Spatial Distribution and Risk Assessment of Johnsongrass (*Sorghum halepense*) in Big Bend National Park, Texas

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Chapter 12 of

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Chapter 12.

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Overview

We present an example of the utility of using remotely sensed and GIS data to model potential habitat for johnsongrass *(Sorghum halepense*, fig. 12.1) in Big Bend National Park (BIBE).We provide a brief species profile, indicate attributes used to model potential distributions, and demonstrate how potential distribution models and vector and pathway models can provide early detection tools to prioritize conservation efforts.

Figure 12.1. Johnsongrass (*Sorghum halepense*) in Big Bend National Park, Texas.

Origins and History

Johnsongrass is native to the Mediterranean region of Europe and Africa (Holm and others, 1977; McWhorter, 1989). Johnsongrass was apparently first introduced into South Carolina around 1830 for livestock forage, but it rapidly spread across the Southern United States (Tellman, 1998; Howard, 2004). Currently, Johnsongrass is fairly widespread through the contiguous United States (Great Plains Flora Association, 1986; Wunderlin, 1998).

Description

Johnsongrass is a tall (heights may reach 3.7 meters or 12 feet) warm-season perennial (Anderson, 1961; Radford and others, 1968; Martin and Hutchins, 1980; Diggs and others, 1999). Leaves have a prominent midvein. Johnsongrass flowers from May to November in the Southwest (Martin and Hutchins, 1980; Diggs and others, 1999). Inflorescence ranges from 10 to 60 centimeters (4–24 inches) with an open panicle. Seeds are approximately 2 millimeters in length (Radford and others, 1968) and may have twisted awns that aid in seed dispersal (Diggs and others, 1999). The leaves of Johnsongrass respond distinctly to solar radiation and, therefore, can be distinguished easily from other plants by remote sensing (McWhorter, 1989).

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Vectors and Pathways

Characteristics of Johnsongrass (fig. 12.2) that aid in its spread include:

- formation of dense rhizomes that host meristematic tissue responsible for regenerating plants (Anderson and others, 1960),
- moderate drought resistance (Anderson and others, 1960),
- salt tolerance (Yang and others, 1990),
- abundant seed production with seeds that remain viable for 2 to 5 years prior to germination (Leguizamon, 1986; Huang and Hsiao, 1987; Allen, 1990; Unger and others, 1999), and
- possible production of toxins that are allelopathic (Warwick and Black, 1983).

Figure 12.2. Large Johnsongrass patch in a riparian area in Big Bend National Park, Texas.

Wind, water, machinery, and animals disperse Johnsongrass seed (Ghersaand others, 1993; Hartzler and others, 1991). Johnsongrass seed has been carried up to 1.0 kilometer (0.62 miles) from parent plants by winds (around 31miles/hour) that occurred during thunderstorms (Ghersa and others, 1993). Seeds are dispersed along waterways by flowing water. Farming equipment also spreads seeds (Ghersa and others, 1993). Johnsongrass seed is a contaminant in hay and commercial seed (Allen, 1990).

Habitats

Johnsongrass is associated with a variety of habitats but is most common in ecosystems at elevations below 1,800 meters (6,000 feet) with moist to mesic moisture regimes, especially riparian habitats (Howard, 2004). This plant is associated with open habitats and does not persist under closed canopies. Johnsongrass can be found in irrigation canals, flood plains, springs, and stock tanks (Bendixen, 1988; Monaghan, 1979). Johnsongrass grows in various sized patches throughout BIBE in depressions, ditches, and waterways that have had historical disturbances.

Predictive Habitat Model

We used Landsat 7 ETM+ imagery to illustrate how remotely sensed data can model predicted Johnsongrass habitat. We used spectral reflectance values for three seasons of data across 5 years (fall 1999, summer and fall 2000, spring and fall 2001, spring 2002, and spring 2003) to capture Johnsongrass vegetation phenology. Johnsongrass occurrences in BIBE consisted of 147 georeferenced localities.

