

Introduction

In recent years, the presence and impact of non-native invasive plants (NNIPs) has become one of the top concerns in natural resources management. Theoharides and Dukes (2007) summarized and qualitatively classified the invasive process of NNIPs into four stages: introduction (transporting from native regions to a new region via long distance movements), colonization (surviving and achieving positive growth rates at low densities in the infested region), establishment (developing self-sustaining and expanding populations) and spread (dispersing within a region over significantly long time periods). However, this classification is not conclusive. The invasion process may be classified into two stages (Davis 2009), three stages Williamson 1996), or up to six stages (Henderson et al. 2006). These classifications are all qualitative and based on the life-history traits of the species, the genetic traits of the species, or environmental factors etc.

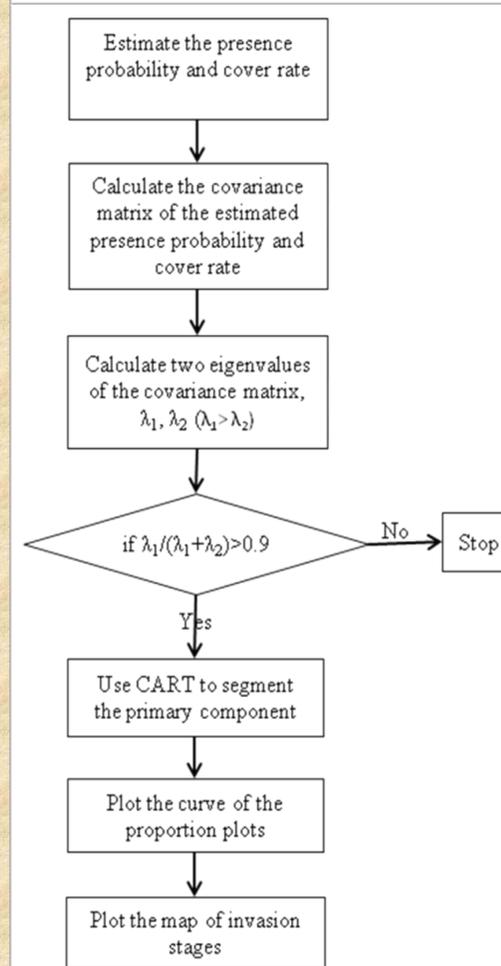
On the other hand, the management of NNIPs depends on the stages of invasion since the cost dramatically increases as the populations expand (Hobbs and Humphries 1995). It is prohibitively expensive to remove the NNIPs from the invaded region after they are well established, so efforts to control invasive plants should focus on the establishment or earlier stages (Webster et al. 2006). Thus, the early detection of the invasion stages of NNIPs is very important for the control of NNIPs.

In this study, we focus on the evaluation of multiflora rose (*Rosa Multiflora*, Thunb. [ex Murr.](#), thereafter MFR) since it has highest occupancy rate on the FIA plots in seven Upper Midwest States. Our objective is to develop a procedure to quantify the invasion stages of NNIPs by using FIA data.

Data

- In this study, U.S. Forest Service, Northern Research Station Forest Inventory and Analysis (FIA) Phase 2 data from the Upper Midwest states for the period 2005-2006 are used.
- The dataset includes 25 invasive plants.
- In this dataset, the presence and cover rate are used to describe the presence and abundance of MFR in each plot. The presence was recorded as 0 (absence) or 1 (presence) and the cover rate as the middle value of the range of percent cover for each cover code.
- In total, we used 8632 phase 2 forested plots to assess MFR, where 1320 plots (15.2%) were invaded by MFR.

