Session 8: Social and Economic Assessments of Biological Control

The Garlic Mustard (*Alliaria petiolata*) Case, What Makes a Good Biological Control Target: The Intersection of Science, Perspectives, Policy and Regulation

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Abstract

In this paper, we present an overview of our shared experiences from a thirteen-year discovery and testing period in search of effective biological control agents for garlic mustard (*Alliaria petiolata* (M. Bieb.) Cavara & Grande). Our experiences during this time reflect much of the dialog, debate, dilemmas, and policy discussions occurring in biological control of weeds today. For example, in the last decade, the values that underpin biological control, as well as standard requirements and stakeholder perspectives have been in a state of flux. Many research programs fail to sustain funding for such long pre-release periods. Policy goals and acceptable safety criteria have changed. Moreover, the fundamental perception of garlic mustard as a pest is shifting, leading some to question whether garlic mustard is a driver of change in invaded habitats or rather a symptom of habitat disruption. If it is a symptom, this can shift the perception of the risks of biocontrol. In this shifting scientific and social milieu, land managers are still challenged by stakeholder demands for management of garlic mustard. Land managers have a responsibility to manage their sites for the purposes for which the land is preserved and have limited control, or no control over potential higher-level drivers such as earthworms, deer, climate change, and human population pressures. The intent of this presentation is to discuss these and other issues common to many who work in biological control, framing the discussion within our garlic mustard experience as the basis for dialog.

Background

Awareness and public interest in garlic mustard invasion of hardwood forests in the Midwest and Northeastern USA gained significant momentum in the 1980s with a series of key publications by Nuzzo (1991; 1996) and Nuzzo et al. (1996), culminating in the effort to develop a biological control program that started in 1998 with a broad base of support. At that time, available assessments 'indicated that the only viable long-term option for successful management of garlic mustard is classical biological control' (Blossey et al., 2001a). As part of the biological control project, a test plant list was developed, and CABI in Delémont, Switzerland contracted to conduct surveys and host specificity testing of candidate agents. Additional host specificity testing began in 2003 at the University of Minnesota, USA on plant species that were difficult to obtain or grow in Switzerland. Throughout this process stakeholders were engaged through various workshops (e.g. Skinner, 2005) and in the development (Blossey, 1999) and implementation of a long-term monitoring protocol for garlic mustard. The availability of pre-release data would allow us to gauge the impacts of anticipated biological control agent release(s) (Evans and Landis, 2007; Van Riper et al., 2010).

Gerber et al. (2009) summarized the biology and host-specificity results for the root-crown mining weevil (*Ceutorhynchus scrobicollis* Nerensheimer and Wagner) based on which, a petition for field release of the species was submitted in 2008 to the USDA APHIS TAG (United States Department of Agriculture, Animal and Plant Health Inspection Service, Technical Advisory Group). Based on the comments of reviewers, additional host testing was conducted from 2009 through 2011. Responses to reviewer comments to the 2008 petition and the results of additional host specificity testing were re-submitted to TAG in September of 2011.

Discussion

How safe is safe enough?

Typical of many weed biocontrol endeavors, the effort to release a biological control insect for garlic mustard in North America has been long and arduous. Thirteen years after officially initiating the research, we are awaiting TAG review of our latest submission. Much has changed during this time. For example, phylogenetic relationships among tribes within the Brassicaceae were redefined (Al-Shehbaz et al., 2006), necessitating continuous adaptation of our test plant list. Also, during this lengthy testing period, the concept of acceptable risk has changed. As common in risk assessments, "safe enough" is rarely achieved to the satisfaction of all stakeholders. One might conclude that agreement is rarely achieved now compared to biocontrol programs in decades past, as seen in papers presented at this conference. Lincoln Smith *(in press)* discussed an insect which has broad support for yellow starthistle (*Centaura solstitialis* L.) control, but ultimately was not approved for release. A retrospective review of past agents approved for release was presented by Hinz et al. *(in press)*, exploring the possibility that most of these agents would not be approved in today's regulatory climate in the USA.

