University of Alberta

Assessing Riparian Health of Astotin Creek of Central Alberta

by

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Abstract

Astotin Creek links two important conservation areas in central Alberta, Edmonton's North Saskatchewan River valley and Elk Island National Park. This study investigated the effects of riparian land use and geomorphological characteristics (i.e., riparian structure) on riparian health of the creek and the variation among up-, mid-, and downstream reaches of the conservation corridor. The results showed that riparian forest, road construction, and channel slope, are among the most critical factors to the poorest health condition of the riparian corridor found ~ 20 km from the headwaters. The variation analysis revealed that land use dominated riparian health and fluvial geomorphology throughout the corridor, while the effects of geomorphological variables on riparian health were relatively weak. In addition, it was found that relatively strong responses of riparian health to structural changes tend to occur upstream and at the midstream. Due to the changes, the up- and midstream connectivity of the corridor may have a stronger effect on the ecosystem than the downstream connectivity. This study has important implications for conservation of Astotin Creek, including (1) the priority of corridor protection located ~ 20 km from the headwaters; (2) the reduction of land use pressure in the up- and midstream of the creek while being mindful of downstream protection.

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CHAPTER I.

Introduction to the landscape pattern of riparian corridors

1.1 General background

For decades, landscape ecologists have been interested in understanding the ecological processes underlying the observed landscape patterns, especially in spatial transition zones, such as riparian landscape. Riparian landscapes are dynamic zones possessing their own properties (Naiman & Decamps, 1990). The unique characteristics of riparian landscapes lie in the presence of the interactions between adjacent systems where water flow plays a key role in connecting riparian habitats. More recently, "riparian landscape" refers to a field of research that examines the ecological systems of streamside and floodplain areas from the perspective of landscape ecology (Malanson, 1993). It has become an important component in landscape ecology since the role of riparian landscape in sustaining biological integrity of both aquatic and terrestrial systems has been increasingly appreciated (Amoros & Bornette, 2002; Gregory *et al.*, 1991; Jones *et al.*, 2004; Meador & Goldstein, 2003; Naiman *et al.*, 1993). Therefore, it is of practical significance to address landscape pattern of a riparian corridor, formed by a stream channel, together with its streamside and flood plains.

1.1.1 Landscape elements and spatial context of riparian corridors

The concept of landscape elements is now becoming the common language in landscape ecology to characterize landscape structure. These elements include patches, corridors, and matrix (Forman & Gordon, 1986; Bernard & Tuttle, 1998; see Fig. 1.1). Patches refer to the areas differing from their surroundings in biotic/abiotic composition and function and can be distinguished by their origins, sizes, and shapes (Forman, 1995). Corridors are usually defined as the relatively narrow strips of particular cover types that differ from adjacent areas on both sides (Forman, 1995). Like patches, corridors can be distinguished by their origins, sizes (length/width), and shapes (sinuosity). The matrix is the background cover type in a landscape, characterized by the largest area, the greatest connectivity, or the most dominant element of land surface (Forman, 1995). Some landscapes may have no definable matrix. Patterns of patches and corridors within a matrix indicate overall heterogeneity of a landscape, which operates to affect the flows of energy, matter, and species and their interactions (Forman & Gordon, 1986). The central theme of landscape ecology is thus to study the feedback between spatial pattern and ecological processes (Turner *et al*, 2001). In the present study, I used the basic concepts of landscape heterogeneity to describe a riparian corridor and to evaluate the spatial relationship.

Before proceeding further, it is necessary to define riparian structure by using landscape elements. Riparian structure is a complex mosaic of landforms that are characterized by the terrestrial-aquatic interface and can be seen as the combination of two landscape elements: patches and corridors. These elements have been widely used to describe riparian landscapes (Amoros & Bornette *et al.*, 2002; Gregory *et al.*, 1991;

Malanson, 1993; Roth *et al.*, 1996; Ward *et al.*, 1999), although few studies have quantitatively combined the spatial patterns of patches with a corridor to characterize the overall heterogeneity. Hence, the present study would focus on a riparian corridor including both a stream channel (a corridor) and its riparian zone (patches). Typical riparian patches commonly include both natural and human features, such as distinct vegetation (i.e., forest, shrub land, or grassland patches), wetlands, residential development, and agricultural areas (FISRWG, 1998). The spatial structure of a stream corridor can be described by channel shape (i.e., length/width), channel pattern (i.e., sinuosity), and channel form (i.e., slope) (Malanson, 1993).

