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Evaluating the relationship between invasive plant metapopulation growth rate and management efficacy using a modified incidence function model

Finite time, labor, and financial resources available to land managers can restrain invasive plant species management efforts and engender a need for a decision framework in which to prioritize management decisions. Habitat suitability or probability of occurrence (PO) models, generated from environmental variables, can be used to estimate or predict the realized geographic distribution of a weed species and can be used as a tool for targeted sampling, monitoring, and management at a landscape scale. In practice, however, these models are rarely employed to assess management strategies to reduce invasion rates (metapopulation growth rates). A modified incidence function (MIF) simulation model was developed to explore the spatial metapopulation dynamics for an invading plant species using PO as a driving variable. Our objective was to use the MIF to simulate the influence of management efficacy on metapopulation dynamics. We measured the response of the metapopulation growth rate over a 20 year time period starting from randomly distributed source populations by varying the probability of source patch mortality as a result of management. Several driving variables were manipulated to determine their relative impact on the success of management at reducing the invasion rate.

The primary goal of this study was to assess implications of management to develop methods for field experiments aimed at asking how management efficacy relates to PO. Consequently, it is important to understand how metapopulation growth rates are affected by increasing management-induced mortality rates of source patches across a gradient of PO values. In the absence of management, invasion rates, increased with increasing PO. When the number of source patches managed each year was held constant, management efficacy had less effect on the metapopulation mean geometric growth rate as PO increased. Our results imply that higher levels of management-induced mortality targeted at populations occupying areas of lower PO might have more influence on invasion and extinction rates than management prioritized in favor of high PO areas. We are currently investigating how changes to numbers of source patches treated each year and how density and rates of emigration from source patches affect invasion rates. The MIF model allowed us to use a theoretical framework to address an applied problem.

Evaluating the relationship between invasive plant metapopulation growth rate and management efficacy using a modified incidence function model

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Introduction

• Land managers are often restrained by limited resources for the management of invasive plant species

• Habitat suitability or probability of occurrence (PO) models could be used to prioritize management decisions (Rew et al., 2005; Rew et al., 2007)

•**Problem:** PO models are rarely used to assess management strategies to reduce invasion rates (metapopulation growth rates)

•Habitat suitability as estimated by PO could be linked to management efficacy on a target species (Maxwell et al., unpub) as well as the effects on the non-target plant community

Objective

• To determine the influence of management efficacy on invasive plant metapopulation growth rates within habitat patches as defined by heterogeneous PO values

Methods

• **Incidence function (IF) (Hanski, 1994):**

• Probability of incidence (occupation) of habitat patch i, J_i, is a function of the colonization rate, C_i, and extinction rate, E_i

•C_i and E_i are functions of the size of the habitat patch, A_i

• **Modified incidence function (MIF) (Maxwell et al., unpub.):**

• Assumptions:

• Area held constant for all habitat patches

• PO is positively related to the source strength of populations and, therefore, positively related to the incidence rate of habitat patches (suggested by Hanski, 1994 and Lehnhoff et al., 2008)

• PO_i substituted for A_i in the modified incidence function (MIF)

· **MIF simulations:**

· Metapopulation dynamics as affected by management decisions of a hypothetical plant species were assessed under two different heterogeneous environments as simulated by the MIF model

· **Empirical data:**

· Data were collected on populations of *Cirsium arvense* populations and associated plant communities across its predicted habitat suitability (PO) gradient

Results

Modified Incidence Function Simulation 1:

• Heterogeneous environment where PO values were randomly assigned to habitat patches (Fig. 1)

• Number of occupied patches managed/yr = 7 (starting at year 3) and management efficacy of target species within a managed patch = 0.75

Modified Incidence Function Simulation 2:

• Heterogeneous environment where high PO values were distributed in PO "hotspots" and along a road (Fig. 2)

• Same management decisions as employed in Simulation 1

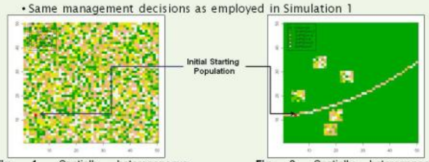


Fig. 1. Spatially heterogeneous environment used in Simulation 1 with random assignment of PO values to habitat patches

Fig. 2. Spatially heterogeneous environment used in Simulation 2 with higher PO values assigned to habitat patches within "hotspots" and along a road

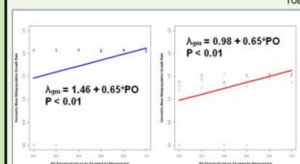


Fig. 3. Results of Simulation 1 (left/blue) and Simulation 2 (right/red). The x-axis represents habitat suitability (PO) threshold values for management (e.g., if PO=0.8, only occupied patches with PO ≥ 0.8 would be targeted for management. PO ≥ 1.0 is equivalent to no management

Empirical Data:

• Survey data for *Cirsium arvense* were used to create a PO model within a watershed in Colorado (methods in Rew et al., 2005) and data were collected within metapopulations located across a PO gradient (Fig. 4)

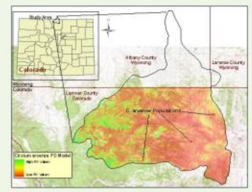
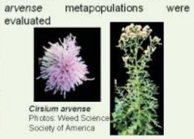


Fig. 4. *Cirsium arvense* habitat suitability (PO) model created for a watershed in Colorado. Four *C. arvense* metapopulations were evaluated



Cirsium arvense
Photos: Weed Science Society of America

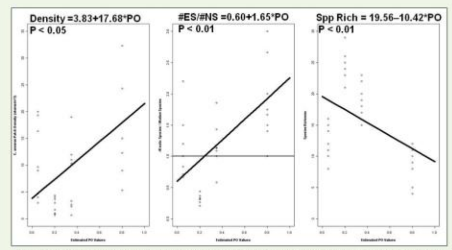


Fig. 5. Patch and plant community attributes for 4 *C. arvense* metapopulations evaluated across its predicted habitat suitability.

Conclusions

• Results of 2 MIF simulations suggest that the geometric mean growth rate (λ_{gm}) of a hypothetical metapopulation increases with increasing PO management thresholds; however, a more random environment (Simulation 1) could result in overall higher growth rates

• Empirical data implied that substituting patch PO for patch area was valid according to suggestions in Hanski (1994)

• Results of the MIF simulations and empirical data suggest metapopulations located in patches of higher PO are likely to have more invasive potential, but management prioritization should include habitat patches with a range of PO values to limit overall growth rates

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