In our case, *C. scrobicollis* did develop on the commercially grown watercress (*Nasturtium officinale* Ait. f.). Adult development on watercress was not consistent throughout tests conducted in different years. Moreover, *C. scrobicollis* development was only found when watercress was grown in artificial dryland mesocosms. Cultivated watercress is grown under water-saturated conditions (e.g., in running water). In refined host-specificity tests altered to simulate these growing conditions, *C. scrobicollis* was not able to complete its development on watercress. Additionally, *C. scrobicollis* has not been recorded as an economic pest, nor even in association with watercress in its native range where both co-exit, arguably the most comprehensive specificity testing possible.

While the overall host specificity package for *C. scrobicollis* on garlic mustard in North America suggests the ecological host range will be narrower than the physiological host range with the latter defined as development under highly artificial laboratory conditions, such data points could prove troublesome for the approval process. 'Troublesome' data points refer to data generated under circumstances which render the data suspect upon further scientific scrutiny. Once generated, however, these 'troublesome' data points do not go

away. Despite subsequent work that more accurately reflects scientifically valid outcomes, the initial data remains in the body of evidence submitted for approval and often result in lingering concerns, particularly at the policy level, rather than at the scientific review process for biological control agents within USDA APHIS.

Is garlic mustard really that bad?

Another phenomenon that has evolved during our lengthy testing period is the notion that yesterday's demonized pest may become today's ecosystem services star. Apropos the papers presented at this symposium by Dudley et al. *(in press)* and Norton et al. *(in press)* discussed litigation over biological control of saltcedar (*Tamarix* spp.) impacting the southwestern willow flycatcher (*Empidonax traillii extimus* A.R. Phillips). Campaigns to disparage target invasives are common, prompting critical reviews reflecting on the fear-based language used with the public to generate support for control efforts (Gobster, 2005). Indeed, we used the Good, the Bad, and the Ugly campaign effectively in Minnesota to generate support for the biological control of purple loosestrife (*Lythrum salicaria* L.). Paradoxically, this terminology is now being used by opponents of biological control to describe the biological control agents. Warner & Kinslow (2011) explored this phenomenon more broadly in the context of manipulating risk communication to the public in the case of biological control of the strawberry guava tree (*Psidium cattleianum* Sabine) in Hawaii, resulting in an outcome different than intended by the scientific and conservation communities.

In the thirteen years since our effort began on garlic mustard, views of how we view this plant are evolving. Some studies have shown negative impacts of garlic mustard in invaded ecosystems while others found no impacts. Is garlic mustard a principal driver of detrimental impacts? Research showed that garlic mustard competition for light negatively impacted tree seedlings and annual herbaceous species (Anderson et al., 1996; Cipollini and Enright, 2009; Meekins and McCarthy, 1999), altered nutrient levels (Rodgers et al., 2008), and was toxic to arbuscular mycorrhizal fungi which could result in altered nutrient and water acquisition by many native species (Callaway et al., 2008; Cipollini and Gruner, 2007; Roberts & Anderson, 2001). Of concern to the forest industry, research suggested garlic mustard negatively impacted desirable tree seedlings (Stinson et al., 2006).

Alternatively, is the presence of garlic mustard merely a symptom of a response to higher-level changes? Indeed, garlic mustard often is observed in disturbed areas that lack native cover (Trimbur, 1973; Nuzzo, 1991; Van Riper et al., 2010). Recently it has been proposed that the action of deer and earthworms facilitate garlic mustard invasion (Blossey et al., 2005; Knight et al., 2009; Nuzzo et al., 2009). Deer herbivory on natives can create disturbed microsites that promote dispersal of garlic mustard seeds (Anderson et al., 1996). Loss of native plants may create suitable conditions for garlic mustard invasion through increased light levels, moisture, and nutrient availability (Anderson et al., 1996) and decreased litter levels (Trimbur, 1973), as well as through anthropogenic effects such as erosion.

Who is the driver?