Within the spatial context of a riparian corridor, tracking the structural changes from upstream to downstream would be a basic step for understanding riparian ecosystems and their values in biodiversity conservation. Gregory *et al.* (1991) have noted the importance of a riparian corridor in a landscape setting. They emphasized the linear spatial configuration and its role in maintaining the interaction of a riparian zone with its surrounding ecosystems. A riparian corridor should be regarded as a functionally dominant feature that contains riparian patches connected with a stream corridor. Indeed, riparian corridors have been known to facilitate connectivity by linking habitat patches in the matrix to form migration and dispersal routes for species (Bennett, 1999; Forman, 1995; Gregory *et al.*, 1991; Haddad, 1999; Naiman *et al.*, 1993; Ward & Stanford *et al.*, 1995b). Many studies have suggested landscape connectivity can substantially increase heterogeneous habitats to sustain a high diversity of flora and fauna (Amoros & Bornette *et al.*, 2002; Bornette *et al.*, 1998; Iwata *et al.*, 2003; Robinson *et al.*, 2002; Van Looy *et al.*, 2006; Ward *et al.*, 1999).

Another important aspect of riparian corridors is the complex interaction of riparian structure (i.e., the stream corridor and riparian patches) and the spatial effect of the interaction on riparian systems is not yet clear. Although it is well known that fluvial processes operating along a riparian corridor can affect the spatial development of the stream channel and riparian patches (i.e., riparian structure) (Amoros & Bornette, 2002; Bornette *et al.*, 1998; Gregory *et al.*, 1991; Johnson, 2000; Nanson & Beach, 1977; Tabacchi *et al.*, 1998; Tucker *et al.*, 2006; Turner *et al.*, 2004; Van Looy *et al.*, 2006), the spatial effect of interactive riparian structure on a riparian corridor has not been commonly stressed. Many ecological studies have attempted to achieve a predictive knowledge of a particular type of ecosystem, without consideration of its size or position in a broader mosaic (Turner *et al.*, 2001). However, conservation strategies for riparian corridor protection and restoration often demand the understanding of spatial context to locate the most critical factors causing riparian deterioration. This can be achieved by investigating the spatial interaction of riparian structure and its effect on riparian systems.

1.1.2 Effects of connectivity on riparian systems

Connectivity of a riparian corridor is a great asset for biodiversity conservation due to its unique role in connecting various habitats and protected areas, as increasingly fragmented landscapes have become a major concern (Forman 1995; Pringle *et al.*, 2001; Rosenberg *et al*, 1997; Tewksbury *et al*, 2002; Wilson, 2000). Connectivity is an important feature that can be characterized by riparian structure in riparian ecosystems (Amoros & Bornette, 2002; Bornette *et al.*, 1998).`

Riparian systems are very complex along a riparian corridor where ecological, geomorphological, and hydrological processes interact (Malanson, 1993). The systems need to be in a delicate balance, and the changes in any one of the processes have cascading effects on the systems (NWCC, 1998). For example, stream power, sediment load, and channel roughness must be in balance. Hydrologic changes that increase stream power, if not balanced by greater channel complexity and roughness, would result in excessively eroding banks or stream bottom. The changes that increase sediment load beyond the transport capacity of the stream lead to deposition and lateral channel movement into stream bank and channel widening. The cascading effects can be transmitted through hydrologic connectivity along riparian corridors and interact with riparian structure.

Riparian systems have been noted to have benefit from increased complexity in physical structure (Gregory *et al.*, 1991; Malanson, 1993; Robinson *et al.*, 2002; Rot *et al.*, 2000; Tabacchi *et al.*, 1998). Structural complexity for streams can be formed by trees fallen into the channel, overhanging vegetation, sinuous channel, and a variety of bottom materials. For flood plains, it can be heterogeneous vegetation coupled with different layers and the way that lateral channel movement interacts with riparian patches. Such complexity closely related to strength of hydrologic connectivity maintains habitat quality for organisms and rehabilitates the balance of riparian dynamics with time. By recognizing the effects of connectivity on riparian systems, the feedback relationship between riparian structure and fluvial processes can be better understood in the present study.

