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RESEARCH ARTICLE

Assessing feasibility in invasive plant management: a retrospective analysis of garlic mustard (*Alliaria petiolata*) control

Jeffrey D. Corbin[1,2], Matthew Wolford[1], Christopher L. Zimmerman[3], Brendan Quirion[4]

Given the difficulty that habitat managers face in controlling invasive species, assessing a project's feasibility before implementation can be a useful exercise. We describe efforts to eradicate a population of garlic mustard (*Alliaria petiolata*) from an area of the Adirondack Park, United States. We applied a retrospective assessment of the feasibility of the project using 2 different decision support tools, the Invasive Plant Management Decision Analysis Tool (IPMDAT) and WeedSearch. We modeled several scenarios in each tool by varying parameters related to the effectiveness of control in order to test the sensitivity of project success to particular assumptions. Except for a small decline between 2007 and 2009, the population increased during the control period. The number of surveyed transects with at least one garlic mustard individual increased, as did plant density within transects. IPMDAT and WeedSearch analysis confirmed that eradication of the garlic mustard population at this site was unlikely. IPMDAT discouraged proceeding with the goal of eradication, and only recommended containment if control of seed production could be effective and subpopulations (e.g. transects) could be eliminated. WeedSearch estimated that time required to achieve eradication would range from 11 years if control was 100% effective to more than 50 years if control was only 90% effective. The application of tools such as IPMDAT or WeedSearch can aid project planning by giving invasive species managers a more realistic picture of the commitment that may be required in order to achieve specific restoration goals.

Key words: decision support tools, eradication, invasive plants, monitoring, scenario modeling, weed management

Implications for Practice

- A variety of decision support tools exist that assess invasive weed control and/or eradication. Such tools have a range of approaches and data sources, and can be tailored to specific project details.
- Only those projects deemed to be feasible given realistic biological, economic, and social constraints should be undertaken in the first place. Decision support tools can aid in assessing feasibility before significant resources are invested in projects that are doomed to fail.
- Particular vulnerabilities or points of emphasis of a weed control project can be identified by using decision support tools to model specific scenarios.
- Wider use of decision support tools in restoration projects that include weed control is encouraged.

Introduction

The recognition that non-native species can have significant negative ecological (Vilà et al. 2011) and economic (Pimentel et al. 2005; Holmes et al. 2009) consequences has spurred development of a variety of strategies to limit their spread and impact. Such strategies, however, are rarely easy to budget or implement. Whether management goals focus on eradicating an entire population, containing a population's range to within or outside of a particular area, and/or suppressing the number of individuals (Wittenberg & Cock 2001; Hulme 2006), they are often multiyear projects requiring significant monetary and personnel investment (e.g. Rejmánek & Pitcairn 2002; Anderson 2005; Panetta 2009; Panetta et al. 2011*a*; Buddenhagen & Tye 2015; Panetta 2015).

Projects that target species that are widely distributed, abundant, and/or whose life histories present particular challenges are especially perilous due to the difficulty in setting reasonable control expectations and allocating resources efficiently (Rejmánek & Pitcairn 2002; Panetta & Timmins 2004; Larson et al. 2011). Habitat managers confronting new infestations of such invasive plants must weigh the benefits of abating the harm or impact versus costs of control and the likelihood of success.

Author contributions: JDC, MW carried out field monitoring and performed statistical analyses; JDC, CLZ, BQ, MW conducted the Invasive Plant Management Decision Analysis Tool and WeedSearch analyses; JDC wrote the manuscript with editing input from CLZ, BQ, MW.

[1]Department of Biological Sciences, Union College, Schenectady, NY 12308, U.S.A.
[2]Address correspondence to J. D. Corbin, email corbinj@union.edu
[3]The Nature Conservancy, New York Chapter, 195 New Karner Road, Suite 2201, Albany, NY 12205, U.S.A.
[4]Adirondack Park Invasive Plant Program, PO Box 65, Keene Valley, NY 12943, U.S.A.

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Such decisions are fraught with emotion, as they force managers to consider "giving up" and accepting a noxious species' status in a community (Fraser et al. 2006; Panetta 2009).