If garlic mustard is not the principal driver of negative impacts, some on our team propose that we should focus efforts on the higher-level drivers (e.g., deer and earthworms), not the symptoms (e.g., garlic mustard). Such ideas are gaining support in the ecological literature where for example, Davis (2011) argued that species such as garlic mustard do not pose as big a threat as scientists think. Some are finding evidence that native insects impacted by garlic mustard may be adapting to it (Keeler and Chew, 2008). As a result, after a decade of testing, we have reached the juncture where our group is discussing whether we should release *C. scrobicollis* even if approved by TAG.

Exotic earthworms are widely discussed relevant to invasion in forest ecosystems (Nuzzo et al., 2009) and once established, few, if any management options exist to remove them. There has long been evidence about the negative impacts of deer on native plants (e.g., Hough, 1965; Tilghman, 1989; Diamond, 1992). However, limiting deer populations is difficult. State natural resource agencies both promote deer for hunting and as an income generator via hunting permits, while concomitantly expending resources to remove deer or to install exclusion devices to promote regeneration of tree species impacted

by deer browse. Neither of these factors is likely to change significantly in the near term. Also, it is not clear how the public would react to deer herd reductions to the low level required to reduce disturbance to a degree that may stop the invasion of plants like garlic mustard.

What is involved if land managers were to shift from managing garlic mustard to instead managing higher-level drivers? Figure 1 shows the relative geographic scale and management difficulty of several drivers that impact invasive species. This concept was adapted from a CABI Biosciences schematic depicting the centrifugal phylogenetic method. This driver schematic assumes garlic mustard as a symptom, not a driver. As we move out from the center, the geographic scale of the potential negative impact of the driver, and concomitantly, the difficulty in altering that impact increases. Earthworms are problematic, but at present are less widely distributed in the Midwest USA compared to deer. As we move to a wider geographic scale, anthropogenic effects such as pollution (e.g., nutrient loading, sediment runoff, etc.) and more broadly, climate change are clearly drivers of negative environmental change. Managing drivers such as climate change is distinctly long-term and the outcome uncertain. Ultimately, it is people and the resultant impact of our lifestyles and actions that is the overarching driver. Changing any of these on a scale to reduce negative impacts to ecosystems is a daunting endeavor, especially for a land manager.

Will garlic mustard go away?

During the time invested to find a biological control agent for garlic mustard, some members of our team have observed a decline in long-standing populations of garlic mustard absent the introduction of a biological control agent (Blossey and Nuzzo, *in press).* Perhaps we are just seeing the beginning of a decline in garlic mustard populations in North America, or are these population density fluctuations, related to climate cycles reflecting the natural ebb and flow of invasive species? If populations do significantly decline, will they resurge and expand to a point where we have populations of garlic mustard that are even more widely dispersed?

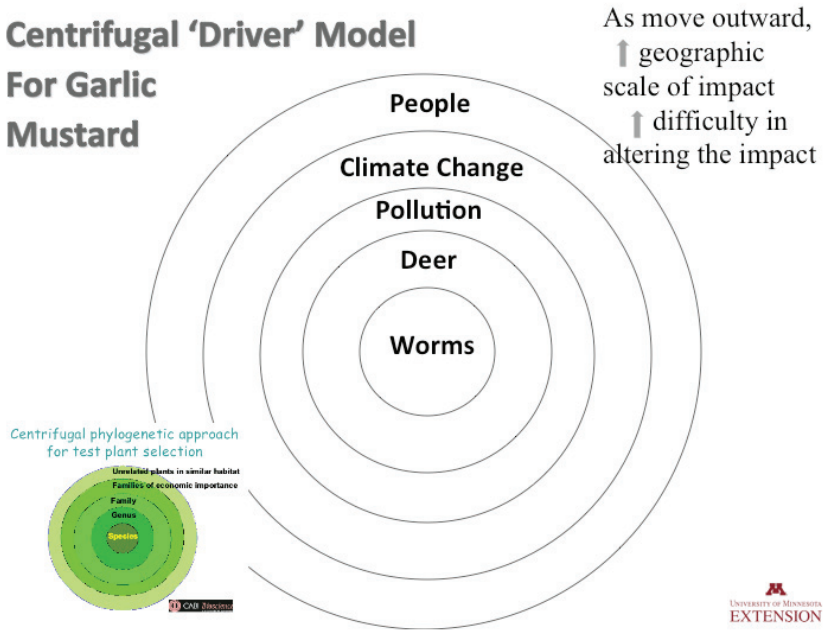

Figure 1. The centrifugal driver model. An adaptation of a CABI diagram depicting the centrifugal phylogenetic method of Wapsphere (1974).

