PREDICTING THE SPATIAL DISTRIBUTION OF *LONICERA JAPONICA*, BASED ON SPECIES OCCURRENCE DATA FROM TWO WATERSHEDS IN WESTERN KENTUCKY AND TENNESSEE

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Abstract.—The spatial distribution of most invasive plants is poorly documented and studied. This project examined and compared the spatial distribution of a successful invasive plant, Japanese honeysuckle (*Lonicera japonica*), in two similar-sized but ecologically distinct watersheds in western Kentucky (Ledbetter Creek) and western Tennessee (Panther Creek). The occurrence data of Japanese honeysuckle and seven environmental variables were collected and measured from 533 random plots at the two watersheds. A spatial logistic regression model was developed to identify the factors that contribute most to the spread of this invasive plant. Our results showed that the spatial distribution of this invasive plant was different at the two watersheds. The Ledbetter Creek watershed, which had heavier anthropogenic disturbances, had a much more frequent occurrence of Japanese honeysuckle than did the forested Panther Creek Watershed. The spatial regression model indicated that elevation was significantly correlated with the spatial distribution of Japanese honeysuckle at the Ledbetter Creek Watershed. In contrast, distance from the main road, soil moisture, light intensity, and plant species richness of each plot were all significant factors in relation to the spatial distribution of invasive species at the Panther Creek Watershed.

INTRODUCTION

Exotic plant species are also called alien plants, non-indigenous plants, nonnative plants, and introduced plants in the literature. Invasions by exotic plants can change the niches of native species in the communities, alter the structure and function of ecosystems, and disrupt the evolutionary processes (D'Antonio and Vitousek 1992, Mack and others 2000, Levine and others 2003). Invasive plants have invaded approximately 700,000 ha of natural communities in the United States, at an annual expense of more than $137 billion (Pimentel and others 2000).

Studies that emphasize specific sites or habitat types have provided a general model of the distribution of invasive plants and have measured their impacts on natural communities. Additional studies have shown that forested regions have been impacted to a lesser extent than other communities (Mooney and others 1986). Management and control of biological invasion have been a great challenge for researchers and the general public. The geography of native habitat, including the availability of water sources, elevation, slope and aspect, and human disturbances are important factors in the process of plant invasion (Gillham and others 2004). The spatial distribution of invasive plants, however, is poorly documented (Dark 2004). We know the general regions where an invasive plant may be found, but detailed maps are usually unavailable.

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Several recent studies have demonstrated the importance of using statistical techniques that incorporate space on some level when assessing species distribution. For instance, Nielsen and others (2008) found that using logistic regression models and incorporating a spatial element into the model output improved their ability to predict the distribution and impact of invasive plant species.

The objectives of this project are: (1) to provide the first geographic characterization of the invasive plant, Japanese honeysuckle (*Lonicera japonica* [Thunb.]), in two distinct watersheds; and (2) to develop test models to identify factors contributing most to the spread of this invader. We hypothesized that the spatial distribution of Japanese honeysuckle is site-specific and that intensive anthropogenic disturbance causes greater invasion.

STUDY AREA

A watershed provides a natural unit for the study of an ecosystem. This study compared the spatial distribution and pattern of Japanese honeysuckle in two watersheds, Ledbetter Creek, in western Kentucky, and Panther Creek, in Tennessee, utilizing geospatial techniques. These two watersheds are similar in size and are roughly 30 km apart (Fig. 1). Both streams empty into the Kentucky Lake Reservoir. Ledbetter Creek is located on the west side of Kentucky Lake. Its watershed contains forest, cropland, grassland, and small communities that cover an area of about 24 km^2. The recently opened highway KY80 cuts through the watershed on the north, which will likely bring more disturbance and change to the area. Panther Creek, an almost completely forested watershed, is located on the east side of the Kentucky Lake Reservoir within the Land Between the Lakes National Recreational Area. Since human disturbance is considered a major factor in plant invasion (Alston and Richardson 2006), we expected to report considerable differences in plant invasion between the agriculture-based Ledbetter Creek drainage area and the forested Panther Creek watershed.

