cemeteries may become increasingly valuable for biodiversity conservation as cemeteries are ubiquitous elements of the green infrastructure in cities worldwide. By implementing a multi-taxon approach at different spatial extents, we analyzed habitat functions of a large urban cemetery in Berlin (Weißensee Jewish Cemetery) and explored related environmental variables. This cemetery is an outstanding cultural heritage site but it also stands for old urban cemeteries that have progressed to urban woodland, an ecosystem type that exists in many regional and religious contexts. The cemetery provided a habitat for 604 species; species of conservation concern comprised 1.6–100% of total species among different groups of taxa (in decreasing order: bats, birds, lichens, bryophytes, carabids, vascular plants, spiders). Species richness and species composition at the plot level were significantly related to differences in management intensity and resulting vegetation structures but differed among taxonomic groups. In vascular plants, carabids and spiders, the species composition varied significantly with habitat age, and there was a set of characteristic species for different age classes in each species group. Our results thus support the use of differentiated management approaches to maintain habitat heterogeneity by allowing wilderness development in some parts of a cemetery while keeping others more open. Since these aims can be combined with efforts to preserve outstanding grave architectures and allow access to visitors, our study indicates ways of reconciling conflicting aims of heritage preservation and biodiversity conservation, a promising perspective for biodiversity conservation in culturally shaped urban landscapes. We conclude that cemeteries provide important cultural ecosystem services within the urban green infrastructure.

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1. Introduction

Cemeteries and other types of burial grounds are regarded as sacred places all over the world, closely linked to community history (Rugg, 2000) and often functioning as "repositories of natural and cultural diversity" (Barrett and Barrett, 2001). Previous work has highlighted considerable conservation functions of sacred sites in non-urban settings. Natural remnants related to sacred groves (Bhagwat and Rutte, 2006) and other culturally protected areas (Frosch and Deil, 2011; Gao et al., 2013; Frascaroli et al., 2016) contribute to the conservation of natural habitats and rare species all over the world. Moreover, old cemeteries may represent habitat islands for native species that are otherwise uncommon in intensively used rural landscapes such as grassland species in the U.S. (Moorehouse and Hassen, 2004) and Australia (Semple et al., 2009), orchids in Turkey (Löki et al., 2015) and Germany (Heinrich and Dietrich 2008), or woodland species in Poland (Sigiel-Dopierała and Jagodziński, 2011) and Australia (Hewitt, 2013).

Cemeteries, however, are also ubiquitous components of the urban green infrastructure that may stretch over large areas in cities (e.g., 1100 ha in Berlin and 1300 ha in London; SenStadtUm, 2014; Wilby and Perry, 2006) and at the country scale (e.g., Szymańska et al., 2015). As the world rapidly becomes urbanized, the question of how urban land-use types function as habitats for native species is of growing importance for biodiversity conservation (McKinney, 2002; Kowarik, 2011; Shwartz et al., 2014). Cemeteries might play an important role for urban biodiversity conservation due to their size, habitat heterogeneity and habitat continuity. Moreover, they may provide important ecosystem services, similar to other tree-dominated habitats. These include regulating services (e.g. climate

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and stormwater regulation) and cultural ecosystem services related to recreation, wellbeing and health (Haase et al., 2014; Shanahan et al., 2015).

A wealth of studies has revealed mechanisms that underlie biodiversity pattern in urban parks, e.g. positive relationships between species richness and size, diversity or heterogeneity of park habitats (see review by Nielsen et al., 2014). While urban parks and cemeteries share some common characteristics (e.g. habitat mosaics with trees and grassland) important differences exist in terms of recreational pressure and specific habitat features (e.g. sepulchral architecture). Thus, biodiversity functions of cemeteries and related drivers need to be disclosed.

Indeed, urban cemeteries have long been addressed as habitats (e.g. Gilbert, 1989; Sukopp, 1990; Laske, 1994), mostly illustrated for birds (e.g. Lussenhop, 1977; Kocian et al., 2003) and vascular plants (Graf, 1986; McBarron et al., 1988; Hewitt, 2013). Yet different from parks, studies on the parameters that shape biodiversity patterns are largely absent. This is a crucial limitation because age, management and important structural factors clearly differ within this land use type.

Take tree dominance as an example. Design schemes of cemeteries differ dramatically in the extent to which existing trees or woodland fragments are incorporated or new plantings are used to distinguish different sections or places within a cemetery (Curl, 1984; Tarlow, 2000; Clayden and Woudstra, 2003; Theune and Walzer, 2011). Moreover, periods of neglect or abandonment may allow succession towards forests as shown for Victorian cemeteries in London (Gilbert, 1989), abandoned Protestant cemeteries in Poland (Sigiel-Dopierała and Jagodziński, 2011) and Jewish cemeteries across Europe (Jacobs, 2008). It is thus the interactions of design, management and natural processes that likely drive important habitat features of cemeteries.