Given that resources are finite and not sufficient to confront every case of need, an assessment of the target species' threat, the feasibility of achieving the desired goals, and the ability to follow a project through to its completion should be a component of most if not all projects (Panetta 2009; Larson et al. 2011). There are a number of tools available for managers to complete such assessments (Hiebert & Stubbendieck 1993; Maguire 2004; Panetta & Timmins 2004; Fraser et al. 2006; Cacho & Pheloung 2007; Larson et al. 2011; Panetta et al. 2011*a*; Skurka Darin et al. 2011; Zimmerman et al. 2011; Kumschick et al. 2012). Such tools vary widely in their detail and scope including their reliance on qualitative versus quantitative population and demographic data. Some consider social/political and economic information alongside ecological information. Finally, they vary in terms of the type of output, including recommendations whether or not to proceed with a project, prioritization of potential eradication targets, and probabilities of eradication within specific time frames.

We describe one effort to eradicate an invasive plant and illustrate the way that such decision support tools could have informed the effort. The project was designed to confront a new infestation of garlic mustard (*Alliaria petiolata*) in the Adirondack Park, NY, United States that was first identified in fall 2006. Garlic mustard is widespread in midwestern and northeastern North America (Nuzzo 2000; Kurtz 2013) and can achieve densities approaching 50–100 individuals per m^2 (Stinson et al. 2007). It also is a prolific seeder, capable of producing hundreds of seeds per plant, each of which is capable of joining a long-term seed bank (Evans et al. 2012). As a result, even relatively intense efforts to eradicate garlic mustard are frequently unsuccessful (Drayton & Primack 1999). Active management, consisting of hand-pulling all known flowering individuals, was pursued for five growing seasons before it was abandoned. Monitoring of the population took place from 2007 to 2012 and in 2015. We hypothesized that intense management would successfully eradicate the population by (1) preventing reproduction and the contribution of new seeds to the next generation or the seed bank and (2) gradually reducing the population as the seed bank was exhausted.

We retrospectively applied two different decision support tools, Invasive Plant Management Decision Analysis Tool (IPMDAT) (Zimmerman et al. 2011) and WeedSearch (Cacho & Pheloung 2007) to assess whether, with the benefit of hindsight, there was evidence that the project's goal of eradication was feasible. We modeled several scenarios in which the effectiveness of control was adjusted in order to test the sensitivity of project success to particular assumptions. We argue that the project would have benefited from a formal analysis using decision support tools prior to initiation, and that these tools can be applied more broadly in the selection and success of invasive species management projects.

Methods

Ecology and Management of Garlic Mustard

Garlic mustard is an obligate biennial herb that germinates in the spring and spends its first year as a basal rosette. It flowers during the early spring of its second year and sets up to several hundred seeds per plant. As many as 10–20% of the seeds may delay germination (Evans et al. 2012), and they may remain viable in the soil for more than 10 years (V. Nuzzo 2016, personal communication). Garlic mustard is widely distributed in New York (Kurtz 2013) and is ranked as a noxious weed in the state and a variety of other jurisdictions. It is able to effectively compete with native vegetation (Anderson et al. 1996; Meekins & McCarthy 1999; Nuzzo 1999, 2000; Stinson et al. 2007; Van Riper et al. 2010) and potentially disrupt below-ground mutualisms between trees and mycorrhizae (Stinson et al. 2006; Callaway et al. 2008; Wolfe et al. 2008), though the ecological threat of garlic mustard has, more recently, been called into question (Nuzzo et al. 2009; Davis et al. 2014).

Efforts to control garlic mustard typically involve preventing seed production by either applying herbicide to first-year rosettes or second-year adults (Nuzzo 1991; Carlson & Gorchov 2004; Slaughter et al. 2007), or by cutting or hand-pulling second-year adults before they set seed (Nuzzo 1991, 2000; Chapman et al. 2012). In theory, the population will decline or go extinct as the seed bank is starved of new inputs (Baskin & Baskin 1992; Nuzzo 2000). Pardini et al. (2009) modeled the demographics of garlic mustard and simulated efforts to control a population. They found that management had to be highly effective, inducing mortality in at least 95 and 85% of rosettes or flowering adults, respectively, for a period of years.

Study Site

The study site was a 13-km length of North Lake Road in the southwestern portion of the Adirondack Park (43.4558°N, 75.0668°W). There was a narrow (approximately 5 m) strip of vegetation between the road's edge and the forest on both sides of the road that was maintained by mowing 1–2 times per summer beginning in late June. The road passed through secondary growth beech-maple-hemlock forest.

