Journal of Environmental Management 128 (2013) 371–379

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

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

Effects of sediment removal on vegetation communities in Rainwater Basin playa wetlands

Benjamin J. Beas[a,c,*], Loren M. Smith[a], Theodore G. LaGrange[b], Randy Stutheit[b]

[a] Department of Zoology, 502 Life Science West, Oklahoma State University, Stillwater, OK 74078, USA
[b] Nebraska Game and Parks Commission, 2200 N. 33rd St., Lincoln, NE 68503, USA
[c] Illinois Natural History Survey, University of Illinois, 1816 S Oak St., Champaign, IL 61820, USA

ARTICLE INFO

Article history:
Received 1 May 2012
Received in revised form
23 April 2013
Accepted 30 April 2013
Available online 17 June 2013

Keywords:
Depressional wetland
Exotic species
Nebraska
Plant species composition
Restoration ecology
Trajectory

ABSTRACT

Sedimentation from cultivated agricultural land use has altered the natural hydrologic regimes of depressional wetlands in the Great Plains. These alterations can negatively affect native wetland plant communities. Our objective was to determine if restored wetlands are developing plant communities similar to reference wetland conditions following hydrologic restoration. For this study, hydrology was restored via sediment removal. Thirty-four playa wetlands in reference, restored, and agricultural condition within the Rainwater Basin Region of Nebraska were sampled in 2008 and 2009. In 2008, reference and restored wetlands had higher species richness and more native, annual, and perennial species than agricultural wetlands. Restored wetlands had similar exotic species richness compared to reference and agricultural wetlands; however, reference wetlands contained more than agricultural wetlands. Restored wetlands proportion of exotics was 3.5 and 2 times less than agricultural wetlands and reference wetlands respectively. In 2009, reference and restored wetlands had higher species richness, more perennial species, and more native species than agricultural wetlands. Restored wetlands contained a greater number and proportion of annuals than reference and agricultural wetlands. Canonical Correspondence Analysis showed that reference, restored, and agricultural wetlands are dominated by different plant species and guilds. Restored wetland plant communities do not appear to be acting as intermediates between reference and agricultural wetland conditions or on a trajectory to reach reference conditions. This may be attributed to differing seed bank communities between reference and restored wetlands, dispersal limitations of perennial plant guilds associated with reference wetland conditions, and/or management activities may be preventing restored wetlands from reaching reference status.

1. Introduction

In the U.S. Great Plains, agricultural practices have altered terrestrial and wetland habitats to make way for crop and livestock pastures (Samson and Knopf, 1996). This has ultimately led to changes in ecosystem services provided in these landscapes (Smith et al., 2011a). This is especially true in the Rainwater Basin (RWB) of Nebraska, where up to 90% of the playa wetlands in the region have been drained or modified for agricultural purposes (Stutheit et al., 2004). A stopover site to over 12 million migrating waterfowl, geese, and shorebirds every year, this environmentally sensitive area has been deemed as one of nine areas in the contiguous United States with the highest wetland loss (Tiner, 1984) and contains one of the most threatened and least studied wetland complexes in North America (Smith, 1998).

Throughout the Great Plains, sedimentation from upland erosion of surrounding agricultural fields is the largest threat to the continued existence of properly functioning depressional wetlands (Luo et al., 1997, 1999; Tsai et al., 2007). Playa wetlands, the dominant hydrogeomorphic feature of the RWB, are the lowest point within a watershed and are highly susceptible to sedimentation (LaGrange, 2005; 2011). Excessive sediment loads within wetlands can bury hydric soils, reduce wetland volume, increase surface area, and shorten hydroperiods (Luo et al., 1997; Tsai et al., 2007) ultimately affecting plant species composition. In addition, sedimentation can further alter plant community structure through burial of seed banks (Jurik et al., 1994; Gleason et al., 2003), allow non-native species to colonize an area (Smith and Haukos, 2002), and select for monotypic stands of invasive native or exotic species (Galatowitsch et al., 1999).

* Corresponding author. Illinois Natural History Survey, University of Illinois, 1816 S Oak St., Champaign, IL 61820, USA. Tel.: +1 814 341 1630; fax: +1 405 744 7824.
E-mail addresses: Beas@okstate.edu, beas@illinois.edu (B.J. Beas).

0301-4797/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jenvman.2013.04.063

Removal of sediment from agriculturally impacted wetlands reestablishes the hydric soils and natural hydrology that were present prior to sedimentation. This process is critical in establishing native wetland plant communities (Keddy, 2000). Sediment removal has also been shown to lower nutrient availability (Klimkowska et al., 2007), remove persistent pesticides (Kiehl and Wagner, 2006), remove persistent weedy and invasive species from the seed bank (Constance et al., 2007), remove established vegetation (Kiehl et al., 2006) that prevents the seed bank from contributing to the development of standing vegetation, and restore ecosystem function (Odum and Barrett, 2005). RWB wetland restoration typically involves removing up to 30 cm of sediment, filling irrigation reuse pits, and reestablishing upland buffers to protect wetlands from future sedimentation. These practices should allow recruitment of pre-impact vegetation; however, only seeds persistent in the seed bank prior to impact will initially become established. Other species found will arrive via dispersal. Therefore, a successful hydrologic restoration by the removal of sediment should develop plant communities similar to reference or pre-settlement conditions, or be on a trajectory to reach reference wetland conditions (Galatowitsch and van der Valk, 1996).