For urban parks Nielsen et al. (2014) state that studies rarely bridge between flora and fauna. To the best of our knowledge, no study has tested thus far for responses of multiple groups of taxa to different environmental conditions within cemeteries. This is an important constraint because different groups of organisms usually respond differently to management intensity or other local factors (e.g. Shwartz et al., 2013; Ferenc et al., 2014).

Since both natural and cultural heritage values inhere in many cemeteries (Barrett and Barrett, 2001), enhanced insights into biodiversity patterns would strongly support balanced conservation approaches. We use the Weißensee Jewish Cemetery (WJC) in Berlin for a multi-taxon approach. This cemetery, as an outstanding cultural heritage site, offers excellent opportunities for shedding light on mechanisms that underlie biodiversity patterns in cemeteries since different cemetery sections represent different development ages and different intensities of management which, together, result in differently structured wooded areas, including highly manicured sections as well as patches of novel urban wilderness, i.e. wooded areas with few remaining human interventions.

In contrast to older Jewish cemeteries (Jacobs, 2008; Theune and Walzer, 2011), both the design scheme and use of plants in WJC are similar to contemporary Christian cemeteries in Central Europe (von der Lippe et al., 2011). The question of how to reconcile different aims, including conserving the cultural heritage, allowing ongoing uses (visits, burials) and preserving biodiversity, is a timely challenge in WJC (Kowarik et al., 2011; Rütenik et al., 2013) as it is in many other cemeteries that have experienced changes in management intensity (e.g. Gilbert, 1989; Waitzbauer et al., 2010; Sigiel-Dopierała and Jagodziński, 2011). Our study is thus relevant for a range of old cemeteries that have progressed towards tree-dominated development stages.

In detail, we address the following research questions: (1) What are the habitat functions of the cemetery (a) for plants (vascular plants, bryophytes, lichens) and animals (bats, birds, ground beetles, spiders), in particular (b) for species of conservation interest and (c) for native species? (2) How are alpha diversity and species composition of groups of important indicator species (ground beetles, spiders, vascular plants) related to environmental parameters (management intensity, site age, habitat structure)? In our conclusion, we present implications for biodiversity conservation for old cemeteries that have developed, at least partly, to woodland and address the role of cemeteries within the urban green infrastructure.

2. Methods

2.1. Study area

The study was performed in Berlin, Germany, which has a population of 3.5 million people in an area of 892 km^2. Berlin has 220 cemeteries within its city limits, covering 1125 ha; five of these are Jewish cemeteries that cover 53 ha in total (SenStadtUm, 2014). Our study site, WJC, is one of the largest Jewish cemeteries in Europe that are still in use, with an area of 39.2 ha and about 116,000 graves (Rütenik et al., 2013). It is situated in northeastern Berlin (52°32′40″N, 13°27′30″E).

The WJC was established by the Jewish community of Berlin in 1880 in what was then an agricultural area, close to the village of Weißensee (Wauer and Losier, 2010). In consequence, no pre-existing forest elements were present on the site since the medieval era. The design scheme by Hugo Licht (1841–1923) differed from those of traditional Jewish cemeteries (Rütenik et al., 2013) as did many components of the sepulchral architecture. Instead, the spatial layout was more similar to Christian cemeteries of the time. The graves are grouped in 134 geometrically shaped sections separated by allées (Fig. 1), and historical analyses have revealed ornamental plantings on grave sites (von der Lippe et al., 2011).

About 50 years after its inception, WJC had become embedded in the fast-growing city of Berlin. Before the Second World War, about 110,000 people were buried here. Due to the Shoah, the number of burials and the maintenance declined dramatically, but WJC was never closed or devastated by the Nazis. After the arrival of the Red Army in Berlin in April 1945, some clearance work was carried out to restore the approximately 4000 graves that had been destroyed by bombings. In the following decades, however, large parts of WJC developed towards woodland because neither the small remaining Jewish community in East Berlin nor the GDR authorities were able to maintain the entire cemetery. After Germany was reunified in 1990, some sections were cleared and managed, while others were intentionally excluded from any management to allow wilderness to develop. As part of a World Heritage Initiative beginning in 2006, a number of analyses were conducted, including historical studies on those buried here, architectural studies of the graves (Rütenik et al., 2013), horticultural assessments of the design (von der Lippe et al., 2011) and the study on habitat functions that we report here.

2.2. Study design and sampling

We sampled different groups of plants and animals at three spatial extents: an area-wide sampling to assess overall habitat functions of the cemetery, a sampling of 30 cemetery sections as a middle spatial extent, and a plot-based sampling to disclose biodiversity drivers at a smaller spatial extent (Table 1). As species of conservation concern, we addressed species that are legally protected (e.g., by the Flora-Fauna-Habitat Directive) or listed in regional Red Lists.

For the total cemetery, we sampled vascular plants, birds and bats (see Table 1 for methods). While the first two groups are often included in urban biodiversity studies (McKinney, 2008), we also

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