Methodology



Results

- MFR is established in Missouri, Illinois, Indiana, Iowa, and southern Wisconsin and Michigan and more widely distributed in northern Missouri, southeast Iowa, central and northern Illinois and Indiana. MFR is not widely established in Minnesota, northern Wisconsin, and northern Michigan (Figure 1).
- There is a positive spatial autocorrelation among the MFR presence (Moral's $I = 0.93$) and abundance ((Moral's $I = 0.85$) (Figures 2 and 3)). The smoothed presence probability (Figure 2) indicates a strong invasion pattern in all directions, but particularly southward and eastward. The clusters of cover rate of MFR are mainly located in Illinois, Indiana and southern Iowa.
- The principal component analysis (PCA) results show that the primary component explained 91% variation among the estimated presence probability and the estimated cover rate.
- The optimal classification tree size should be 4 (Figures 4 and 5). The corresponding cutoffs are (Figure 6):
Stage I: $pp < 16.95\%$ and $pp > 0$; Stage II: $pp > 16.95\%$ and $pp < 39.67\%$;
Stage III: $pp > 39.67\%$ and $cr < 8.14\%$ Stage IV: $pp > 39.67\%$ and $cr > 8.14\%$.
- The non-linear relationship between the estimated cover rate and the estimated presence probability (Figure 6) is consistent with the characteristics of MFR dispersal: a mixture of long-distance dispersal (by bird) and short-distance dispersal, and the history of MFR introduction, which was introduced into US in 1866 as rootstock for ornamental roses.
- On average, the counties in stage IV were infested by MFR earlier than that in stage I. The plots in stage IV have a greater coverage of MFR than that in stage I. For the greater cover classes, the proportion of plots in stage IV is greater than that in stage I; for the smaller cover classes, it is reversed (Figure 7).
- The counties in the stage IV are more clustered in southern Iowa, northern and central Illinois, and north-west and central Indiana (Figure 8).

Conclusion

The procedure based on the estimated presence probability and cover rate provides more accurate classification since it uses not only information of presence/absence of MFR but also the information of abundance of MFR. However, the coarse data of cover rate may affect the reliability and accuracy of the classification.

The results support classifying the invasion process into four discrete stages. Different from previous studies, this classification procedure, based on the information of occupancy (presence/absence) and abundance of MFR, does not need knowledge of the life-history of MFR, the genetic traits of MFR, or environmental factors, etc.

The map of invasion stages delineates the condition (e.g., hot spots), extent and dispersal direction of MFR, and provides useful information for resource managers to prioritize the infested areas and allocate resources for treatment. The non-linear relationship between the abundance and the occupancy of MFR is consistent with the observation that MFR primary dispersed by birds.

Cited References:

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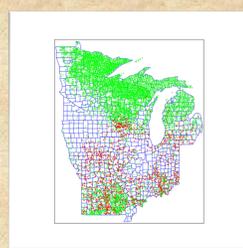


Figure 1 The distribution of FIA Phase 2 Plots without (green) and with the presence of MFR (red) in the Upper Midwest, 2005-2006

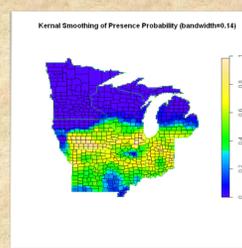


Figure 2 The smoothed presence probability (pp) of MFR in the Upper Midwest, 2005-2006.

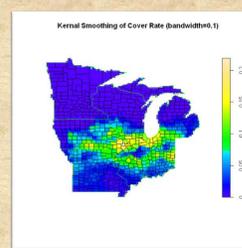


Figure 3 The smoothed cover rate (cr) of MFR in the Upper Midwest, 2005-2006.

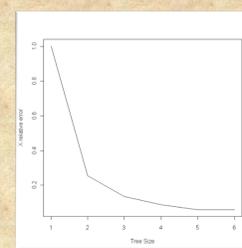


Figure 4 The plot of relative cross-validation error vs. the number of terminal nodes in the CART.

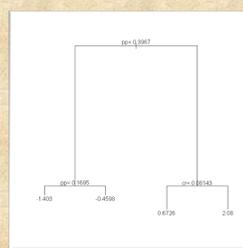


Figure 5 Classification and regression tree partition of the estimated presence probability and estimated cover rate of MFR

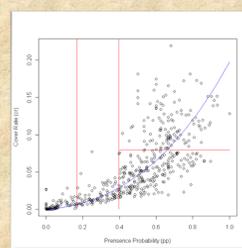


Figure 6 The plot of estimated cover rate vs. estimated presence probability and the result of classification and regression tree partition

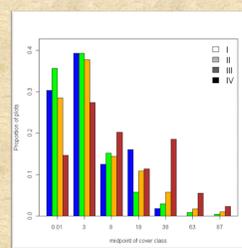


Figure 7 Proportion of plots vs. the midpoint value of cover class.

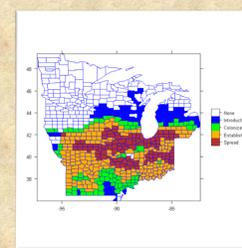


Figure 8 The map of invasive stages based on the estimated presence probability and estimated cover rate of MFR