Garlic mustard was detected in fall 2006, and some localized herbicide spraying of first-year rosettes was conducted that same season. It is not known when or how the plants were introduced, but given previous surveys of the area, it is unlikely that the infestation was more than 3 years old (S. Flint 2007, APIPP, personal communication). We suspect that importation of soil or hay mulch associated with road and culvert maintenance was the propagule source.

Population Control and Monitoring

In June 2007, we established 82 20-m transects parallel to the road for the purposes of monitoring the garlic mustard population. Transects were randomly located along both sides of the road; distances between nearest transects ranged from 0.1 to 0.4 km. Each transect was staked outside the range of mowing and other road maintenance and georeferenced for the purposes of relocation. We counted the number of flowering/fruiting (e.g. second-year) garlic mustard individuals along the length of each transect and laterally from the road edge through the mowed area to 1 m into the forest, typically approximately 6 m. Sampling took place from 2007 to 2012, and again in 2015. Monitoring was timed to coincide with the period of peak flowering, but we were also able to observe individuals who flowered either 1–2 weeks earlier or later. Thus, we are confident that we were able to record almost all adult individuals within each transect.

Besides the one-time use of herbicide on first-year juveniles in fall 2006, control consisted exclusively of hand-pulling flowering and fruiting adults. Work crews surveyed the entire length of the road by foot or slow-moving vehicle after transect monitoring but before garlic mustard seed-drop in 2007–2010. In 2011, removal only took place within the 82 transects, and from 2012 onward there was no removal at all. The effectiveness of the hand-pulling was assessed in 2010 by resampling garlic mustard density in all 82 transects in June 2010, after treatments had been completed.

Plot locations and garlic mustard density data are available from the Dryad Digital Repository (Corbin et al. 2016).

Population Data Analysis

Because garlic mustard populations often experience a biennial cycle in density (e.g. Meekins & McCarthy 2002; Pardini et al. 2009; Van Riper et al. 2010), we focused our comparisons of trends in garlic mustard abundance within even-numbered years and within odd-numbered years. Specifically, we compared garlic mustard populations in 2007, 2009, 2011, and 2015; and in 2008, 2010, and 2012.

We tested for trends in garlic mustard's abundance in two ways. First, we considered only plots that had at least one plant at the start of a time sequence (e.g. 2007 for a comparison of 2007 → 2009). For each of those transects, we calculated the ratio of the number of transects in which garlic mustard density increased:decreased by the end time-point (e.g. 2009 in the above example). The ratio was compared to a binomial distribution with probability of 0.5. Second, we also considered all transects at the start of a time sequence. For those, we tested whether the number of plants per transect decreased during the sequence (e.g. 2007 → 2009). Because so many transects in each time period had no garlic mustard plants, our dataset violated the assumptions of regression even using alternative distributions such as Poisson or quasi-Poisson. Instead, we grouped transects into 0.25-km "bins" based on their location along the road. There were 52 such bins with 0–4 transects per bin. The number of plants in the bins was compared between two time periods using paired *t* tests. We also made the same bin comparisons using the non-parametric Wilcoxon rank-sum, but because it gave qualitatively the same answer, we only report the results of the paired *t* tests. We also conducted the paired *t* test analysis using bins that were 0.5 and 0.75 km in length. Results were qualitatively similar, so we report only the 0.25-km results.

We calculated the growth rate of the population, lambda (λ), between two time periods by dividing the mean number of plants per bin in the ending year (e.g. 2009) by the mean number of plants per bin in the starting year (e.g. 2007). All statistical analyses were performed using R version 3.2.2.

Assessment of Project Using Decision Support Tools

We evaluated the efforts to manage the garlic mustard population using IPMDAT (Zimmerman et al. 2011; IPMDAT 2016) and WeedSearch (Cacho & Pheloung 2007) (Appendices S1 &S2, Supporting Information). IPMDAT generates a recommendation whether to proceed with a predetermined control strategy, stop/consider an alternative control strategy, or to gather further information/data (Figure S1). WeedSearch uses quantitative demographic data and anticipated search effort to estimate the number of years required to eradicate a population. Neither tool existed when the control of the North Lake Road garlic mustard population began in 2006.

We used IPMDAT to assess the feasibility of control under two scenarios related to detection and control of adult plants (Appendix S1). In one scenario, we assumed that all adults could be detected and therefore new seed input could be prevented. In the other scenario, we acknowledged that some adults would escape detection and therefore some seeds would escape. Otherwise, inputs with regards to population characteristics, control effectiveness, and the sociopolitical environment were the same for both scenarios.

