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A river runs through it: Land-use and the composition of vegetation along a riparian corridor in the Cape Floristic Region, South Africa

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ABSTRACT

Riparian zones are important for the many ecosystem services they supply. In settled areas, the vegetation of such zones is shaped by human land-use; this often creates conditions under which alien plant species thrive. Alien plants have been shown to induce large-scale changes in riparian habitats, and they pose a major threat to the continued provision of key ecosystem services. We used direct gradient analysis to assess correlations between land-use and the composition of vegetation along a riparian river corridor in the highly transformed landscape surrounding Stellenbosch in South Africa's Western Cape Province. Vegetation plots were sampled along the entire length of the river from headwaters to estuary (ca. 40 km). Plant community composition was analyzed in relation to land-use data collected in the field, and additional land-use variables computed from digital land-cover data. Patterns of plant community structure were found to be directly related to land-use, with measures of cover, richness, and diversity differing significantly among land-use types. Portions of the riparian zone adjacent to agricultural land had the greatest level of alien plant cover, while areas bordered by urban land maintained the highest alien species richness. Areas adjacent to grazing and natural lands showed intermediate and low levels of invasion, respectively. Several native species were found to persist in areas with high abundance and diversity of invasive alien plants, suggesting that they will be valuable focal species for future restoration attempts. Due to the level of human-mediated change in many areas of the riparian zone, restoration to historic conditions over most of the river is not considered feasible. These areas should be recognized as examples of novel ecosystems, and management efforts should focus on restoring or creating desirable ecosystem functions, rather than on achieving assemblages comprising only native species.

1. Introduction

In many human-transformed landscapes, riparian zones represent the last remaining areas of semi-natural habitat. These zones provide important ecosystem services, including riverbank stabilization, nutrient cycling, flood attenuation, regulation of stream flows and stream temperatures, groundwater recharge, and water purification (Kauffman et al., 1997; Tickner et al., 2001). Riparian habitats also provide refuge for wildlife in urban and rural areas and act as corridors for movement of species and transport of plant propagules (Forman and Godron, 1986; Naiman and Decamps, 1997; Botkin and Beveridge, 1997). In many areas, riverine corridors play a key role in planning for conservation in the face of global climate change, both to safeguard routes for migration and to allow for exchange between inland and coastal biotas (Rouget et al., 2003). Riparian areas increase the aesthetic value of agricultural and urban landscapes and expand opportunities for outdoor activity (Postel and Carpenter, 1997). These services are of particular value in developing areas of the world, where many people rely upon rivers for irrigation, drinking water, and recreation.

With the possible exception of recreation, all of these ecosystem services are ultimately governed by the composition of vegetation along riparian zones (Naiman and Decamps, 1997; Sweeney et al., 2004). As riparian zones are the focus of concentrated human activity, this vegetation is very often shaped by human-mediated disturbances (Holmes et al., 2005). Intensive land-use along riparian areas may lead to increased soil erosion and sedimentation in rivers, increased nutrient inputs, and increased availability of physical resources such as light (Davis et al., 2000; Holmes et al.,

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2008). Coupled with reduced flooding as a result of water impoundment or abstraction, human-usage factors may be responsible for creating ideal conditions for the establishment, proliferation and spread of alien plants (Richardson et al., 2007). Such species often attain high densities, and are frequently associated with degradation of riparian habitats (Richardson et al., 2007; Holmes et al., 2008). Among the many changes associated with invasion of alien plants in riparian areas are: alteration of river channel morphology (Rowntree, 1991), reduced recruitment of native species as a result of changes in canopy cover (Galatowitsch and Richardson, 2005), and increased transpiration leading to reduction in flows (Dye and Jarmain, 2004). Alien plants can further reduce key ecosystem services provided by riparian zones by affecting flood patterns, water table levels, and soil moisture conditions (Tickner et al., 2001). Concurrently, anthropogenic activity in the surrounding landscape may facilitate growth of alien plant populations by modifying environmental conditions and establishing new sources of propagules (Hobbs, 2000; Foxcroft et al., 2007, 2008). Despite these connections, few attempts have been made to assess the effects of land-use on patterns of alien invasion in riparian zones.

It is important to understand how anthropogenic activities affect riparian areas so that informed decisions can be made regarding management, conservation and restoration of these habitats. As so few studies have addressed the impact of surrounding land-use on the structure of riparian ecosystems, there is very little scientific foundation on which to base objective recommendations for mitigation. Human-mediated changes have often led to a complex gradient of land uses adjoining riparian ecosystems. In order to study how this gradient of land uses affects patterns of biodiversity, it is useful to employ the process of direct gradient analysis (Whittaker, 1967). Direct gradient analysis addresses the composition and function of ecosystems in relation to a set of external environmental variables. Performing direct gradient analysis in a landscape characterized by anthropogenic disturbance allows an examination of the role of land-use in explaining ecological patterns (McDonnell and Pickett, 1990). Knowledge garnered from such studies can then be utilized for the institution of effective riparian corridor management.

