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Low Impact Development for Protecting Urban Riparian Ecosystem: Evaluation of Watershed Protection Ordinance in City of Austin, Texas

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Abstract

This study examines the mitigation effect of Low Impact Development (LID) on biological invasions in urban riparian zones. 12 riparian vegetation communities in The City of Austin, Texas were surveyed. The result exhibits that watershed urbanization is positively related to the cover percentage of alien species. The riparian communities in LID watershed are less vulnerable to the invasion of alien species. The cover percentage of alien species in riparian zones of LID watersheds is in average 7.3% lower than the one in non-LID. Accordingly, LID could be a remedy for the control of biological invasion in urban riparian zones.

Keywords
Urban Hydrology, Watershed Urbanization, Biological Invasion

A. Introduction

Urbanization threatens riparian habitats by altering the natural hydrologic regime. Impervious surface along with an engineered drainage system quickly discharges stormwater into downstreams, which in turn results in more frequent floods (Arnold and Gibbons, 1996; Walsh et al., 2005). Meanwhile, urban riparian zone experiences drought during non-storm periods because impervious surface impeded stormwater infiltration and consequently lowers groundwater table (Groffman et al., 2003). Besides the hydrologic impact, urbanization also degrades stream water quality. Increased runoff washes off fertilizers excessively applied to lawns and other pollutants generated by urban activities (Hatt et al., 2004; Schoonover et al., 2005). Other urban structures, such as roads, bridges, and culverts, physically disturb the stream by increasing stream bank erosion (Chin and Gregory, 2001; Jones et al., 2000). Accordingly, urban riparian zone is expected to suffer from harsh environment with flash hydrology, i.e., higher peak discharge but lower base flow, as well as degraded water quality.

Increased disturbances make the urban riparian zones more vulnerable to the invasion of alien species. More frequent floods massacre mature trees, create canopy gaps, and provide the opportunities for seed germination (Bendix and Hupp, 2000). However, the new seedlings in the urban riparian zones compete under more xeric conditions due to the deeper groundwater table. Along with other anthropogenic disturbances, such as elevated nutrient concentrations, vegetation communities in the urban riparian zone are more likely invaded by disturbance-tolerant alien plant species (King and Buckney, 2000; Maskell et al., 2006; Tickner et al., 2001). The consequence of the biological invasion may not be limited the riparian zones *per se* because they protect adjacent stream ecosystems by buffering harmful effects from surroundings (Rodewald and Bakermans, 2006). Many aquatic taxa adapting to the service provided by native riparian vegetations could be affected. In addition, in the arid and semi-arid climate, riparian zone often forms narrow vegetated patch which serves as refuges for regionally rare wetland species (Aguiar and Ferreira, 2005). Altered habitat conditions in the riparian zones result in the extinction of wetland species and significantly decrease the regional biodiversity in the arid and semi-arid climate.

One potential solution is to develop urban watershed with low impact development (LID) strategy. LID is a site design alternative which maintains predevelopment hydrology through various techniques including structural stormwater best management practices (BMPs), porous pavements, and vegetated buffers (US Environmental Protection Agency, 2000; Hood et al., 2007). Since hydrology is one of the most determining factors for the riparian vegetation communities, it is expected that LID preserves native species which adapt to the predevelopment hydrologic regime. However, LID planners and designers focus only on flood mitigation or on in-stream water quality improvement function, which significantly underestimates its benefit. Thus, this study aims to examine the ecological benefit of LID. Specifically, this paper is intended to answer two questions: 1) whether watershed urbanization facilitates the invasion of alien species in riparian zones, and 2) whether LID application mitigates the biological invasion in the urban riparian zones. To evaluate the effect of LID, this study compared riparian vegetation communities in LID watersheds with those communities in conventionally developed watersheds in The City of Austin, Texas.

This paper presents the part of the large project that evaluates the various aspects of watershed-wide LID implementation. Understanding hydrological benefit of LID is another important task of the project. Once it is done, we can provide a comprehensive guideline to assist LID practitioners.

A. Methods

B. Study Area

The study area is The City of Austin in central Texas, which has a long regulatory history to combat against the degradation of water resources. In early 1980s, Austin began to enact a series of watershed ordinances, which were integrated into the Comprehensive Watershed Ordinance (CWO) in 1986 covering all of the city's planning area but urban watersheds. The cornerstone event was The Save Our Springs (SOS) ordinance of 1992, established by citizen's initiative. It is the first ordinance which adopts the non-degradation principle for watersheds hydraulically connected to Barton Springs Zone (BSZ). Currently, the city has five watershed protection zones – urban, suburban, water supply suburban, water supply rural, and BSZ – that are regulated by different levels of impervious cover limit, BMPs, and riparian buffer width (City of Austin, 2008). Since the goal and regulations of SOS meet LID concept, Austin provides a unique quasi-experimental setting to test the effects of LID on stream hydrology and riparian ecology.

B. Data and Analysis

This study surveyed twelve urban riparian zones (six in BSZ and six in other watershed protection zones) in Austin. These sites were selected because United States Geological Survey (USGS) National Water Information system (NWIS) surface water monitoring stations have monitored daily stream discharges since pre-SOS era. Higher order streams which are either dammed or receiving discharges from municipal waste water treatment system (Colorado River) are excluded. Figure 1 illustrates USGS water stations used in this study.

"place Figure 1 about here"
"Figure 1: Locations of 12 USGS water stations in Austin, Texas which has monitored daily stream discharges since pre-SOS era."