We used WeedSearch to assess the number of years required to achieve eradication under four different scenarios in which we varied the effectiveness of detection and control (Appendix S2). In our four scenarios, "efficiency of control," namely the proportion of adults that would be killed, was set to be 100, 95, 90, and 85%, respectively. WeedSearch returns the number of adults (and seeds and juveniles) in each year after the control project's initiation. Eradication was judged to have been achieved if in a year there were no adults and fewer than 0.1 seed per hectare, as recommended by Cacho and Pheloung (2007).

Results

Effects of Control Efforts

The garlic mustard population exhibited a strong 2-year cycle in adult density, as each odd-numbered year had several times more plants per 0.25-km section of the road, or "bin," than the subsequent even-numbered year (Fig. 1). Garlic mustard adult density declined slightly (Table 1) in the first 2-year interval (2007–2009) from an average of 20.2 plants per bin to 18.3 ($\lambda = 0.91$; Fig. 1). This was the only interval in which density declined—in all subsequent comparisons, it was either stable or increased. The largest increase was from 2008 to 2010, when the number of adults per bin doubled, albeit from the relatively low 3.2–6.9 plants per bin ($\lambda = 2.13$; Table 1; Fig. 1). Density increased in 26 of the 81 transects and declined in only five transects (Table 2). There was also significant growth in the adult population from 2009 to 2011, when the number of plants

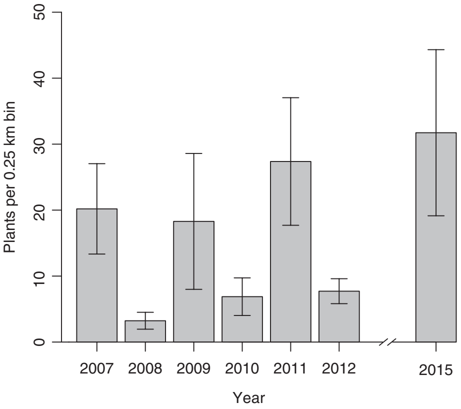

Figure 1. Mean (± SE) number of plants per 0.25-km bin in each sample year.

Table 1. Results of paired *t* tests testing whether garlic mustard density in each 0.25-km bin changed from one time-point to the next. Significant results ($p < 0.05$) and nonsignificant trends ($0.10 < p < 0.05$) are indicated in bold. [a]Degrees of freedom = 51.

Comparison	t *Stat*[a]	p *Value*	*Direction*
2007–2009	**1.83**	**0.072**	**Decreasing**
2007–2011	−0.43	0.7	
2007–2015	−0.82	0.5	
2008–2010	**−1.87**	**0.067**	**Increasing**
2008–2012	**−2.45**	**0.02**	**Increasing**
2009–2011	**−2.35**	**0.022**	**Increasing**
2009–2015	**−4.33**	**0.0001**	**Increasing**
2010–2012	**−2.935**	**0.005**	**Increasing**
2011–2015	−0.45	0.7	

per bin increased by 50% to an average of 27.4 plants per bin ($\lambda = 1.50$; Table 1; Fig. 1), while density increased in twice as many transects as it decreased (Table 2). By 2015, when active control had ceased, there was an average of 31.7 adults per bin, an increase of over 50% since the first monitoring period ($\lambda = 1.57$).

Elimination of garlic mustard from transects was rare—only 5 of the 30 transects with at least one individual in 2007 were free of plants in 2011. Meanwhile, garlic mustard was observed in 10 new transects during the same time period, and the number of transects with at least one adult increased steadily from 2007 until 2015 (Fig. 2).

Our 2010 assessment of control efficacy showed that hand-pulling killed many plants, but not all of them. In sampled areas that had at least one garlic mustard individual in 2010, the mean number of plants per 20 m decreased from 17.9 (pre-treatment) to 2.6 (post-treatment) (85% decline). However, on a per-transect (e.g. paired pre- and post-control) basis, the mean decline was 68%, with a median of 88%. Treatment was most effective in reducing garlic mustard density in transects with a large number of individuals: densities in transects with more than 10 individuals declined by a mean of 91%, while densities in transects with fewer than 10 individuals declined by a mean of 58% (Fig. 3).