Additionally, would there be a benefit to uninvaded communities if a biocontrol agent could avoid a boom and bust cycle of garlic mustard?

More broadly, the field of ecology is exploring fluctuations in population densities of invasive species (Simberloff and Gibbons, 2004, Ahern et al., 2010). In the experiences of an Extension State Weed Scientist at the University of Minnesota (Becker), it is well known that species shift, population densities ebb and flow, and weed patches move around on the landscape. Landscape-scale changes in problem species in agricultural systems are driven by what weed scientists call the 'big hammers'; typically system-wide shifts in tillage, fertility, periodicity of operations, or the periodic dominance of one herbicide mode of action in the marketplace. An example of dramatic population fluctuations that may inform invasions that dominate the landscape and then moderate, was the effort in the USA to domesticate the native common milkweed (*Asclepias syriaca* L.) during World War II to produce floss (pappi) to fill life jackets when imports of goose down were blocked. Common milkweed in North America can be found throughout a broad habitat range. As it naturally occurs, common milkweed remains at low population densities and scattered across the landscape. In attempts at domestic production, when planted in monocultures in fields, density-dependant diseases quickly became an impediment to successfully growing the crop in many locales, and in many cases resulted in abandonment of fields. Experienced weed scientists often recount such phenomena, but as is often the case with experiential knowledge, it is seldom documented in peer-reviewed journal articles. Similar to the disease limiting phenomena seen in milkweed, we have observed that Canada thistle populations approaching monotypic stands decline after six to seven years due to generalist pathogens *Fusarium* and *Pythium* resulting in reduced population densities that are relatively dispersed.

Herbaceous perennial or biennial weeds in the Upper Midwest USA are dynamic in population density, population size, and location in response to climate. Minnesota is at the intersection of the hardwood forest, boreal forest, and the tall grass prairie regions of the USA. Here, herbaceous invasive plants respond to temperature and moisture cycles. Historically, these occurred in 20-year cycles in records since the 1800s, but with climate change, the cycles are lengthening and becoming more local with drought and flood cycles occurring in the same season within the same county (Minnesota Climatology Working Group, 2011). These climate changes can be tracked by shifts in the species that become problematic for land managers. During wet cycles in Minnesota it is common to see Canada thistle (*Cirsium arvense* (L.) Scop.) and buttercup (*Ranunculus* spp.) thrive and expand geographically. Conversely, during dry cycles hoary alyssum (*Berteroa incana* (L.) DC.), wormwoods (*Artemisia absinthium* L.), and leafy spurge (*Euphorbia esula* L.) thrive and expand. This increase in localized variability due to climate change will accentuate changes in population dynamics of many of the invasive weeds with which we work.

Garlic mustard is a biennial species cycling in a perennial system. Sustaining a population is wholly dependent on constant regeneration of rosettes from seedlings. Seedling regeneration depends on disturbance and is subject to episodic widespread seedling mortality. At some of our garlic mustard monitoring sites in Minnesota, we see cycles where either the seedling/rosette or the flowering second-year growth stage dominate in a given year, while at other sites they occur simultaneously (Van Riper et al., 2010). By its biennial nature, garlic mustard populations will fluctuate dramatically, and in extreme climatic events, may even skip population cycles altogether, only to resurface in the future. Thus, multiple forces are at work resulting in garlic mustard populations that are very dynamic. Our challenge is to determine the long-term trends, and what that means within the construct of our original justification for biological control of garlic mustard.