Riparian vegetation communities were surveyed using the line intercept method (Caratti, 2006). Two 30 m lines parallel to the edges of streams (one abut and the other 5m apart from the first line) were laid out beginning at 10m downstream from the USGS water station. Unlike the conventional method, this study records species along the lines parallel to the streamline because remnant riparian zones in urban area are often too narrow to establishes the sampling line perpendicular to the stream. Street trees and other ornamental trees were excluded in the survey. In the case that the downstream riparian zones were not accessible due to fences installed by property owners or were significantly disturbed by humans, alternative sampling locations were selected in the following order: 1) downstream riparian zones across the stream from USGS stations, 2) upstream at the same side of USGS stations, 3) upstream across the stream from USGS stations. When sampling upstream vegetation communities, the transect lines are drawn beginning at 10m toward the upstream direction. Lengths and starting locations of transect lines are same as the original sampling scheme. The canopy lengths for all tree and shrub species taller than 1m intersecting the sampling lines were measured to estimate the cover percentage of native/alien species. The cover percentages of two lines at the same site were pooled for the final analysis. Nomenclature and nativity status for each species follow United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) PLANTS database (2008).

To test the effect of watershed urbanization, the percents of impervious surface were measured for each watershed using remote sensing technology. Landsat TM image taken June 07, 2004 were classified using Support Vector Machine (SVM), the state-of-the-art image processing algorithm (Burges, 1998). Watersheds for USGS stations were delineated using BASINS software (US Environmental Protection Agency, 2001). The cover percentages of invasive species were then regressed on the percent of impervious surface. The cover percentages of invasive species were also compared between BSZ and non-BSZ riparian zones to evaluate the ecological benefit of LID.

A. Results

There are 35 tree/shrub species taller than 1m in the twelve study sites. Most common native species include Roughleaf Dogwood (*Cornus Drummondii*), Sugarberry (*Celtis laevigata*), Cedar Elm (*Ulmus crassifolia*), Netleaf Hackberry (*Celtis reticulate*), and Sycamore (*Platanus occidentalis*). Of 35 species, four are aliens: Chinaberrytree (*Melia azedarach*), Japanese Privet (*Ligustrum japonicum*), Chinese Tallow (*Triadica sebifera*), and Chinese Privet (*Ligustrum sinense*). *T. sebifera* is currently listed as noxious plant by Texas (4 TAC §19.300). Although some alien herbaceous species were also found in the study sites, e.g., Giant Reed (*Arundo Donax*), they were not included in the final analysis. *M. azedarach* appears to be the most cumbersome invader in the study area. This species was found at seven study sites. *L. japonicum*, *T. sebifera*, and *L. sinense* are found at four, three, and one of the study sites, respectively.

The result of vegetation survey showed that watershed urbanization facilitates the invasion of alien species in the riparian zones. Shoal Creek located at the urban center of Austin is mostly invaded by alien species. The percent impervious surface is greater than 30 percents of the total watershed for this site. Alien species covers almost 40 percents of the sampling lines. Four sites not invaded by alien species (Plum Creek, Slaughter Creek, Little Barton Creek, and Onion Creek) have less than 10 percent of impervious surface. Figure 2 shows that cover percentages of alien species are positively related to the degree of watershed imperviousness.

“place Figure 2 about here”
“Figure 2: The relation between watershed imperviousness and the cover percentage of alien species”

LID appears to mitigate the biological invasion in the riparian zones. Figure 3 illustrates that the means of the cover percentage of alien species are 7.3% lower in BSZ than in non-BSZ. Three of six BSZ sites, compared to one in BSZ sites, are not invaded by alien species. Two other BSZ sites were also relatively less invaded by alien species (less than 10 percent). Among BSZ sites, Williamson Creek is an exception. At this site, alien species cover 37 percent of the sampling vegetation community. This result may be attributed to the fact that Williamson Creek watershed is most urbanized among BSZ streams. 16 percent of the Williamson Creek watershed is covered by impervious surface.

“place Figure 3 about here”
“Figure 3: The comparison of cover percentage of alien species between BSZ and non-BSZ riparian zones”

A. Discussion and Conclusion

Main findings of this paper are two folds. First, as watersheds are urbanized, riparian zones become more vulnerable to the invasion of alien vegetation species. Second, LID mitigates the adverse effect of urbanization on these ecosystems. Although the result of this paper cannot specify the types of disturbances that cause the biological invasion, it can be argued that, based on the findings of previous researches, the altered hydrologic regime changes the urban riparian zones to those favorable to the biological invasion (Tichner et al., 2001). This argument is further supported by the finding of this paper. Since the SOS ordinance is intended to maintain the predevelopment hydrology, the difference in vegetation compositions between LID and non-LID watersheds could be attributed to the difference in hydrologic regimes. Thus, the finding that the riparian zones in the LID watersheds are less invaded by alien species implies that altered hydrology is a primary factor to facilitate the biological invasion.

Ongoing study on the hydrologic effect of LID may help us understand the complex causal relationship. The result of Williamson Creek seems to suggest that there is confounding effect between SOS regulation and other factors, such as urbanization. To evaluate the net effect of LID, those factors needed to be factored out. This could be done by comparing riparian communities with similar rates of urbanization since SOS ordinance. Once we understand the hydrologic characteristics for each watershed, we will pair LID and non-LID streams based on the similarity of pre-SOS hydrology as well as the changes in urbanized areas since SOS ordinance. Comparing the paired streams will allow us to control for other factors that may influence the invasion of alien species.

The results of this study should be cautiously read. The benefits of watershed ordinance in Austin are still under debates. SOS might be harmful for an overall environment because limiting impervious cover only allows low density development, which facilitates urban sprawl and social segregation (Clark-Madison, 1999). This study does not discuss these issues. Therefore, the results should be interpreted within the contexts of water resource and/or riparian ecosystem managements.

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