Table 2. Number of transects in which garlic mustard density increased or decreased from one time-point to the next. The *p* value is the result of a two-tailed binomial analysis testing whether the proportion of transects that changed in each direction was significantly different from an expected random (0.5) distribution. Significant results ($p < 0.05$) and nonsignificant trends ($0.10 < p < 0.05$) are indicated in bold.

Comparison	*Number of Transects With Decreasing Density*	*Number of Transects With Increasing Density*	p *Value*
2007–2009	22	14	0.3
2007–2011	18	20	0.9
2007–2015	19	25	0.5
2008–2010	*8*	*17*	0.11
2008–2012	5	**26**	**0.0002**
2009–2011	12	**24**	**0.07**
2009–2015	11	**31**	**0.003**
2010–2012	10	**27**	**0.008**
2011–2015	20	23	0.8

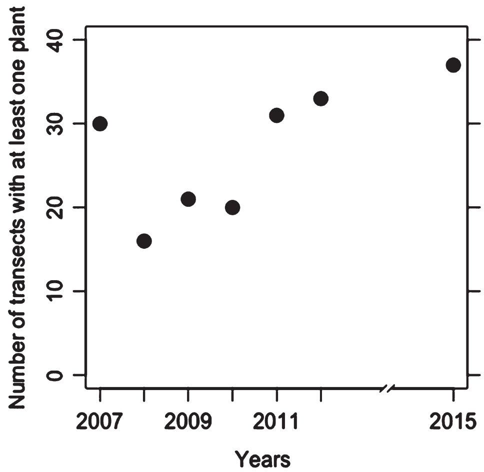

Figure 2. The number of transects (out of 82) that had at least one adult garlic mustard plant. Transects were not sampled in 2013 and 2014.

Decision Support Tool Analysis

In both scenarios modeled using IPMDAT, eradication was not recommended as a feasible project goal, based on garlic mustard's regional distribution and the large area of infestation (Appendix S1). When we assumed that all adults could be detected and therefore controlled, IPMDAT concluded that the less ambitious goal of containment was feasible and recommended that the project proceed (Appendix S1, Scenario 1). However, when we reran the assessment without assuming that control would be 100% effective (Appendix S1, Scenario 2), IPMDAT recommended against containment and instead recommended that managers consider suppressing the population. After the final stage of analysis, in which the financial costs were weighed against the benefits of the project, IPMDAT recommended that suppression, or reducing population size short of eradication, was a feasible strategy. However, given the roadside location of the infestation and the absence of any species of

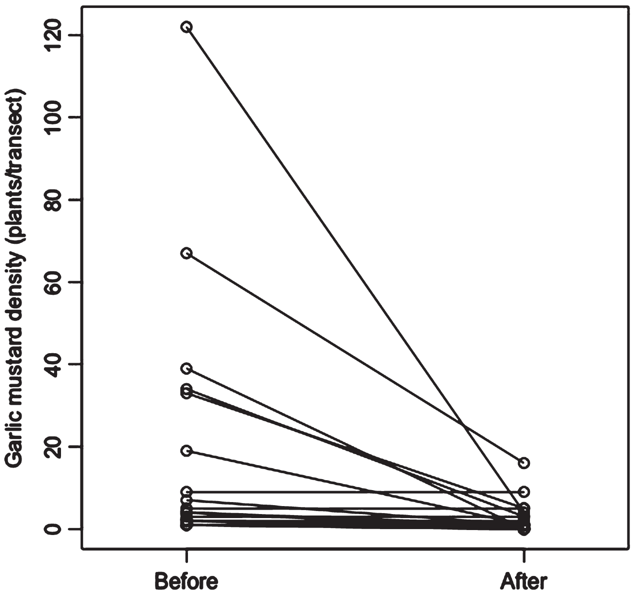

Figure 3. Effectiveness of 2010 hand-pulling of adults, as indicated by the garlic mustard density (plants per transect) before and after treatment took place. Each open circle represents a single transect, connected by a line to show the change in density. Only transects with at least one plant before treatment are included. While the decline among transects that started with many plants was steep, the trend among transects with <10 plants at the start was relatively flat.

