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Plant community development as affected by initial planting richness in created mesocosm wetlands

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ABSTRACT

The gain or loss of plant species may alter the development of structural and functional attributes critical to developing or restoring ecosystem services in created mitigation wetlands. A three-year study was conducted in created mesocosm wetlands to determine the role of initial planting richness (IPR) in vegetation community development using five species of plants common to natural and created wetlands in the Virginia Piedmont. The mesocosms were naturally colonized by volunteer species after planting the same as in real-world mitigation wetlands created in the region. At the end of each growing season, all species present were identified, and species richness (S) and cover percentages (i.e., percent total, planted and volunteer species) were measured. Indices for diversity (Shannon–Weiner H') and prevalence (PI) were calculated. After establishment of planted rhizomes, hydrology was maintained solely by precipitation. However, unintended leaking in six mesocosms in the beginning of the study created two distinctively different hydrologic conditions (i.e., wet vs. dry conditions) that were factored into the final data analysis. Both richness (S) and biodiversity (H') varied significantly with initial planting richness (IPR). Differences in these two attributes were mainly due to differences between monotypic mesocosms (IPR = 1) and those with the greatest number of species initially planted (IPR = 5). Hydrologic conditions impacted some of the plant community characteristics, including total percent cover being higher in one year and PI being lower both in "wet" conditions. The mesocosms were becoming typical of wetlands with more hydrophytes present over the course of the study. The outcome of the study showed that the mesocosm wetlands were following a similar pattern found in vegetation community development trajectory of newly created mitigation wetlands. The study showed the positive effect of initial planting richness on species richness and diversity in the early development of plant community. Our findings also reinforce the importance of maintaining adequate hydrologic conditions for the early development of vegetation community in created mitigation wetlands.

1. Introduction

The role of species richness on ecosystem functioning has emerged as a key research topic in ecology during the past decade (Hooper and Vitousek, 1997; Tilman et al., 1997; Engelhardt and Ritchie, 2001; Kinzig et al., 2006; Loreau et al., 2002; Hooper et al., 2005). A number of previous studies indicated that ecosystem functions, such as primary productivity, are often significantly influenced by the assemblage of plant species present in a community (Hooper et al., 2005). A positive relationship between plant species richness and a variety of ecosystem functions, including carbon and nitrogen accumulation and net primary productivity (NPP), has been observed (Hooper and Vitousek, 1997; Tilman et al., 1997; Schläpfer and Schmid, 1999; Engelhardt and Ritchie, 2001; Kinzig et al., 2006; Loreau et al., 2002; Hooper et al., 2005; Lawrence and Zedler, 2013). Most studies on the role of plant richness are based on grassland on various ecosystem structure and functions (Collins and Adams, 1983; Cardinale et al., 2006; Balvanera et al., 2006; Isbell et al., 2011). However, there is a lack of information on the relationship between species richness and ecosystem development in created wetlands. Created wetlands are wetlands constructed in an area where a wetland did not previously exist.

Legally, and ecologically, wetland mitigation requires the development and establishment of wetland vegetation communities (USACE, 1987; NRC, 2001; Spieles, 2005). Planting, the deliberate placing of wetland species, is an important part of wetland mitigation since vegetation development is the most

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commonly used metric for determining mitigation success. However, vegetation establishment is most often achieved by intentional seeding or planting of wetland species along with natural recruitment of volunteer species from adjacent communities. To date, many created mitigation wetlands have developed lower species richness and total plant cover and had fewer native species volunteer compared to natural wetlands (Balcombe et al., 2005; Gutrich et al., 2009). Currently there is no consideration of planting diversity in mitigation wetlands when created, nor is planting diversity mandated for vegetation management. Lack of these considerations may lead to a monotypic development of wetland vegetation community ending in a mitigation failure (Galatowitsch and van der Valk, 1996; Zedler and Callaway, 1999; Farrer and Goldberg, 2009).