METHODS

SPECIES SELECTION

Japanese honeysuckle, a perennial woody vine, was selected as the target invasive species for this study for the following three reasons. (1) Japanese honeysuckle has been a highly successful invader since its introduction to the United States from eastern Asia in the 1800s as an ornamental and forage plant. It is very common in the southeastern states and is now found in 45 states (Miller 2003). (2) Japanese honeysuckle has had an enormous negative impact on native ecosystems (Dillenburg and others1993a,b). (3) Very little information on the spatial distribution of Japanese honeysuckle has been collected in the study area.

FIELD DATA COLLECTION

Field data collection was conducted between June and December 2008. To avoid pseudo-replication in the data collection, 63 random sampling points were assigned to two watersheds based on the aerial maps. We established 32 sampling points at the Ledbetter Creek Watershed and 31 sampling points at the Panther Creek Watershed. Each sampling point contained 10 to 20 plots, each 1-m x 1-m in size. The plots were distributed approximately 15 m apart along the transect lines. Each transect length was determined by measuring the distance from the sampling point to the main road. We collected data from 210 plots within the Ledbetter Creek Watershed and 323 plots within the Panther Creek Watershed. We measured the following six variables, which are most likely to constrain the geographic distribution of the species: species richness per plot, distance from the main road, elevation, soil moisture, soil pH, and light intensity. Light intensity measures

