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Replacing natural wetlands with stormwater management facilities: Biophysical and perceived social values

R.C. Rooney [a,*], L. Foote [b], N. Krogman [c], J.K. Pattison [d], M.J. Wilson [e], S.E. Bayley [e]

[a] Department of Biology, University of Waterloo, B2-251 Biology, 200 University Ave. W., Waterloo, ON N2L 3G1, Canada
[b] Department of Renewable Resources, University of Alberta, T6G 2H1, Canada
[c] Department of Resource Economics and Environmental Sociology, University of Alberta, T6G 2H1, Canada
[d] Natural Resources Institute, University of Greenwich, ME4 4TB, United Kingdom
[e] Biological Sciences, University of Alberta, Edmonton, AB, T6G 2E9, Canada

ARTICLE INFO

Article history:
Received 14 September 2014
Received in revised form
22 November 2014
Accepted 20 December 2014
Available online 20 January 2015

Keywords:
Agriculture
Constructed wetlands
Ecosystem services
Wet ponds
Wetland health
Wetland services

ABSTRACT

Urban expansion replaces wetlands of natural origin with artificial stormwater management facilities. The literature suggests that efforts to mimic natural wetlands in the design of stormwater facilities can expand the provision of ecosystem services. Policy developments seek to capitalize on these improvements, encouraging developers to build stormwater wetlands in place of stormwater ponds; however, few have compared the biophysical values and social perceptions of these created wetlands to those of the natural wetlands they are replacing. We compared four types of wetlands: natural references sites, natural wetlands impacted by agriculture, created stormwater wetlands, and created stormwater ponds. We anticipated that they would exhibit a gradient in biodiversity, ecological integrity, chemical and hydrologic stress. We further anticipated that perceived values would mirror measured biophysical values. We found higher biophysical values associated with wetlands of natural origin (both reference and agriculturally impacted). The biophysical values of stormwater wetlands and stormwater ponds were lower and indistinguishable from one another. The perceived wetland values assessed by the public differed from the observed biophysical values. This has important policy implications, as the public are not likely to perceive the loss of values associated with the replacement of natural wetlands with created stormwater management facilities. We conclude that 1) agriculturally impacted wetlands provide biophysical values equivalent to those of natural wetlands, meaning that land use alone is not a great predictor of wetland value; 2) stormwater wetlands are not a substantive improvement over stormwater ponds, relative to wetlands of natural origin; 3) stormwater wetlands are poor mimics of natural wetlands, likely due to fundamental distinctions in terms of basin morphology, temporal variation in hydrology, ground water connectivity, and landscape position; 4) these drivers are relatively fixed, thus, once constructed, it may not be possible to modify them to improve provision of biophysical values; 5) these fixed drivers are not well perceived by the public and thus public perception may not capture the true value of natural wetlands, including those impacted by agriculture.

* *Corresponding author*. Tel.: +1 519 888 4567x33820.
E-mail address: rrooney@uwaterloo.ca (R.C. Rooney).

http://dx.doi.org/10.1016/j.watres.2014.12.035
0043-1354/

1. Introduction

Population growth and urban sprawl are on a continuing course of conflict with urban and suburban wetlands. Seventy percent of the world's population is expected to live in urban areas by 2050 (UN-HABITAT, 2008); however, in Canada this is already the case (StatsCan, 2012). The expansion of cities in response to growing urban populations is exacerbated by a global trend of suburbanization and sprawl whereby the surface area of cities grows more quickly than their populations (UN-HABITAT, 2008). The City of Edmonton (Alberta, Canada) is the second fastest growing metropolitan area in Canada: its population grew 12.1% between 2006 and 2011 (StatsCan, 2012) and 93% of Edmonton's growth during that same period was in suburban areas. Urban sprawl contributes to negative social (Clement, 2010) and human health effects (Ewing et al., 2003), as well as environmental degradation (Johnson, 2001). This includes increased carbon emissions (Seto et al., 2010), habitat degradation (Herrera-Montes and Aide, 2011) and water balance and quality issues (Brabec et al., 2002; Haase, 2009).

A concurrent increase in impervious surfaces and loss of natural wetland habitats associated with conversion from agricultural to suburban lands necessitates stormwater control measures (Bodnaruk et al., 2012). Wetlands are effectively replaced by constructed living spaces and excavated water holding facilities for runoff capture. For example, Edmonton estimates that 80% of wetlands have been lost from within its corporate boundary as a result of urban and suburban expansion (ONA, 2008).