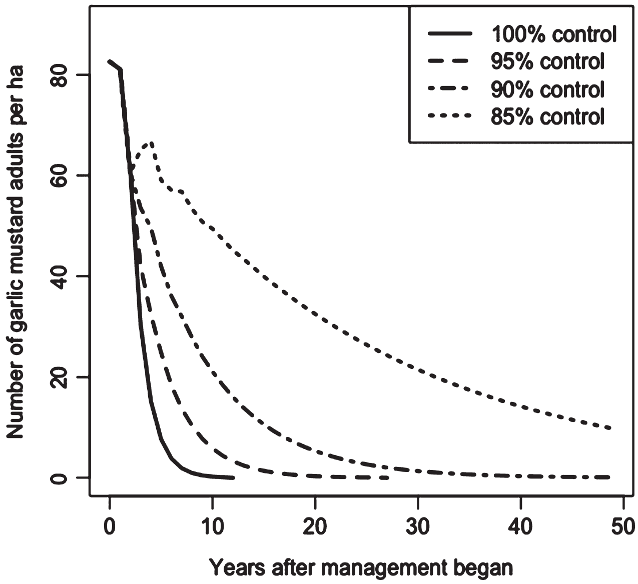

Figure 4. Number of adults in each year following initiation of treatment in WeedSearch model. Four different scenarios are presented: 100, 95, 90, and 85% control of adults. Eradication was achieved in 12 and 27 years, respectively, for the 100 and 95% treatments. In the 49th year of the simulation, there was 1 adult per hectare in the 90% treatment and 10 adults per hectare in the 85% treatment.

concern (e.g. rare species) to consider, suppression would likely not be warranted.

Results from WeedSearch's output varied widely depending on settings for the effectiveness of control. When effectiveness of control of adults was set at 100%—that is, all individuals in the population in a given year were killed—the modeled population was eradicated in 12 years (Fig. 4). However, eradication took considerably longer as the effectiveness of control decreased even slightly. When control was only 95% effective, it took 27 years; for 90 and 85% control effectiveness, eradication was not achieved within 50 years.

Discussion

Effect of Management on the Garlic Mustard Population

Garlic mustard's spread at our site and its increasing abundance indicate that 5 years of control did not successfully eradicate, or even contain, garlic mustard along North Lake Road. Neither of the proposed hypotheses regarding the effectiveness of control was supported. Even during the period of active control, the population growth rate (λ) was above one in all time periods except 2007–2009 and frequently above 1.5. These values are within the range reported for unmanaged populations (e.g. Drayton & Primack 1999; Meekins & McCarthy 2002). We note that, without a no-treatment control area, we cannot assess the extent to which management suppressed the population or limited its spread. However, we observed only infrequent invasion beyond the roadside into the forest.

Our treatments were not effective enough to meet the threshold of 85–95% control of adults as set by Pardini et al. (2009). As a result, rather than exhausting the seed bank by preventing new propagules, the population grew in every time period except for one. Control was least effective in lower-density patches, which was likely a function of the reduced likelihood of detection of isolated individuals, a frequent observation in invasive species management (e.g. Christy et al. 2010).

Other studies have reported that, while management may reduce garlic mustard populations, it often is insufficient to achieve eradication. For example, Drayton and Primack (1999) reported that hand-pulling of flowering adults for 4 years significantly reduced population growth compared to unmanaged controls, but only 23% of their 61 managed populations were eradicated. The number of plants declined (though not to zero) in another 20%; meanwhile, one quarter of their populations experienced "steep growth." Carlson and Gorchov (2004) found that 2 years of spraying with glyphosate herbicide significantly reduced the number of garlic mustard individuals, but again did not eradicate the populations. These findings emphasize the challenges that efforts to eradicate garlic mustard face.

Decision Support Tools' Recommendations

Assessment of the project using IPMDAT and WeedSearch generally confirmed observations in the field. Assuming realistic control parameters, neither concluded that eradication was a feasible option within the time frame of the project. Using decision support tools to simulate management revealed how critical it was to detect and kill as many adults as possible before seed set. IPMDAT recommended against eradication in all scenarios, and only recommended that containment be considered if all individuals could be detected and killed before they set seeds. WeedSearch analysis also clearly showed the sensitivity of the project to the control effectiveness. If 100% of the adults were killed, then the model concluded that management would have nearly eliminated the population with several more years of treatment beyond the 5 years that were conducted. However, even small deviations from that exacting standard led to a significantly longer time commitment—more than 50 years if just 10% of adults escaped treatment. Even without accounting for rising costs, it would have required more than $500,000 to complete the latter scenario. This conclusion mirrors other analyses of the feasibility of controlling garlic mustard and other invasive species. For example, Panetta et al. (2011*b*) applied WeedSearch to efforts to eradicate 41 Australian invasive species, and concluded that eradication was possible for all but one—*provided* sufficient funding and labor were applied to each project. Yet, the mean predicted time to achieve eradication was 17 ± 10 years, and for more than a quarter of the species, the predicted cost was more than $1 M. Quantifying such a large commitment could significantly influence the feasibility and viability of a proposed eradication project.