We used the program Maxent (*http://www.cs.princeton.edu/~schapire/maxent/*; Phillips and others, 2006) to predict Johnsongrass distributions. Maxent is a general approach for modeling species distributions using presence-only data sets (see Chapter 7 for general discussion of modeling data options). Maxent estimates a target probability distribution by finding the probability distribution of maximum entropy (the distribution that is most spread out, or closest to uniform). Maxent uses pixels with known species occurrence records to constitute the sample points. Remotely sensed and GIS data sets can provide environmental variables measured at each sample point (see Chapter 6). Analysis output includes a probabilistic interpretation, grading from least to most suitable habitat conditions.

We evaluated the Johnsongrass predicted habitat model in Maxent by withholding 10 percent of the occurrence locations for testing. Maxent evaluates model performance by testing if the model performed significantly better than random (Phillips and others, 2006).This approach, considered threshold-dependent, used a binomial test (Wilcoxon signed-rank test) based on omission and predicted area. Model performance is evaluated using extrinsic omission rate (fraction of the test localities that fall into pixels not predicted as suitable) and the proportion of all the pixels that are predicted as suitable habitat.

The second approach to evaluating model performance is considered a threshold-independent procedure and uses receiver operating characteristic (ROC) curves (Phillips and others, 2006).The advantage of ROC analysis is that area under the ROC curve (AUC) provides a single measure of model performance, independent of any particular choice of threshold. The AUC can be interpreted as the likelihood that habitat quality is correctly classified by the predictive model at randomly selected sites (Phillips and others, 2006). Chapter 9 provides additional discussion on threshold-dependent and threshold-independent metrics as well as ROC interpretations.

The predictive habitat model indicated that BIBE hosts approximately 14,137 hectares of habitat highly suitable for Johnsongrass. Large patches of potential Johnsongrass habitat exist in the northern part of the park and in major drainages throughout BIBE (fig. 12.3). Threshold-dependent evaluation using the "equal test for sensitivity and specificity" with a cumulative threshold of 23.1 indicated a 14 percent error of omission ($P < 0.01$) (fig. 12.4). ROC curves indicate that both the training and test data performed better than a random prediction (fig. 12.4). The AUC for test data was 0.92, standard deviation = 0.029, and 0.97 for training data, indicating that the likelihood that a random positive Johnsongrass occurrence and a random negative location were accurately predicted to 92 percent.

