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Original Articles

Count population viability analysis finds that interacting local and regional threats affect the viability of a rare plant

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ABSTRACT

Ensuring the best use of limited conservation resources requires comprehensively assessing the relative importance of multiple threats, some of which occur at local and some at regional spatial scales. Multiple threats are rarely modeled in traditional population viability analyses (PVAs) due to the high data requirements necessary to parameterize age or stage based population models. Count based PVAs have been shown to provide robust results, and count data are readily available from many monitoring programs. Despite this, we are not aware of any studies that have used count based PVAs to assess multiple threats for plant populations. To demonstrate the utility of count based PVAs of assessing multiple treats at multiple spatial scales, we use long-term monitoring data by the Chicago Botanic Garden's Plants of Concern program to assess the main and interactive effects of two local threats (woody invasive species, browsing by deer) and one regional threat (climate change) on the viability of the rare forb, *Eurybia furcata*. We found an interaction between local and regional threats, which suggests that management actions targeting local threats can improve the viability of *E. furcata* populations both by directly reducing the risk of extinction and indirectly by decreasing this species vulnerability to climate change. Therefore, we recommended that land managers prioritize local scale management, specifically woody invasive species encroachment, to reduce this species' overall risk of extinction. The threat of climate change will act in concert with other anthropogenic factors, but conservation planning has historically focused on local scale threats. Adapting management to consider the regional threat of climate change requires threat analysis from multiple populations and at regional spatial scales. This task may seem daunting, but our results provide an optimistic outlook that count data can be effectively utilized for this purpose. Applying this approach widely to count based monitoring data already in existence would result in robust recommendations to land managers for many species of concern.

1. Introduction

The best spatial scale for management of a species depends on which factors most threaten populations within a region and how those factors interact (Oostermeijer, 2003; Brook et al., 2008). If a local scale threat, such as an herbivore or invasive competitor, has large effects on population viability, then local scale management aimed at removing the threat and monitoring to ensure that the population size increases should be the conservation priorities (e.g. Vitt et al., 2009). If a regional scale threat, such as climate change, has large effects on population viability, then regional scale management such as prioritizing populations best positioned for persistence for increased conservation effort should be implemented in response (e.g. Lendvay and Kalapos, 2014). Lastly, if both local and regional scale threats affect population viability, management effort should be balanced to create the best chance for long term persistence (e.g. Marrero-Gómez et al., 2007; Phillips-Mao et al., 2016). For example, in a review of conservation options for four species endemic to Southern Florida, Maschinski et al. (2011) found that local scale management, such as removal of invasive species, could only decrease these species' extinction risks in the short term. In the long term, no local management option was predicted to be effective against climate change induced sea level rise. Only managed relocation to higher elevations had the potential to prevent the extinction of these species. Thus, the authors recommended balancing management

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efforts, enacting local scale management only to increase these species' chances of persistence while the necessary research and legislative actions are taken to enact managed relocation.

Management at both local and regional scales can be costly (Walpole and Al., 2009; Maschinski et al., 2011), so to ensure the best use of limited conservation resources it is important to comprehensively assess the relative importance of multiple threats to inform management plans. For terrestrial plant species, quantifying the effects of threats (e.g. Maschinski et al., 2006; Pardini et al., 2015) and determining management strategies (e.g. Bernardo et al., 2016; Menges, 2007) are typically done with stage or age based population viability analyses (PVA) or integral projection models (Crone et al., 2011). These methods require quantitative data on the demography of multiple populations over long time periods (> 10 years; Morris and Doak, 2002). These long-term demographic data rarely exist (Eldred et al., 2003), and even when they do, many studies cannot consider multiple threats because doing so further increases the data required (but see e.g. Bowles et al., 2015; Phillips-Mao et al., 2016; Souther and McGraw, 2014).

However, long-term population count data are much more readily available through, for example, large scale plant monitoring programs (Parks, 1993; Bittman, 2001; Havens et al., 2012). Count data are much less laborious to collect than stage or age based demographic data and can often be collected over longer periods of time and for more populations within a region. There have been calls for better use of count data in rare plant species management for almost two decades (Morris et al., 1999; Eldred et al., 2003; Bakker and Doak, 2008), and there is now good evidence that count based PVAs can be used similarly to age or stage based PVAs when comparing relative extinction risk and developing management plans (McCarthy et al., 2002; Morris and Doak, 2002; Lotts et al., 2004; Sabo et al., 2004; García et al., 2010). Despite this, only a few peer-reviewed studies have used count based PVAs to assess the effects of threats on plant species (DePrenger-Levin et al., 2010; Molano-Flores and Bell, 2012; Morris et al., 1999; Ramula et al., 2008; Thomson and Schwartz, 2006), but none of these studies have used the method to compare among many threats acting at different spatial scales. Here, we extended the traditional count based PVA approach to assess the relative effects of multiple, interacting threats acting on different spatial scales for *Eurybia furcata*, a rare, woodland forb endemic to the Midwestern USA. Our approach provides solid recommendations to land managers about whether they should prioritize local scale management of their individual populations, network with other managers to conduct regional scale management, or some combination of both.