Conclusions

Many on our team were also part of the biological control effort of purple loosestrife in North America, informing our approach to biological control of garlic mustard. Many of the same stakeholders and funding sources were used in both efforts, and the perceived success of purple loosestrife biocontrol resulted in built-in enthusiasm for the garlic mustard effort. For example, the network of pre-release garlic mustard monitoring sites included many managers who were

cooperators on the purple loosestrife effort. Blossey et al. (2001b) was in part a response to criticisms of the purple loosestrife biological control effort. Yet almost two decades after the release of *Galerucella* spp. for biological control of purple loosestrife, science has not settled the debate surrounding biological control of that invasive species (Lavoie, 2010). More studies are being proposed to answer the next set of garlic mustard research questions. We are on the cusp of gaining approval for release of *C. scrobicollis*, but are debating similar questions that are still debated for purple loosestrife. Experience indicates that scientific discourse will be unable to expeditiously address the complex interactions to manage higher-level drivers, nor quickly settle the more direct question of whether invasion by garlic mustard negatively impacts native ecosystems.

So, considering the debate over whether garlic mustard negatively impacts forest ecosystems and whether it is only present because of higher-level drivers, what can land managers do in response to public demands for action? As is the case for many pest problems, the default action is to treat the symptoms – in this case an invasive weed that has become abundant. This option is something we can do and can measure the success of in terms of cost and effectiveness, providing justification to those who fund such programs. Control of invasive, noxious weeds is often required via regulated weed laws in the USA. Managing higher-level drivers arguably might be the most efficacious and efficient approach; however, it would involve a higher degree of complexity, is more difficult to implement, and is an approach that takes a long time to provide results, thus, making it more challenging to garner and maintain support.

One of our team members summed it up this way: We should address the symptoms, i.e., control garlic mustard if it: 1) provides additional time to address root causes, 2) prevents degradation in the meantime, 3) poses minimal risks, and 4) does not clearly jeopardize a long term solution. Doing so may spare uninvaded and minimally invaded habitat in the Midwest the upheaval of a garlic mustard invasion. This may not be true in parts of the northeast. Midwest ecosystems could benefit from delay or reduction of garlic mustard invasion considering our host specificity data suggest minimal risk.

We are left with a dilemma. On one hand, we must consider the implications of releasing an organism against a pest that may not be the root cause of detrimental changes. This would be an especially egregious error if the biological control agent caused unintended nontarget damage in the future. On the other hand, we must also consider the implications of not releasing a biological agent deemed safe for a target that many stakeholders feel has significant negative impacts. Managers may not be able to eliminate earthworms and deer, but biocontrol could give them a tool to reduce one stressor to the system: garlic mustard. Not releasing a biocontrol agent is particularly problematic if future work confirms significant impacts on forest ecosystems, and populations do not undergo a natural decline but rather persist across the landscape. Considering the ongoing controversies regarding biological control of weeds, we must also reflect on the implications these two scenarios may have for the future of biological control of weeds, both from a policy and funding viewpoint.

Acknowledgements

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources, the USDA Cooperative State Research, Education, and Extension Service, USDA Forest Service, and USDA Animal and Plant Health Inspection Service.

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Public Engagement with Biological Control of Invasive Plants: The State of the Question

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Abstract

The practice of biocontrol has been impacted by in the evolution of environmental values in societies, and difficulties in obtaining release permits. These challenge biocontrol stakeholders, researchers and regulators to foster more effective public engagement with invasive species management. To succeed, public engagement requires the disambiguation of research activities from public agency decision making. This requires greater up-front investment in public communication and consultation, and more transparency by agencies in the application of their decision making criteria. However, these additional costs can be offset if the result is attenuated surrounding controversies and amplified public support for invasive plant control. This article draws from a five year comparative study of biocontrol practice, policy & public engagement in the U.S., South Africa, New Zealand, and Australia. It presents key findings to guide public engagement with biocontrol of invasive plants.

Introduction

The social context of weed biocontrol has changed dramatically since the first International Symposium on Biological Control of Weeds (ISBCW). Formerly, biocontrol researchers labored in autonomy from society, but now they are increasingly expected to communicate their work to non-expert public officials and members of the public. With the rise of environmental values and legislation, environmental scientists and agencies funded with public monies were increasingly asked to justify their activities to the public (Speth, 2004). This gave rise to early efforts to cultivate public support for biocontrol of invasive plants, using the tools of public outreach and public consultation. These early efforts push information out to the public, or gather comments from the public. In the 21st century social context, unidirectional communication to or from the public regarding science is not sufficient to garner public monies, nor public support, for any type of scientific activity.