Few studies have been conducted specifically on the impact of IPR on species richness, species diversity, or vegetation indices of plant community development in created wetlands. In a whole-system experiment, Mitsch et al. (2005) found that a planted created wetland showed more diversity and greater cover but less productivity than a non-planted wetland after 10 years. In 1- to 3-year old depressional created wetlands in Wisconsin, Reinartz and Warne (1993) found higher species diversity in mitigation sites that had been intentionally seeded with wetland species at time of creation (i.e., construction) than in unseeded sites, or ones left barren. Bouchard et al. (2007) found that increasing the number of functional groups planted increased the development of plant root biomass. Other studies have found that plant community development in created mitigation wetlands is closely related with construction elements such as microtopography (Bruland and Richardson, 2005; Moser et al., 2007), altered hydrology (Wilcox, 1995), and soil physicochemical conditions (Dee and Ahn, 2012). These elements, in turn, also affect ecosystem functions such as enhanced carbon storage (Wolf et al., 2011a), nitrogen cycling and removal (Wolf et al., 2011b), soil hydraulic properties (Petru et al., 2013), and wetland microbial communities (Ahn and Peralta, 2009, 2012). Establishment of wetland vegetation during the five years immediately following creation of permitted compensatory mitigation projects is one of the performance standards required by Section 404 of the Clean Water Act and Sections 9 and 10 of the Rivers and Harbor Act [§33CFR 332.6(b)] (Votteler and Muir, 2002; Connolly et al., 2005).

In the present study, carried out in outdoor mesocosms over three growing seasons, we investigated vegetation establishment as affected by IPR. We monitored several structural attributes of vegetation and investigated how the development of these attributes was affected by initial planting richness and hydrologic conditions that are often realistic in large-scale mitigation wetlands created in the Virginia Piedmont. Our main hypothesis was that the community diversity of vegetation in created mesocosm wetlands would be positively impacted by the initial planting richness.

2. Methods

2.1. Mesocosm description and planting

Our experiment was carried out under field conditions for three growing seasons (2010–2012) in a 0.1 ha research site (38°50′3.46″N, 77°19′14.17″W). The site is on a 100 year floodplain adjacent to a stormwater management pond on the Fairfax campus of George Mason University. Twenty 568 l (0.99 $m^2 \times 0.64$ m) elliptically-shaped polyethylene tubs manufactured by Rubbermaid® and placed in this site were used as mesocosms, small outdoor experiment units that are often used to simulate a large-scale wetland (Bloesch, 1988). The mesocosms were buried in the ground to insulate roots against possible freezing (Fig. 1a). Standpipes connected to each mesocosm that rose aboveground allowed visual monitoring of the water level (Fig. 1b). Each mesocosm was filled with 10 cm of river pea gravel on the bottom, topped by 20 cm of commercial garden topsoil, the same kind used in local mitigation wetlands during their construction. The soil was allowed to settle in the mesocosms for several days prior to planting.

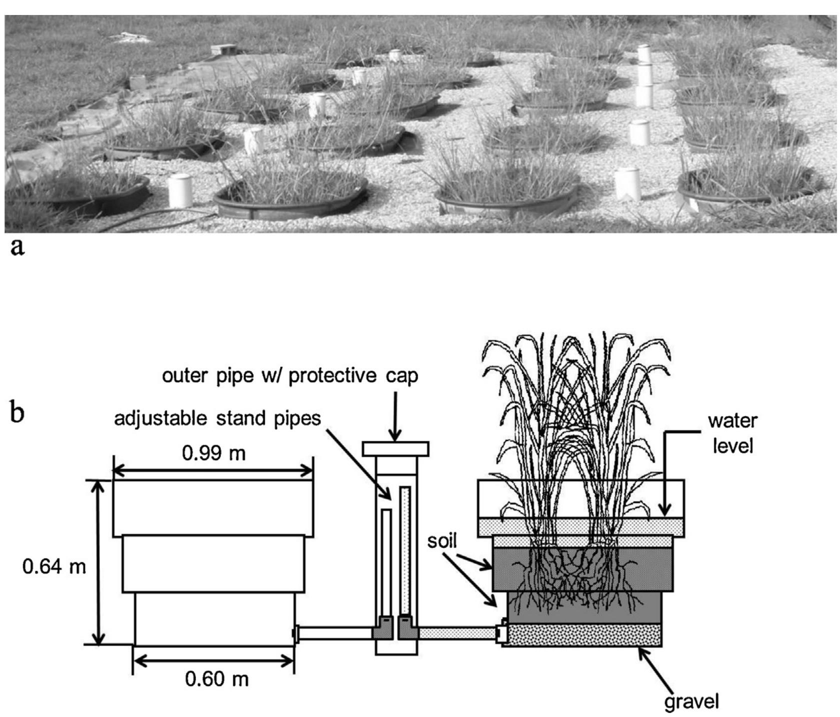

Fig. 1. (a) Study site at the Wetland Research Compound at George Mason University, Fairfax, VA, illustrating the layout and stand-pipe set-ups for the mesocosms used in this study. (b) Mesocosms with stand-pipe set-up allowing monitoring of the water levels in each mesocosm.