1.1.3 Riparian structure and health assessment

In order to investigate the structural changes of the complex landform along a riparian corridor, riparian land cover and channel morphology are used to describe the characteristics of the terrestrial-aquatic interface. Noticeably, these two aspects of structural changes are usually disturbed by human activities, in terms of land use and channel alteration. Human impact has frequently intervened in riparian functions and downgraded conservation value of riparian landscapes (Alberti, 2005; Allan, 2004; Busse *et al*, 2005; Cuffney *et al.*, 2000; Forman & Deblinger, 2000; Gergel *et al.*, 2002; Gregory, 2006; Harding *et al.*, 1998; Jones *et al*, 2004; Opperman *et al*, 2005; Pringle, 2001; Strayer *et al*, 2003). Human activities on riparian landscapes, such as deforestation, cropping, grazing, and road construction, have directly impaired connectivity by creating barriers and converting habitats into smaller and less heterogeneous patchiness. The consequence of these activities is to seriously reduce structural complexity and increase the isolation of small populations that leads to their elevated risk of extinction (Bennett, 1999; Brothers & Spingarn, 1992; Newmark, 1987; Rosenberg *et al*, 1997; Wilson, 2000). Therefore, the inclusion of land use in land cover is vital not only to reflect riparian patches on landscape surfaces, but also to detect human impact on riparian systems.

As the performance of riparian function is considered as the outcome of the interaction among ecological, geomorphological and hydrological processes, one may assess the performance reflected in the physical environments of riparian corridors. Key functions of a riparian corridor include: (1) trapping/storing sediments and nutrients (N, P, etc.), (2) recharging aquifers, (3) sustaining bank stability, (4) filtering/buffering water and (5) maintaining biodiversity (Fitch *et al* 2001). In order to link a visual assessment of the physical condition to the performance of these key functions, they are categorized according to how they physically present on the landscape surface (for more details, see Subsection 2.2.1 Health assessment).

The first and second functions are relative to channel alteration. Channel engineering usually imposes dikes or levees on streams or rivers, but these constructions restrict flood plain width and/or prevent access to the flood plain (Hood, 2004). The channelization reduces infiltration due to decline of the frequency and extent of floodplain inundation, so aquifers narrowly store and hold water (Ward & Stanford, 1995b). Furthermore, it interrupts fluvial equilibrium leading to excess sediment and actively down cutting (Reed *et al.*, 2006).

The third function, sustaining bank stability, depends on the balance with erosion. Unstable banks typically are higher than active flood plains as a result of excess erosion. The common symptom of the instability is the outside bends of stream meanders actively eroding. The eroding surfaces of the banks are often not protected by a large proportion of trees or plants with deep roots (Pimentel & Kounang, 1998). The fourth and fifth function, filtering/buffering water, can be evaluated by the width a vegetation buffer extends on each side of banks. Riparian plants can intake and absorb nutrients and contaminants, thus improving water quality by functioning as a bio filter (Jones *et al*, 2004).

Lastly, the fifth function, maintaining biodiversity, is considered to represent the condition of riparian vegetation and canopy cover. Abundant vegetation can sustain livestock, fish, and wildlife by forming heterogeneous habitats. Shade cover is especially important for fish by providing suitable microclimate and shelter, maintaining stream temperatures, and supplying large woody debris (Roy *et al.*, 2005; Stauffer *et al.*, 2000; Wang *et al.*, 2003). With consideration of these key functions, riparian health can be visually assessed based on the physical conditions. Once we know riparian health, we have a way to link its structural pattern in order to understand the riparian system and improve our management actions

1.2 Study site: a riparian corridor of Astotin Creek

The present study was conducted along Astotin Creek, located about 60 km northwest of Edmonton, Alberta, Canada (Fig 1.2). The headwater of the creek is Astotin Lake within Elk Island National Park, draining into the downstream of Beaverhill Creek that empties into North Saskatchewan River. The study site was defined along the riparian corridor of Astotin Creek extending from Astotin Lake (53°41′N, 112°52′W) to the junction (53°51′N, 112°56′W) with Beaverhill Creek, before North Saskatchewan River (Fig. 1.3). The length of the extracted corridor was approximately 36.5 km and the width was 100 m from the centre line to each side of the creek. The background knowledge of ecoregion and current environmental conditions in terms of topography, climate, and human impact can help interpret the spatial relationship between riparian structure and health assessment for the riparian corridor of Astotin Creek.

1.2.1 Ecoregions

The riparian corridor is located in the Aspen Parkland ecoregion (Fig 1.4), which is a climatic and ecological transition zone between boreal forest and grassland environments (Strong, 1992). According to Strong (1992), the dominant types of vegetation include aspen forest (15% of the land) with grass and shrub communities composing the remaining cover. In the southern portion of the ecoregion, aspen patches are dotted on the grassy landscape where moisture is adequate to maintain tree growth throughout the growing season. Such sites are mostly north-facing slope, seepage areas, depressions, and creek banks.