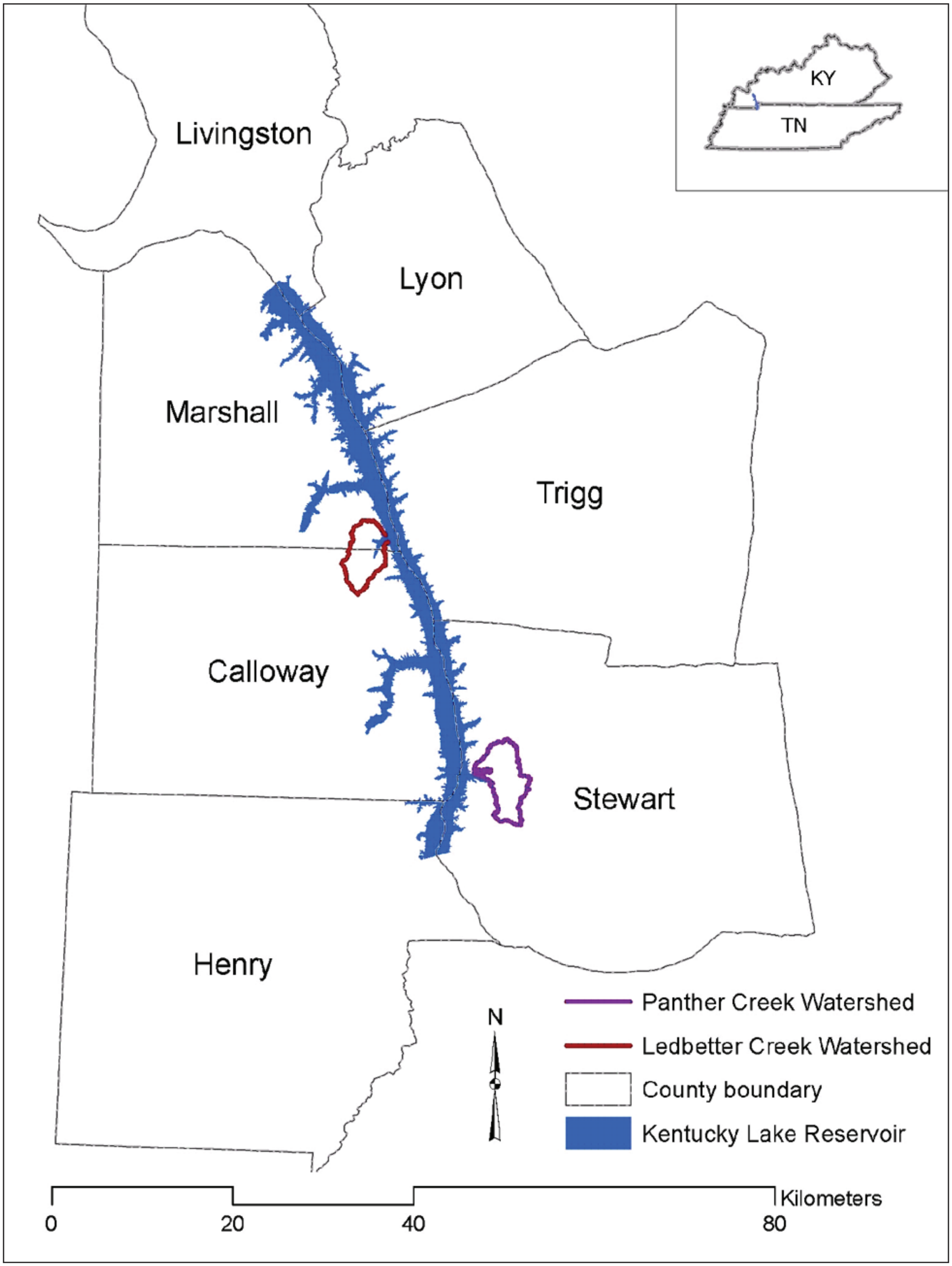

Figure 1.—The study area, showing the location and boundaries of each watershed.

were made early in the morning and late in the afternoon with an EA 30 Light Meter (Extech Instruments Corp., Waltham, MA). Distance from the main road was measured with a meter tape, and elevation data were obtained with a Garmin GPS 76 Global Positioning System (Garmin, Olathe, KS). Soil moisture and soil pH measurements were determined by a Kelway Soil Meter (Kel Instruments Co., Inc., Wyckoff, NJ). Last, Japanese honeysuckle occurrence data (1-presence, 0-absence) were recorded at each plot of both watersheds. Occurrence data were used to compare the distribution of Japanese honeysuckle within the two watersheds.

STATISTICAL ANALYSES

Logistic regression models were developed at plot level to identify contributing factors in the region using SYSTAT 12.0 (SYSTAT Software, Inc., Chicago, IL). We used logistic regression models because of the robust nature of the models with binary data (Smith 1994) and their good performance in predicting the distribution of invasives at different spatial scales (Evangelista and others 2008, Nielsen and others 2008). The data for light intensity and distance to the main road were log-transformed before the analyses. All other residuals were normally distributed, so no transformations were necessary. To build the landscape-level predictive models, we extracted five explanatory variables from a GIS database, Kentucky Lake Geographic Information System (MARC Associates 1998) using ArcMap (ESRI, Redlands, CA). These variables were distance from the main road, elevation, depth of water table, slope, and aspect. The occurrence data (1, 0) of Japanese honeysuckle at the landscape level were determined based on the plot-level occurrence data. We recorded "1" if Japanese honeysuckle covered more than 50 percent of the plot, and "0" if it covered less than 50 percent of the plot.

RESULTS

The occurrence of Japanese honeysuckle clearly differed between the watersheds. The invasive plant was found on 87.1 percent of the plots in Ledbetter Creek Watershed (n = 183, based on a total of 210 plots). In contrast, Japanese honeysuckle occurred on only 30.7 percent of the plots in the Panther Creek Watershed (n = 100, based on 323 plots).

Factors contributing to occurrence also differed significantly between the two watersheds. At the plot level, the results of logistic regression models indicated that elevation was the only significant factor ($p < 0.05$) at Ledbetter Creek Watershed (Table 1). For Panther Creek Watershed, the significant factors determined by the logistic regression model were distance from the main road, soil moisture, light intensity, and species richness (Table 2).

The geographic factors that may contribute to the potential spread of Japanese honeysuckle differed as well between the two watersheds. At the landscape level, the logistic model indicated that slope was the only marginally significant factor at Ledbetter Creek (Table 3). Elevation and soil water depth were significantly correlated with the spatial distribution of this invasive species at the Panther Creek Watershed (Table 4).

DISCUSSION

Specific habitat type and intensive anthropogenic disturbance have been hypothesized to account for the different spatial distribution of Japanese honeysuckle between two distinct watersheds. We predicted that the geographic conditions of habitats and heavy anthropogenic disturbance could cause a greater occurrence of Japanese honeysuckle because both factors have been found to play a significant role in plant invasion (Gillham and others 2004, Alston and Richardson 2006). The results of our study showed that the occurrence

Table 1.—Results of logistic regression model at Ledbetter Creek at plot level.