Since the 1980s, the City of Edmonton has adopted a retention and channelization approach to stormwater management, using two types of stormwater management facilities linked to underground conduits to control flooding following heavy rainfall: stormwater ponds and naturalized stormwater wetlands (i.e., constructed wetlands). These stormwater management facilities currently process stormwater from 8800 ha or 26% of Edmonton's urban footprint (Edmonton, 2010). Stormwater ponds and wetlands are almost exclusively a feature of suburban developments as municipalities have tasked developers with capturing first pulse rainfall runoff in the last 30 years. These runoff-capture facilities have also been re-cast as an aesthetic amenity for suburban dwellers, with terms like “lake-front property” and “homes with close proximity to park areas.”

Stormwater ponds are more common than stormwater wetlands and typically consist of large open water areas with steep-sided slopes and minimal wetland vegetation, occasionally with bank stabilization of cobbles, brick or rip-rap and often surrounded by park-like landscaping. During the last decade, developers have been encouraged to build stormwater wetlands (Bodnaruk et al., 2012), which are designed to resemble natural wetlands with more gently sloping shorelines, increased emergent vegetation, and less open water area (see summary in Table S1).

The province of Alberta released a new wetland policy in September 2013, which is representative of the move towards value-based management of wetland resources currently taking place in many jurisdictions as the importance of ecosystem services is recognized (e.g., Eigenbrod et al., 2011; Marlow et al., 2013). This policy gives partial compensation credit for destroyed or altered wetlands to developers who build stormwater wetlands in place of stormwater ponds (GoA, 2013). The justification provided for this credit is the presumed provision of ecosystem services. Moore and Hunt (2012), for example, demonstrated that stormwater wetlands provide increased carbon sequestration and plant diversity relative to stormwater ponds.

However, these stormwater wetlands and ponds are replacing natural wetlands in peri-urban lands (e.g., Fig. S1), begging a comparison of stormwater management facilities and natural wetlands, not just a comparison between stormwater wetlands and stormwater ponds. We compared both stormwater ponds and stormwater wetlands to naturally occurring wetlands in agricultural and protected reference areas. Based on previous studies (e.g., Moore and Hunt, 2012; Wilson et al., 2013a,b), we hypothesized that these categories would exhibit increasing “biophysical value” in the form of increased biodiversity, biological integrity, and reduced environmental stress in the following order: created stormwater ponds, created stormwater wetlands, agriculturally impacted wetlands of natural origin, relatively undisturbed wetlands of natural origin. We name these wetland attributes values in recognition of their benefit to humans (Novitzki et al., 1996).

In any assessment of stormwater management facilities as compensation for natural wetlands, their value to the public cannot be simply confined to biophysical contributions because cultural, economic, aesthetic and security features of landscape types are also considered in policy formulation. Furthermore, while the public's awareness of ecosystem goods and services is broadened through more frequent discussion in schools, the media, policy debates and neighbourhood politics, most of the public likely lacks a critical level of basic knowledge about wetland ecosystem goods and services (Lewan and Soderqvist, 2002; Manuel, 2003) and the differences between natural and created wetlands.

There are substantive differences between natural and created wetlands. For example, stormwater management facilities are surface-water fed systems required to be totally isolated from groundwater by liners. In contrast, most natural wetlands in our study region are highly variable headwater wetlands with some degree of groundwater connection. Runoff is minimal because soil storage capacities and potential evapotranspiration rates are usually high (Hogg, 1994), but many serve as either recharge or discharge sites for groundwater (Holden, 1993). Whereas stormwater management facilities are typically weir-controlled and possibly overstabilized leading to altered vegetation (Wilcox et al., 1985), natural wetlands experience dramatic inter-annual differences in drying and wetting and open water storage, providing a myriad of niches. Do these fundamental differences affect ecosystem values in created wetlands?

Our objectives are twofold. First, we compare the biophysical values of natural wetlands to those associated with stormwater ponds and stormwater wetlands. Second, we compare resident perceptions of ecological services of natural wetlands and stormwater ponds with their biophysical values. The second objective is complementary to the first because it allows us to compare scientific assessments with