Decision Support Tools in Managers' Hands

Invasive plants are frequently a component of ecosystem degradation, and so their control is often a critical element of restoration efforts. Given budgetary pressures on land management agencies and conservation organizations, it is critical that resources be allocated as efficiently as possible and on projects that have a high likelihood of success. Decision tools such as IPMDAT and WeedSearch can help inform which projects are worth the investment and which ones are not. Thus far, their application has focused on North American and Australian case studies (e.g. Panetta et al. 2011*b*; Skurka Darin et al. 2011; Panetta 2015), but such tools should be useful globally and across a range of life histories.

In a practical sense, decision tools such as IPMDAT, WeedSearch, and others can be used in a variety of ways. Most obviously, they can be used to assess project feasibility before implementation (Cacho & Pheloung 2007; Panetta et al. 2011*a*; Zimmerman et al. 2011) or to select target populations (Skurka Darin et al. 2011; Kumschick et al. 2012). The process of assembling the information required to complete the analysis can serve as a kind of "checklist" (sensu Gawande 2010) that ensures that critical factors are being considered. For example, IPMDAT considers such biological and social factors as nontarget impacts of the control method, the existence of local support, and the likelihood of reintroduction, among others (Appendix S1) that could imperil a project. Such issues are better identified in the planning stage, when strategies can be adjusted accordingly. Furthermore, these tools may serve to complement each other when more than one is used, as collectively they may allow habitat managers to consider a wider range of factors than if they were used individually.

Decision tools can also aid in project design by examining the importance of particular components of a management strategy, or by highlighting particular vulnerabilities. An example of this was our sensitivity analysis using WeedSearch, which identified how vulnerable the project's goals were to even a small number of escapees. Such knowledge at the outset of the project could have reinforced how critical it was to prevent flowering adults from escaping detection, and led to a modification of the control strategy. The impact of search intensity—e.g. the number of hours spent searching or the speed—could also be modeled, as could aspects of the population's demography—λ, seed bank, lifespan, etc. Any of these applications could identify critical components/vulnerabilities of a project's strategy and improve restoration planning. Population models have been applied to the design of invasive species control projects in the past (e.g. Parker 2000; Govindarajulu et al. 2005; Davis et al. 2006; Pardini et al. 2009; Cunniffe et al. 2016), but the technique is particularly tractable using WeedSearch and similar tools.

Control of the North Lake Road population ended after 2011 because it was clear that the population was not shrinking. It is likely that, if IPMDAT and WeedSearch analysis had been conducted on this project in 2006, the North Lake Road population would not have been targeted for control in the first place. It would have been clear that eradication was unlikely given how widely distributed garlic mustard was along the roadside, and the exacting control threshold the project needed to reach if it was to succeed. Despite this experience, APIPP staff continues to selectively manage garlic mustard in other areas of the Adirondack Park including trailheads and campsites, where the area in need of control is smaller and the likelihood of detecting all individuals is higher. In at least some of these cases, local eradication—defined by at least 3 years with no observed plants—has been achieved (B. Quirion 2016, APIPP, personal observation). These successes are taking place, however, in the context of an overall expansion of garlic mustard's population: the number of known populations within the Adirondack Park boundaries has tripled between 2006 and 2015 (APIPP, unpublished data).

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Supporting Information

The following information may be found in the online version of this article:

Appendix S1. Description of assessment of the North Lake Road garlic mustard population using IPMDAT (Zimmerman et al. 2011; IPMDAT.org 2016).
Figure S1. Steps of the Invasive Plant Management Decision Analysis Tool (IPMDAT).
Appendix S2. Description of WeedSearch methods in the retrospective analysis of North Lake Road garlic mustard population.

[Correction added on 30 September 2016, after first online publication: The web address for Appendix S1 has been changed from “IMPDAT.org” to “IPMDAT.org”.]

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