By studying cases where there is greater public support for the application of science and technology in addressing social needs, social scientists have articulated a new model for relating scientists and their institutions to society: public engagement (McCallie et al., 2009). Unlike the unidirectional communication implicit in public communication and comment, participatory public engagement with science and technology (shortened to "public engagement") facilitates mutual learning among publics, scientists, and others with respect to the development and application of science and technology in modern society (Rowe and Frewer, 2005; Mooney, 2010). Public engagement is more costly in terms of time and resources. However, members of the public are challenging publicly-funded researchers and regulatory agencies to be more transparent in their decision making, and the early models of public communication do not support effective responses. Public engagement has the potential to cultivate greater public support for biocontrol.

Invasive plant control in the future will require more than passive public support. It will require active and sustained engagement by citizens and stakeholders, who reasonably expect public agencies to demonstrate how this practice addresses economic and conservation goals. Public engagement fulfills democratic values, which is especially important for any public interest science (Warner et al., 2011), but also good practice to minimize social conflicts over biocontrol agent releases (Warner and Kinslow, *in press*). Since the public funds most invasive species control programs, it is reasonable to educate and engage them on a continuing basis. Controversies surrounding the introduction of biocontrol agents have dogged high profile and costly restoration projects, and the future of classical biocontrol as an invasive species management practice is threatened by persistent unresolved controversies (Strong and Pemberton, 2000; Warner, *in press*). To be effective, public engagement must:

1. Construct greater social understanding of the problems of invasive plants;

2. Create greater social consensus on the need to control invasive plants and the conditions under which biocontrol is a socially preferable approach; and

3. Incrementally increase the public's trust that government agencies are upholding the public's interest through appropriate regulatory review.

Here is the state of the question: "could greater public engagement with biocontrol of invasive plants foster greater stakeholder support without hindering research?" Public engagement challenges scientists and their institutions to develop skills in public communication, and challenges public regulatory institutions to facilitate appropriate public review with biocontrol release decisions. Researchers and public agencies need forms of public engagement that do not:

1. Interfere with scientific research and practice;

2. Impose significant additional burdens on their own time;

3. Delay regulatory review.

To avoid these problems, public engagement should disambiguate scientific research activities from public agency decision making. This requires greater up-front investment in public communication and consultation, and more transparency by agencies in the application of their decision making criteria. However, these additional costs can be offset if the result is attenuated surrounding controversies and amplified public support for invasive plant control. The balance of this paper introduces the material and methods supporting this study; explains how public engagement differs from early forms of public communication; and summarizes conclusions from this study.

Methods and Materials

Social science field work was conducted in the U.S., South Africa, Australia and New Zealand. Between 2007 and 2009, 183 semi-structured interviews were conducted with 178 research scientists, laboratory directors, regulators, communication officers, critics, and clients of the practice of classical biocontrol in all four countries. Interviews addressed the following topics: the history of invasive species control, and biocontrol practice and their institutions; the impact of rising concern about nontarget effects of biocontrol agents; and how legislation and regulatory institutions have responded to risk concerns regarding biocontrol agent introductions. Several of these interviewees provided extensive documentation on the policymaking and regulatory processes in these countries.

Results

The introduction of a novel biocontrol agent is a socio-political decision as well as a biological and environmental action. At the time of the first ISBCW in 1969, virtually all biocontrol decisions could be made within one public agency. Target selection, agent selection, testing criteria, and release permitting were all internal to one institution, often a department of agriculture. Now these decisions are generally distributed between multiple public agencies and are at times more contested, reflecting broader social unease about environmental issues.