Parameter	Estimate	Standard Error	Z	p-value	95% Confidence Interval Lower	Upper
Constant	-38.300	15.644	-2.448	0.014	-68.961	-7.639
Distance to road	0.180	0.126	1.427	0.154	-0.067	0.426
Elevation	4.477	1.804	2.482	0.013	0.942	8.012
Soil pH	1.792	1.366	1.312	0.190	-0.886	4.470
Soil moisture	-0.002	0.016	-0.152	0.880	-0.034	0.029
Light intensity	-0.010	0.009	-1.078	0.281	-0.028	0.008
Richness	-0.107	0.133	-0.802	0.422	-0.368	0.154

Table 2.—Results of logistic regression model at Panther Creek at plot level.

Parameter	Estimate	Standard Error	Z	p-value	95% Confidence Interval Lower	Upper
Constant	-3.204	9.159	-0.350	0.726	-21.155	14.747
Distance to road	-0.360	0.107	-3.376	0.001	-0.569	-0.151
Elevation	-0.085	0.626	-0.136	0.892	-1.313	1.143
Soil pH	0.412	1.106	0.372	0.710	-1.756	2.579
Soil moisture	0.062	0.014	4.467	0.000	0.035	0.090
Light intensity	-0.073	0.028	-2.652	0.008	-0.127	-0.019
Richness	0.536	0.124	4.313	0.000	0.293	0.780

Table 3.—Results of logistic regression model at Ledbetter Creek at landscape level.

Parameter	Estimate	Standard Error	Z	p-value	95% Confidence Interval Lower	Upper
Constant	-96.822	51.003	-1.898	0.058	-196.786	3.141
Elevation	18.758	10.331	1.816	0.069	-1.490	39.007
Aspect	0.190	0.462	0.411	0.681	-0.716	1.095
Slope	0.120	0.064	1.877	0.060	-0.005	0.244
Distance to road	0.074	0.376	0.198	0.843	-0.663	0.812
Water depth	0.132	0.297	0.446	0.656	-0.450	0.714

Table 4.—Results of logistic regression model at Panther Creek at landscape level.

Parameter	Estimate	Standard Error	Z	p-value	95% Confidence Interval Lower	Upper
Constant	76.678	32.284	2.368	0.018	13.207	140.150
Elevation	-14.635	6.535	-2.239	0.025	-27.444	-1.826
Aspect	0.063	0.441	0.142	0.887	-0.802	0.927
Slope	-0.110	0.061	-1.792	0.073	-0.229	0.010
Distance to road	0.522	0.389	1.341	0.180	-0.241	1.284
Water depth	-0.641	0.301	-2.132	0.033	-1.231	-0.052

of Japanese honeysuckle is heavily associated with anthropogenic disturbances in general. However, it provided little evidence that the distribution of Japanese honeysuckle is determined by habitat conditions when there is prevalent anthropogenic disturbance. The degree of disturbance better accounts for the observed differences in the distribution of Japanese honeysuckle between the two watersheds.

We concluded that if a watershed is associated with heavy human interference, then the factors that usually determine the habitat conditions, such as soil moisture, light intensity, and species richness do not play a significant role in relation to the spatial spread of invasive species. The predominant influence of human activity is apparent in the Ledbetter Creek Watershed, where there is ongoing human interference from farming, habitation, and frequent traffic. On the contrary, if the watershed had less exposure to human activities, then factors such as distance from the main road, soil moisture, light intensity, and species richness are all significantly related to the spatial distribution of the invasive species. The results from the Panther Creek drainage area, an almost completely forested watershed, are in perfect agreement with our conclusions. Furthermore, our modeling results indicate that invasion risk is much higher in areas with constant anthropogenic disturbance.

Our study provides the first geographic characterization of Japanese honeysuckle in the region. Moreover, we identified factors associated with successful invasion and evaluated the future risk of invasion at both watersheds. The results of this study should be very useful when recommendations for future land-use practices and conservation policies are considered. This study approach also may be applicable to the study of invasive plants in other watersheds or other geographic regions.

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