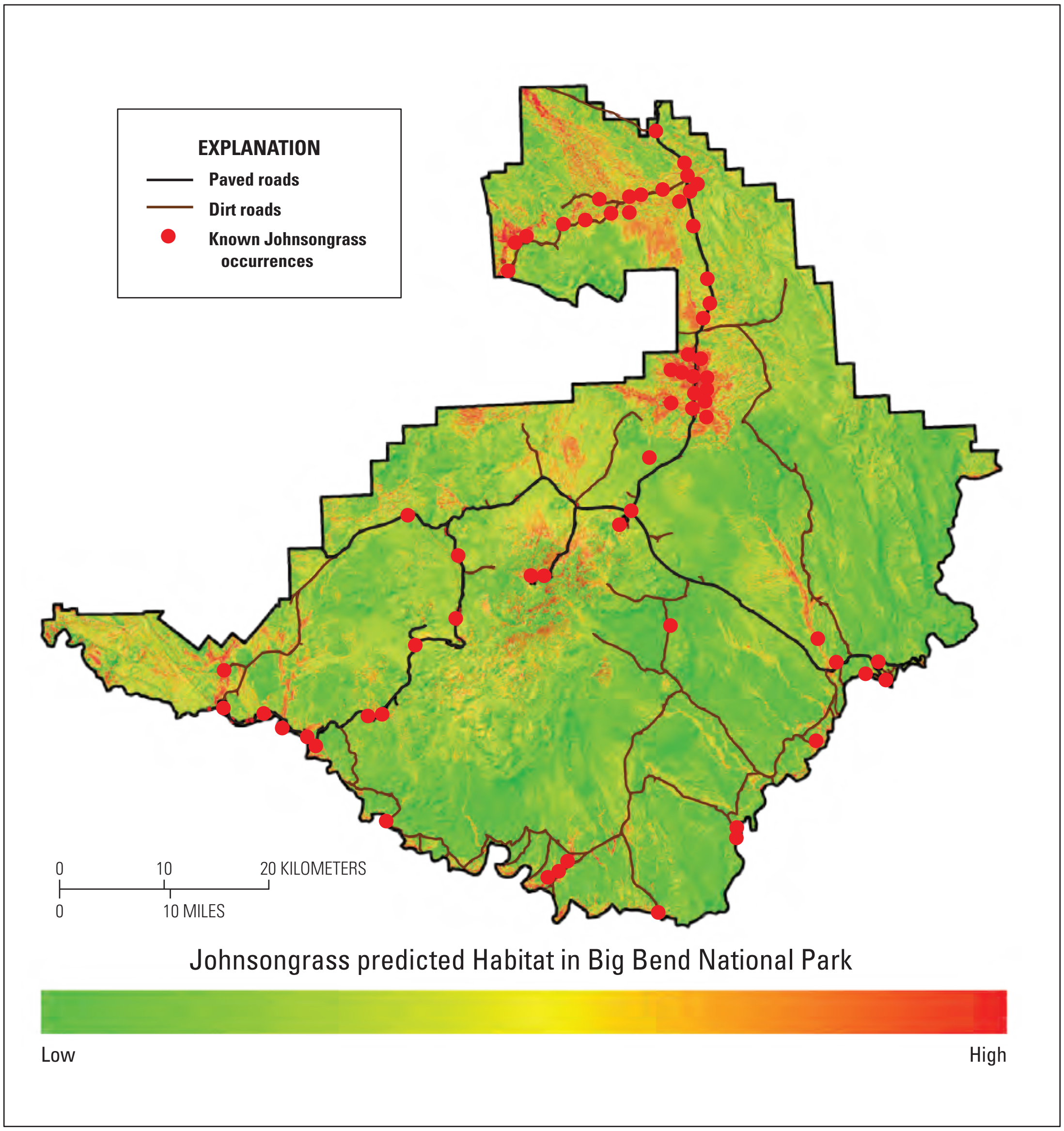

Figure 12.3. Johnsongrass predicted habitat model constructed from remotely sensed data. Predictions were generated using Maxent software (Phillips and others, 2006).