Public communication by public agencies has improved over the past 20 years, but the new media environment is remaking social context for mass communication faster than public agencies can respond (Press and Williams, 2010). The new media environment highlights trust-destroying events: facts and science are disputed, the public doubts the existence of the problem, and public skepticism of proposed remedies grows. This results in fraying of the relationship between scientists and society at large, and undermines the ability of scientists to address social needs. Public mistrust in scientists and government agencies (and what they do) is generally on the rise. Studies have demonstrated that the public does not evaluate novel risks on the basis of data, but on the basis of trust based on the trustworthiness of messengers. This finding has been repeatedly confirmed across scientific applications and novel technologies (Slovic, 2001). This mistrust—and the potential of public engagement to foster trust -- is an issue that has implications for all stakeholders in the biocontrol of invasive plants: researchers, regulators, conservationists, and beneficiaries.

Public engagement is a semi-structured transparent deliberative process that establishes consensus views on evidence, method, interpretation, and social values frameworks as the basis for making a scientifically-informed decision (Rowe and Frewer, 2005). Public engagement differs from public outreach or consultation in that it requires bidirectional communication between scientists, decision makers, and lay publics (McCallie et al., 2009). It is a deliberative "dialogue" in which publics and scientists both benefit from listening to and learning from one another, which can be described as mutual learning (McCallie et al., 2009). Public engagement includes members of the public doing more than merely asking questions of experts. It requires scientists to do more than merely present their knowledge and perspectives. Public engagement requires lay publics to learn about science and policy, and scientists to learn what members of the lay public know and don't know about science, but also about social values. Thus, "engagement" in this sense includes both political engagement and educational engagement. Participants from a variety of perspectives participate over a sustained period of time, guided by shared goals and a code of conduct. It has the ability to actually foster trust and consensus (McCallie et al., 2009).

The U.S. was a pioneer in early models of public participation; however, 1970s era legislation required only public communication and gathering public comments. This model is now unable to support social expectations of transparency and the need to cultivate active public participation these decisions. In the U.S., biocontrol agent review and permitting are functionally inaccessible to the public, and have remained so despite calls for greater transparency, peer review and public input (Strong and Pemberton, 2000). In contrast, New Zealand has created participatory public processes for identifying targets and cultivating support for biocontrol projects, and has created a new agency to review proposed introductions of all novel organisms, including biocontrol agents. New Zealand has a national extension system for the biological control of weeds (Hayes, 1999). Although described as a technology transfer program, in reality it is much more sophisticated, for it trains local land managers in the ecology of weeds, the management of released control agents, and public outreach. This has the potential to prompt public interest and demand for invasive species control. In 1996, New Zealand passed legislation to require transparency in decision-making processes regarding proposed novel organism introductions. It also requires the applicant to provide evidence of anticipated benefits exceeding risks (Campbell, 2010). This has created the world's most sophisticated decision-making process for evaluating novel organism introductions, with explicit reference to biocontrol agent introductions. It lays out clear decision-making criteria based on transparent and replicable ecologically-based risk-cost-benefit analysis, fixed time periods for

decisions, and participatory public engagement (Campbell, 2010). New Zealand has developed biocontrol decision making structures that best reflect the goals and methods of participatory public engagement. Australia and South Africa have also undertaken efforts to enhance public engagement activities surrounding biocontrol.

Discussion

This section summarizes key findings emerging from this study.

Most members of the public are not interested in invasive plants

There is little return on efforts to reach out to generic publics. Instead, public engagement strategies suggest public agencies should identify, reach out to, and convene all possible stakeholders, especially including potential critics. For public engagement to succeed, it is essential to begin by identifying stakeholders with strongly-held opinions, pro or con, and to convene them in a dialogical process. Stakeholders with strongly-held opinions -- but are unknown to those leading biocontrol projects -- are those most likely to contest and delay biocontrol projects. Identifying these stakeholders is a task proper to public agencies and the stakeholders themselves. For example, Australia has an on-line stakeholder registry, and New Zealand actively encourages public comments on proposed introductions. However, these need to be designed so as to not amplify risk concerns (Slovic, 2001).