We used a modified count based PVA projection technique to determine the scale dependent management needs of *E. furcata* in response to multiple threats. First, we assessed the relative main and interactive effects of two local threats, encroachment by woody invasive species and browsing by deer, by associating *E. furcata's* growth rate values with varying threat levels. Second, we assessed a regional threat, climate change, by associating *E. furcata's* growth rate values with historic and future climatic conditions. Last, we assessed the interactive effects between threats at a local versus regional scale.

2. Materials and methods

2.1. Study system

Eurybia furcata (Burgess) G.L. Nesom, formerly *Aster furcatus*, is a perennial, woodland herb endemic to the Midwest USA (Les et al., 1992). It is known to occur in six states (Fig. 1) but has only two large concentrations of populations, one in Southern Missouri and one in upper Illinois/lower Wisconsin (Les et al., 1992; NatureServe, 2016). It is listed as vulnerable, endangered or critically endangered by NatureServe in all six states (NatureServe, 2016) and has state level Threatened status in five states (IA, IL, MI, MO & WI; USDA and NRCS, 2016).

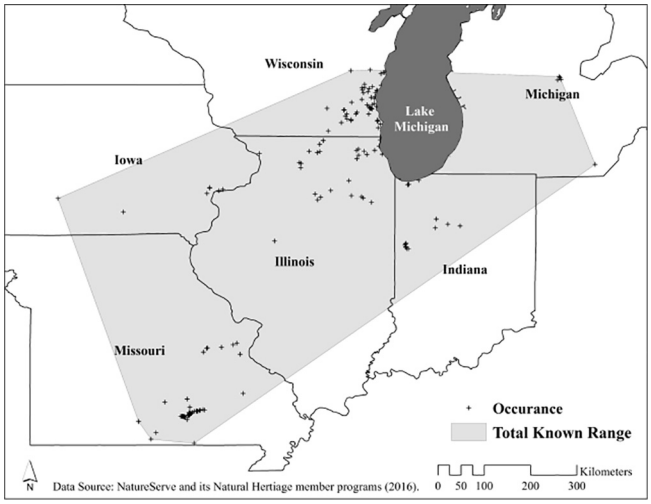

Fig. 1. Map of the Midwestern United States showing all known current and historic occurrences of *Eurybia furcata*. This information is provided by NatureServe (NatureServe, 2016; www.natureserve.org) and its Natural Heritage member programs, a leading source of information about rare and endangered species, and threatened ecosystems.

Eurybia furcata is found in isolated patches on north-facing woodland slopes (Les et al., 1992). It reproduces both sexually and asexually via rhizomes, sometimes forming dense patches of genetically identical individuals (Les et al., 1991, 1992). The major threats to *E. furcata* are thought to be habitat loss (NatureServe, 2016), loss of genetic variation (Les et al., 1991; Reinartz and Les, 1994), encroachment by woody invasive species and browsing by White-tailed deer (R. Goad *pers. obs.*).

This species is ideal for a count based assessment. First, sexual reproduction is rare because it is limited by a self-incompatibility system and generally low levels of genetic variation within populations (Les et al., 1991; Reinartz and Les, 1994). This means that *E. furcata* likely does not form large dormant seed banks, which could bias above ground population size counts. Infrequent sexual reproduction also means seedlings are rare, and since even small individuals are easily identifiable, thus the likelihood of observer bias in population size counts is low. Lastly, our monitoring data do not suggest a tendency for extreme fluctuations in population size, which can bias population projection results (Morris and Doak, 2002). Therefore, using population size counts based on the number ramets is likely to provide a representation of this species short-term population dynamics that is sufficient for comparatively assessing the effects of various threats to this species' persistence (Eriksson, 1994; Colling and Matthies, 2006).

2.2. Data collection

The Chicago Botanic Garden's Plants of Concern (POC) program (Havens et al., 2012) is a citizen science initiative that tracks the population size of, and local threats to, rare plants in Northern Illinois, Northwest Indiana and formerly in Southeast Wisconsin (hereafter referred to as the Western Great Lakes region). The data used in this study are from seven populations of *E. furcata* in Illinois and Wisconsin monitored from 2001 to 2015 (Appendix S1: Table S1). For logistic purposes, when populations have two or more patches separated by 50 m or more, those populations are broken into subpopulations treated as independent units for data collection. There are 21 subpopulations being monitored across the seven populations. Monitoring occurs once per subpopulation per year during peak flowering. Data for a variety of attributes are collected. The relevant data for these analyses are: 1) the total number of individuals (N), 2) stem density (N/area), and 3) the categorical impact of two local threats (woody invasive species encroachment and browsing by deer) as no impact (0%; no woody