This study aims to examine changes in riparian plant community composition along a gradient of land-use types (natural, urban, agricultural, and communal grazing) for the Eerste River corridor located in the Cape Floristic Region of South Africa. Specific goals of the study are to: (1) assess whether riparian plant composition is influenced by adjacent and surrounding land uses; (2) determine whether patterns of alien plant composition can be explained by these human-usage characteristics; and (3) to identify species of native riparian plants that persist in areas of high alien invasion.

As with any study of land-use along river systems, specific correlations between vegetation structure and land-use will always vary in riparian zones across different landscapes. The Eerste River has a particular spatial configuration of land-use, and the patterns of plant community structure found along the Eerste River may not occur in riparian areas with different land-use sequences. Nevertheless, the Eerste River provides a classical example of river systems in mediterranean-climate regions which often have relatively pristine upper catchments, but have been heavily transformed by anthropogenic activities in the lower reaches of the river. As such, the concepts and patterns presented here should be of interest to managers of riparian areas in other mediterranean-climate zones. Furthermore, we know of no other study that has explored these issues in detail along the entire length of a river; this study will therefore be useful as a baseline for further research and comparison.

2. Methods

2.1. Study area

The source of the Eerste River lies in the Jonkershoek Mountains at an altitude of 530 m, approximately 60 km east of Cape Town in the Western Cape Province of South Africa. From Jonkershoek, the river flows in a north-westerly direction into the town of Stellenbosch, where it turns south and ultimately discharges into the Atlantic Ocean in False Bay at Macassar (Fig. 1). The Eerste River is approximately 40 km long, with a catchment area of 420 km^2. Along its route to Macassar, the river receives flows from several major tributaries, with bank-to-bank width increasing from an average of 5 m near the headwaters to an average of 14 m in the lower river zone. The average gradient of the river ranges from 24 m/km in the mountain stream zone to an average of 2 m/km in the lower reaches of the river (King, 1981). The Eerste River catchment lies in a mediterranean-climate zone with hot, dry summers and cool, wet winters. At 4000 mm per annum, the upper reaches of the river receive some of the highest recorded rainfalls in South Africa, while the lower reaches receive as little as 570 mm per annum (DWAF, 2004).

The landscape surrounding the Eerste River supports a number of land uses including various forms of agriculture (vineyards, orchards, and crop production), commercial forestry, and communal grazing, as well as domestic use in highly urbanized residential areas. Stellenbosch (human population ca. 117,000) is the main urban area along the river, with additional urban development present in Macassar. Currently, forestry plantations of *Pinus radiata* exist in the landscape surrounding the upper reach of the river, although a wide buffer zone of natural fynbos vegetation has been maintained between the river and plantation areas. Approximately the first 6 km of the upper river is bordered by natural vegetation and relatively unaffected by human influence. Since 1981, the upper reach of the river has been regulated by the Kleinplaas Dam, above which the Eerste River is perennial (DWAF, 2004). The Kleinplaas Dam overflows during winter, and compensation releases are made from the dam during summer to provide water for downstream users. The river is canalized in places as it flows through the town of Stellenbosch, after which it is joined by the Plankenburg River. At this confluence, water is abstracted by the local Irrigation Board, which has an additional abstraction point just above the confluence with the Blouklip River. The river is subject to further abstraction by owners of riparian properties for most of its length. Treated municipal effluent from the Stellenbosch Waste Water Treatment Works enters the river through the Veldwagters tributary. Below the confluence of the Veldwagters and Eerste Rivers, this treated effluent is a major component of river flow during the summer months (DWAF, 1993).

2.2. Field sampling

A detailed survey of the vegetation of the riparian zone was undertaken along the entire length of the Eerste River from headwaters to near the estuary. Field data were collected between mid-September and mid-December 2008 (i.e. spring), during which time most herbaceous species should be apparent. Plots were paired at intervals of 500 m along both banks of the river, for a total of 150 plots. In order to capture all species of regular occurrence, plot sizes were adjusted depending upon structure of the vegetation community at each plot location. Herb-dominated communities were sampled with plot areas of 20 m^2, shrublands/thicket with an area of 50 m^2, and forest communities with an area of 100 m^2. Plots were primarily rectangular in shape, with the longest edge placed perpendicular to the river. Decisions regarding plot