Projecting the Spread of an Invasive Species in an Urban Park Using Historical Spread Rates and a GIS

David Boschman[1,2], Joseph Piwowar[1], Julia Siemer[1]

[1] Department of Geography, University of Regina
[2]Corresponding Author, E-mail address: boschmad@uregina.ca

Abstract

Habitat conservation areas within cities and urban parks provide educational and recreational opportunities, in addition to providing many ecosystem services that increase the quality of life for urban residents. Invasive species are recognized as one of the most significant threats to ecosystem functioning, global biodiversity and a main component of human induced environmental change. In order to assess the risk posed by an invasive species it is vital to have knowledge of the rate in which it is spreading. Geographic Information Systems (GIS) are a common tool for modelling plant spread and distribution. Common GIS modelling methods are based on parameters of habitat characteristics that often neglect the importance of the rate of spread, or mathematical models that often neglect the spatial element of an invasion. A simple, projective GIS model is developed based on the dynamics of the historical spread rates calculated from the historical spatial extent of *Caragana arborescens*, an invasive shrub in the Habitat Conservation Area of Wascana Centre, Regina, Saskatchewan. The GIS model produces lower projections of future distribution than produced by regression models. This is accredited to the GIS's ability to incorporate spatial limitations on *caragana* spread whereas the regression models assume unrestricted growth. These methods can be useful in studies of relatively small, homogeneous areas, where spatial limitations may be a factor or of small isolated population of an invasive species.

Background and Relevance

The spread of invasive plant species has been identified as "one of the most significant threats to global biodiversity and ecosystem functioning" (Underwood et al., 2003). Many introduced species that proliferate in a new ecosystem can alter fundamental ecosystem structure and nutrient and resource flows, thus causing cascading detrimental effects for the native species in the ecosystem (Crooks, 2002).

The Waterfowl Park Habitat Conservation Area of Wascana Park in Regina, SK. is approximately 13-hectares in size and has been left relatively undisturbed for over thirty years. The area is home to numerous native marsh species along the shores of Wascana Lake, as well as many native prairie plant species further inland. There are also a variety of introduced species that flourish in the area, the most noticeable of which is *Caragana arborescens*.

The effects of urban parks have been well studied; these effects may include: health benefits to the individual residents who use the park (Ulrich, 1981; Kaplan, 1983), economic benefits to the city (Chiesura, 2004), educational opportunities and various beneficial environmental services and functions (Livingston *et al.*, 2003; Cornelis and Hermy, 2004). If the ecosystem integrity of Wascana Park is compromised, the benefits it provides to the city of Regina and its residents will also be compromised.

Geographic Information Systems (GIS) are commonly used to analyse resource management issues. This tool for exploring spatial information can be effectively used to study the explicit spatial dimension associated with an invading plant species. Many studies that use GIS to predict the future spread of a species identify a combination of habitat parameters (soil type, slope / aspect, drainage features etc.), associated with the current known distribution of the species and then use the GIS to identify other areas with a similar combination of habitat parameters to predict other locations where the species may be found, or where it may spread to (Rouget *et al*., 2002; Guisan and Zimmermann, 2000). This method is effective over large study areas, with heterogeneous topography and habitat parameters and requires large amounts of data and complex statistical analysis. This method is not as effective for small isolated populations common to urban parks. While the focus of most studies pertains to relatively large areas, it has been suggested by Higgins, (2000) that targeting the small, isolated populations of invasive species is the most cost effective way of controlling the invasion.

Methods and Data

The data used in this study consisted of six georeferenced, remotely sensed images (digitized aerial photographs and high resolution satellite images) of the study area for the years 1968, 1978, 1989, 1999, 2002 and 2005. Polygons outlining the extent of the *caragana* for each year were created through on-screen digitizing of each image using ESRI's ArcGIS software.

Total *caragana* extent was calculated for each image and average annual spread rates were determined for the time periods between the image dates by calculating the increase in *caragana* extent between images. Linear and exponential trend lines were plotted based on the historical data and these regression equations were extrapolated and used to project future spread rates and future extents of the *caragana* for 10, 15 and 20 year periods.

The study area and the most recent *caragana* extent polygons were encoded into a raster dataset within a GIS. Using the projected spread rates from the regression equations to calibrate a zonal 'expand' function, the cells/area representing the *caragana* are increased according to the projected annual spread rates. By repeating this step 10, 15 and 20 times projected future *caragana* extents can be mapped for the selected time periods of 10, 15 and 20 years. For some of the scenarios the projected extents of the *caragana* extends beyond the boundaries of the Habitat Conservation Area, there are several physical barriers that make this highly unlikely and these areas are removed by multiplying the modelled raster by a binary raster eliminating any cells outside the study area.

Results

The historical spread rates of the *caragana* increased from 0.0260 hectares per year between 1968 and 1978 to 0.156 hectares per year between 2002 and 2005. Using the linear regression model the calculated values suggest the *caragana* will increase in extent from 2.759 hectares in 2005 to 3.663 hectares in 2025. Using the GIS model based on the linear regression equation the projected 2025 extent is 3.626 hectares. Using the exponential regression equation the calculated values suggest an increase from 2.759 hectares (2005) to 6.068 hectares and the exponential GIS model projects an increase to 5.498 hectares by 2025. In 2005 the *caragana* covered about 36.1% of the meadowland habitat in the study area. The projected extents of the GIS models suggest the *caragana* will cover 46.3% (linear growth) and 70.1% (exponential growth) of the meadowland habitat of the study area in 2025.

Conclusions

The *caragana* within the Habitat Conservation Area of Wascana Centre is spreading at increasing rates, reducing biodiversity and ecological integrity of the area, and as a result the ecological and social services the park provides. The GIS models project lower values of future extents than the corresponding calculated values. This can be attributed to the ability to account for several spatial restrictions on the growth of the *caragana*. This makes the results of the GIS model more realistic than the simple mathematical models and well suited for small isolated populations or homogeneous study areas with spatial limitations on spread such as urban parks.

References

Chiesura, A., 2004. The role of urban parks for the sustainable city. Landscape and Urban Planning. **68:** 129-138.

Cornelis, J., and Hermy, M. 2004. Biodiversity relationships in urban and suburban parks in Flanders. Landscape and Urban Planning. **69:** 385-401.

Crooks, J.A. 2002. Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. Oikos. **97:** 153-166.

Guisan, A., Zimmermann, N.E. 2000. Predictive habitat distribution models in ecology. Ecological Modelling. **135:** 147-186.

Higgins, S.I., Richardson, D.M., Cowling, R.M. 2000. Using a dynamic landscape model for planning the management of alien plant invasions. Ecological Applications. **10**: 1833-1848.

Kaplan, R. 1983. The analysis of perception via preference: a strategy for studying how the environment is experienced. Landscape and Urban Planning. **12**: 161-176.

Livingston, M., Shaw, W.W., Harris, L.K., 2003. A model for assessing wildlife habitats in urban landscapes of eastern Pima County, Arizona (USA). Landscape and Urban Planning. **64:** 131-144.

Rouget, M., Richardson, D.M., Nel, J.L. Wilgen, W.V. 2002. Commercially important trees as invasive aliens – towards spatially explicit risk assessment at a national scale. Biological Invasions. **4:** 397-412.

Ulrich, R.S. 1981. Natural versus urban sciences: some psycho-physiological effects. Environment and Behaviour. **13:** 523-556.

Underwood, E., Ustin, S., DiPietro, D. 2003. Mapping nonnative plants using hyperspectral imagery. Remote Sensing of Environment. **86:** 150-161.