The Aspen Parkland is one of the most productive agricultural zones in Alberta, producing livestock along with forage and annual crops of cereals and oil plants; as a result, less than five percent of the Aspen Parkland remains as natural habitat. Remnant natural parkland tends to occur in areas that are not suitable for arable agriculture, such as river bottomlands, wetlands, and dune fields. The wetlands and adjacent uplands of Aspen Parkland constitute an important waterfowl production area (Strong, 1992).

1.2.2 Topography and climate

The elevation along Astotin Creek varies from 716 m to 614 m downstream. The general characteristics of topographic Map Sheet 83H, given by the Canada Land Inventory (http://geogratis.cgdi.gc.ca/CLI/mapping/descriptions/edmonton.html) indicates that soils in about 65% of the area have developed on glacial till, 25% have developed on lacustrine deposits, and 10% on alluvial and aeolian deposits.

Moisture availability peaks in the late summer (July) with about 70% of the annual precipitation (45 mm) falling during the growing season. Snowfall tends to accumulate from November to March and then runoff occurs over a short period of rapidly rising temperatures in March-April. All other months have more evaporation than precipitation. In the summer there is little runoff except during exceptionally high rainfall events, such as thunderstorms. As a consequence, Astotin Creek tends to be an intermittent stream.

1.2.3 Human impacts

In pre-evergreen times, wet upland landscapes were dominated by prairie ponds, marshes, bogs and shrub-lands before the landscapes were converted to agriculture. Dry upland landscapes were dominated by aspen and white spruce while the valleys were dominated by balsam poplar and white spruce. Fires were an important regime changing the aspen and grass vegetation. Since extensive agricultural use is the primary impact throughout the region of Astotin Creek, lands for crops and pastures have led to soil erosion and nutrient runoff (Jones *et al.*, 2004). In non-crop lands, grazing pressure usually converts the natural vegetation to a mixture of Bluegrass and other non-native vegetation (Mandryk & Wein, 2006).

In addition, stream-road crossings affect wetlands, streams, plants, wildlife, amphibians and birds (Forman & Alexander, 1998; Forman & Deblinger, 2000; Forman *et al.*, 2003). Along Astotin Creek, there are in total 28 road crossings, including two railroads crossing the creek and nineteen crossings are bridges, while the rest of them culverts at approximately one mile intervals. Recreational use by vehicles, such as quad bikes, snow mobiles and mountain bikes, is also evident in the riparian areas.

The clearing of trees close to the creek due to the increase of riparian land use can cause profound influences on riparian systems (Gregory *et al.*, 1991; Lees & Peres, 2007; Roy *et al.*, 2005; Tabacchi *et al.*, 1998; Turner *et al.*, 2004). Fee clearing also affects beaver populations that use aspen for food and dam-building materials. Beaver dams capture the spring runoff, essentially extending the stream flow later into the summer. Although in treed areas beaver are still active in the riparian areas, with fewer poplar trees, fewer beavers can be supported to slow runoff and summer rainfall. As a result, the stream flows become more intermittent. In summary, decreased riparian forest and riparian land use of cropland, grazing, and construction, including all types of roads and farm buildings, would negatively affect the riparian corridor of Astotin Creek.

1.3 Objectives and thesis overview

The objectives of this study are to investigate the spatial patterns of riparian structure of Astotin Creek and to connect the observed patterns with riparian health in order to understand the riparian system affected by land use at the corridor scale. In the first data chapter, the spatial patterns of riparian structure were quantified along Astotin Creek. The relationships between measures of riparian structure and riparian health were analyzed. In this study, the riparian structure was defined by riparian land cover (in terms of forest conversion to land use) and channel morphology (i.e., meander belt width, sinuosity, and channel slope). The riparian health was visually assessed based on the physical characteristics of the riparian corridor, in terms of channel alteration, bank stability, riparian vegetation, and percentage shade on the water surface.

In the second data chapter, I investigated spatial variation of the effects of the structural changes on riparian health. Astotin Creek was partitioned into the up-, mid-, and downstream reaches to examine the variation. Based on the variation, responses of the health to the structural changes should provide information about the trend of the effect of corridor connectivity on the riparian ecosystem from upstream to downstream and help detect the reach of the creek with the most deteriorated health.

Chapter 4 synthesized the results derived from the two data chapters (2 and 3). Management implications of this study and improvements to future studies are discussed.

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