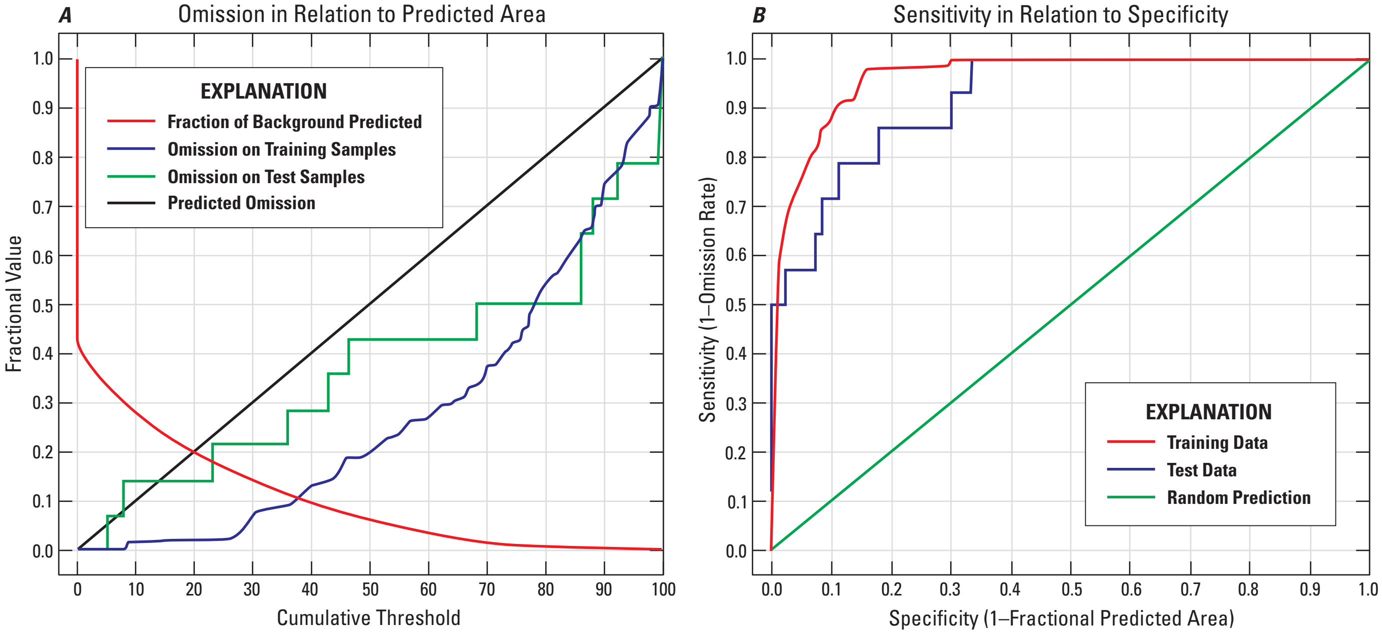

Figure 12.4. Comparison of model performance using threshold-dependent *A*, and threshold-independent; *B*, methods. Graph *A* represents omission rate and predicted area as a function of the cumulative threshold for Johnsongrass training and test data; whereas graph *B* illustrates receiver operating characteristic (ROC) curves plotted as a function of sensitivity compared to specificity. Graph *A* shows an optimal omission curve for test samples that would resemble the predicted omission curve. For graph *B*, both the training and test dataset outperformed a random prediction, indicated by the steep rise at the origin, leveling off near the sensitivity value of one (see Chapter 9).

Vector and Pathway Spatial Model

With the exception of animal movements, spatial models of vectors and pathways can be easily created. Animal movement vectors may be spatially modeled where sufficient data exist. However, no data were available for animal movement vectors in BIBE. We obtained GIS data sets from either BIBE (roads and trails) or USGS (hydrology) to represent vectors and pathways. Water flow from summer monsoons and flood events represent one of the primary vectors (mechanisms of plant introduction) for the spread of Johnsongrass seed in BIBE, with streams and rivers being the primary pathway. As such, we created a 300-meter buffer around perennial streams and springs and a 30-meter buffer around intermittent streams. A representation of a stream pathway is provided in figure 12.5. Wind dispersion of seeds is also an important vector. We created 400-meter x 250-meter ellipses around each known Johnsongrass location to model potential wind distribution. Ellipses were oriented to the direction of the prevailing winds. The top of the ellipse was positioned at the georeferenced plant location. Since roads, trails, and campgrounds are common pathways for the spread of invasive plants, we buffered paved roads and campgrounds 150 meters, dirt roads 30 meters, and trails 15 meters. Buffer distances should be adjusted for individual parks or projects.

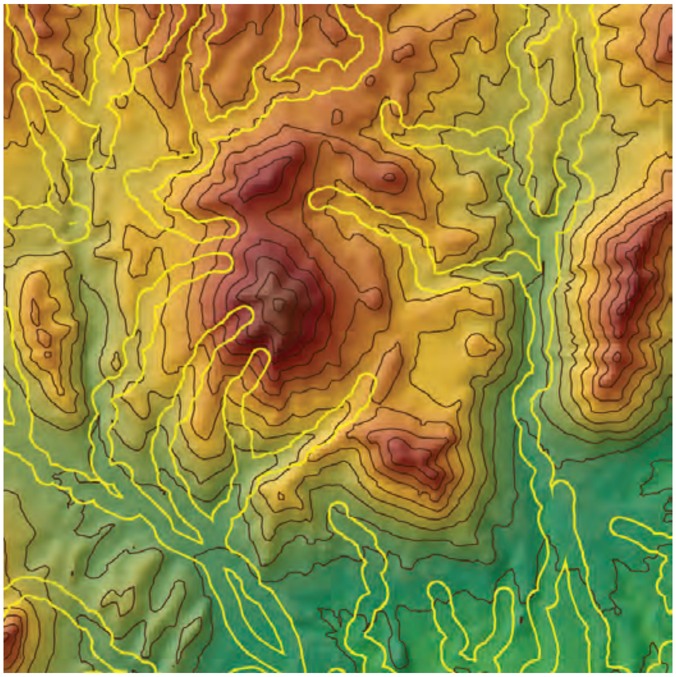

Figure 12.5. Graphical representation of a stream buffer (yellow lines) that serves as the primary pathway for the spread of Johnsongrass in Big Bend National Park, Texas.