Most restored wetlands within the RWB are allowed to revegetate naturally following sediment removal and are assumed to resemble historic conditions or be on a trajectory to reach reference conditions (LaGrange, 2011). Therefore, the objective of this study was to determine if restored wetlands are developing plant communities that are similar to reference wetlands both characteristically and compositionally. We predicted that restored RWB wetlands have developed plant community characteristics (species richness, number of annuals, perennials, native and invasive species, and composition) similar to reference wetlands, as well as similar wetland plant species and guilds.

2. Methods

2.1. Study area

The RWB Region encompasses 15,907 km^2 and includes all or parts of 21 counties on the Central Loess Plains of south-central Nebraska (LaGrange, 2005). The area was named for its abundant natural wetlands that formed where clay-bottom depressions catch and hold precipitation from rain and run-off (Stutheit et al., 2004). Annual precipitation averages 460 mm in the western portion of the region and 710 mm in the east; evapotranspiration generally exceeds precipitation (Stutheit et al., 2004). Playas range from 0.1 ha to 1000 ha in size and are defined by the presence of Massie, Scott, and Fillmore soil series (Stutheit et al., 2004) and are the most notable hydrogeomorphic feature on the landscape. The RWB was originally mixed grass prairie in the western region and tall grass prairie in the eastern region (Kaul, 1975), but presently the region is intensively cultivated with corn and soybeans causing a heavily fragmented landscape. Domestic livestock graze most uncultivated areas.

2.2. Study sites

Thirty-four wetlands were sampled in 2008 and 2009 among three land use treatments: reference standard (from here forward known as reference), restored, and agricultural (defined below). In 2008, 12 reference, 11 restored, and 11 agricultural wetlands were sampled and in 2009, 11 reference, 11 restored, and 12 agricultural wetlands were sampled. Most wetlands were sampled both years (one reference and one restored wetland were removed in 2009, one agricultural wetland was restored in late 2008, and two agricultural wetlands were added in 2009).

Reference wetlands were selected by the Nebraska Game and Parks Commission (NGPC) using the hydrogeomorphic (HGM) approach which is a classification that differentiates wetlands by geomorphic setting, water source and its transport, and hydrodynamics (Brinson, 1993). Reference wetlands selected represented the most highly functioning wetlands within the region based on five primary functions: 1) water storage, 2) cycle nutrients, 3) remove, convert, and sequester elements, compounds, and particles, 4) maintain habitat for characteristic plant communities, and 5) provide wildlife habitat within the wetland (Stutheit et al., 2004). The 12 reference wetlands with the highest functional capacity index (FCI) scores from the NGPC HGM study (Stutheit et al., 2004) were selected. In 2008, 6 of the sampled reference wetlands were seasonal and 6 were semi-permanent. In 2009, 5 were seasonal and 6 were semi-permanent.

Restoration of wetlands impacted by sediment was performed by NGPC, U.S. Fish and Wildlife Service (USFWS), and Ducks Unlimited (DU). Each of these sites was at one time impacted by cropping. Restored wetlands had an average of 30.4 cm of sediment removed from the center and then were graded out to a depth of 10.6–15.2 cm around the perimeter. Due to the limited number of wetlands with the entire basin restored via sediment removal, all wetlands (total of 12) with this restoration technique were used in this study. Restored wetlands sampled in 2008 ranged in age from 2 to 11 years since sediment removal and in 2009 from 1 to 12 years since sediment removal. In 2008, 1 of the restored wetlands was temporary, 6 were seasonal, and 4 were semi-permanent. In 2009, 1 was temporary, 7 were seasonal, and 3 were semi-permanent. Within the RWB, temporary and seasonal wetlands function similarly and are often grouped together as one class.

Agricultural wetlands were surrounded by crop production on at least two sides of the wetland. All sites had upland sediments covering hydric soils (Smith et al., 2011b) and were similar in size to reference wetlands (Appendix A). In 2008, 2 of the agricultural wetlands were temporary, 6 were seasonal, and 3 were semi-permanent. In 2009, 3 were temporary, 5 were seasonal, and 4 were semi-permanent.

2.3. Field studies

We surveyed the vegetation at each wetland once a month from June–August to account for cool- and warm-season species occurrence, high species turnover, and hydrologic variability (Smith and Haukos, 2002). Step-point surveys were used to estimate plant composition and cover (Bonham, 1989) along two parallel transects that ran the length of the longest basin axis, usually northwest to southeast, starting and ending at the basin edge and passing through the center of the wetland. Surveys involved identification of plants encountered at each step, generating point-cover estimates approximately every 1 m. Smith and Haukos (2002) showed that species richness is not correlated with playa size. However, to account for playa size, we generated species accumulation curves (B. Beas, unpublished data). Species accumulation curves indicated that 400 steps were sufficient in encountering 90% of the species present at each wetland site. All wetland sites contained a minimum of 400 steps. Water depth was measured at 10 random locations along each vegetation transect where water was encountered to determine if there were differences in maximum and average water depths among the wetland types. Water depth was measured to the nearest centimeter and averaged for each wetland. In 2008, all sampled wetlands contained water during the growing season. In 2009, 4 reference, 5 restored, and 1 cropland wetland contained water during the growing season, the rest were dry.