Risk Analysis Model

Areas of potential risk for the invasion of Johnsongrass in BIBE (figure 12.6) were estimated by placing current known occurrences, potential suitable habitat, modeled vectors and pathways, areas with adequate soil moisture regimes (given desert environment), and areas with disturbances (for example, fire) into a spatial context. Areas near current populations that have pathways connecting to other potential habitat are considered at risk of invasion. These areas can be monitored to detect invasions before they become established. Further, existing plant populations can be controlled to reduce the possibility of spread to potential habitats. Barriers along pathways may help reduce the risk of spread.

Risk analyses can provide an effective approach for prioritizing areas for invasive species conservation efforts. For example, areas at risk of invasion can be placed in context to sensitive plant populations, or other management considerations, to further refine areas to be monitored. Further, risk surfaces provide a spatially explicit model that could be used to develop a ground-based sampling strategy to locate or monitor invasive plant populations (see Chapter 8).

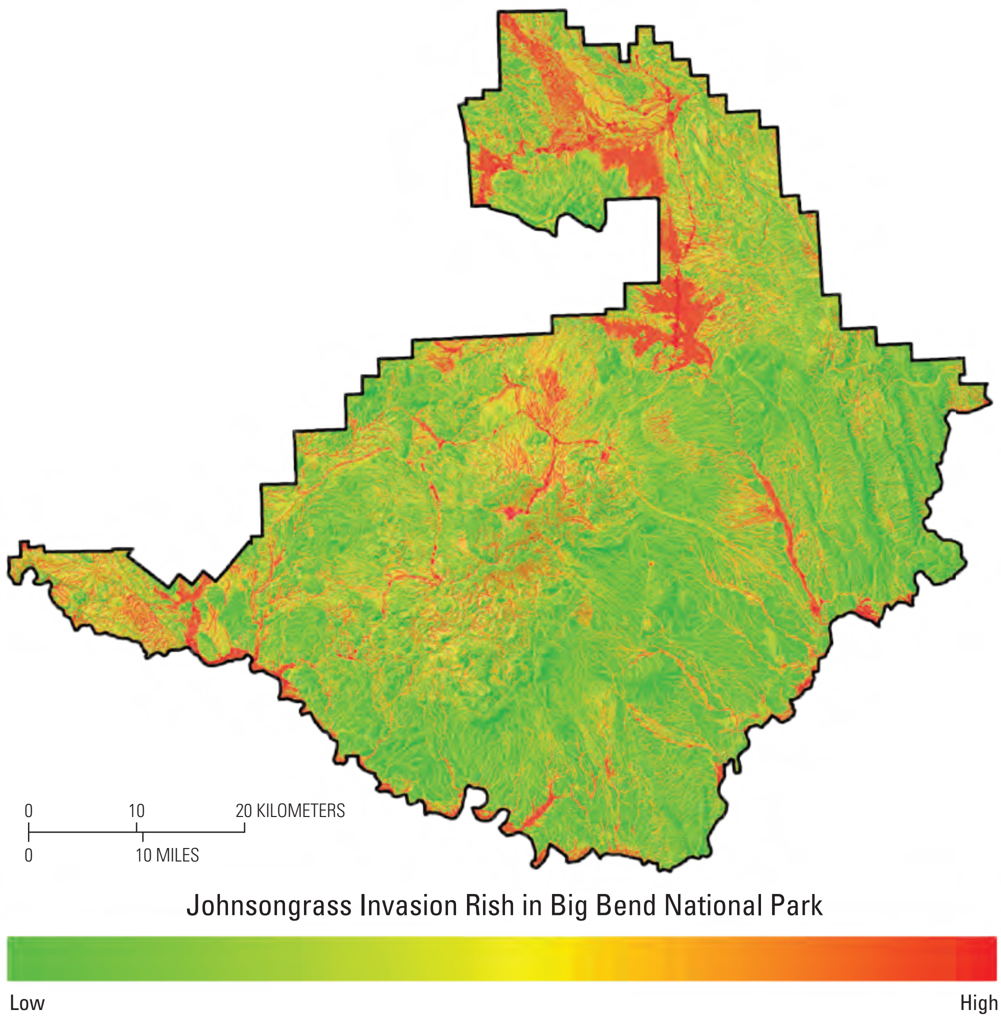

Figure 12.6. Johnsongrass risk assessment in Big Bend National Park, Texas estimated by using current known occurrences, potential suitable habitat, modeled vectors and pathways, areas with suitable soil moisture regimes, and disturbed sites.

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