A public process should enhance the capacity of stakeholders to understand science and agency decision making processes

For public engagement to succeed, it must convene a structured co-learning process in which everyone, from critics to supporters, participates over time in establishing the same scientific information about the invasive species and possible control methods. Public engagement fails if parties have divergent information about the problem and possible remedies. Most public concerns about biocontrol are founded, at least loosely, on conservation values, such as: is the invasive plant really a problem?; why introduce another organism?; what other organisms will the agent attack?; and what will the agent do when it consumes all its hosts? These have a scientific but a democratic dimension as well, because concerned citizens want to be heard and have their views respected. Few stakeholders are able to play any kind of constructive role with the knowledge that they bring to such a process, therefore, education of stakeholders is integral to any kind of engagement. For example, in South Africa, Rhodes University offers a two week short course which enhances the capacity of anyone to understand the basics of biocontrol, and a wide range of stakeholders are invited to attend it (Gillespie et al., 2003). In New Zealand, efforts to engage indigenous Maori communities have dealt with biocontrol issues chiefly from the perspective of cultural and ethical values, and not biology, however, they have been successful because everyone's opinion is dealt with respectfully (Hayes et al., 2008).

The beneficiaries (stakeholders, not researchers) are the most appropriate parties to explain why control of the invasive plant is in the public's interest

Creating greater consensus on the need to take action is a critical first step that is fundamental to success. For example, Australia has a national weeds strategy that justifies action (Natural Resource Management Ministerial Council of Australia, 2006). In New Zealand, regional councils serve as critical intermediaries between tax payers (or rate payers) as stakeholders with research institutions (Hayes, 1999). This insulates researchers from public suspicions of conflict of interest, in other words, that the researcher loses objectivity by promoting a project that advances their career.

The beneficiaries should present a risk/cost/benefit analysis that justifies a biocontrol strategy

In New Zealand, regional councils articulate an economic justification that makes clear the advantages of biocontrol over other forms of control to tax payers. In the New Zealand regulatory

system, these regional councils are generally those who petition for invasive plant biocontrol release permits, and they are better positioned to articulate these advantages, and to engage in discussions over conflicts of interest. These regional councils represent the public better than a scientist can, so the scientist serves as scientific expert advisor, and never the advocate for controlling a pest (Campbell, 2010). Legislation imposes the burden of public consultation and engagement on the petitioner for a permit. Although this appears costly, in practice it appears that this is more than offset by decreased costs and conflicts associated with the actual regulatory decision (Campbell, 2010). Other countries could benefit from this approach, although in the U.S., it would require going beyond what is required by law.

Public agencies should articulate their decision criteria clearly and gather stakeholder input of how their criteria apply to a specific permit application

The New Zealand permitting system is efficient because any decision to release a biocontrol agent is made on a very narrow basis. It presumes that there has been prior public engagement with the desirability of targeting the invasive plant and the suitability of the biocontrol agent. Then, the question upon which the decision is made is simple (as in straightforward): are the anticipated benefits greater than the costs and risks? In New Zealand, this has frontloaded costs and public engagement efforts, but has made release decisions less contested.

Conclusion

Biocontrol of invasive plants is a public interest science. It is chiefly funded by governments and is done on behalf of the public. Some form of public consent is necessary in a democratic society. To foster sustained public engagement over time, the problem definition of invasive plants should be disambiguated from the solution of biocontrol.

Public engagement can be structured so that it enhances public stakeholder support for biocontrol of invasive plants without imposing burdens upon researchers. However, lessons of prior public engagement suggest that scientific research activity should not be confounded with advocacy for invasive plant management using biocontrol. Fostering social consensus on the need to control the invasive plant is a pre-requisite. Public engagement requires careful attention to devising appropriate roles for stakeholders, and nodes for public input in decision making processes. Greater public engagement with biocontrol of invasive plants can be achieved by disambiguation of problem definition from solution options, and research activities from stakeholder advocacy.

Acknowledgements

This research was supported by the California Department of Food and Agriculture and the U.S. National Science Foundation (award 0646658).

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Outreach Challenges for Biological Control in Hawaii

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Abstract

Public understanding of Hawaii's use of biocontrol is limited. This can create problems when support for releases is sought. Release of a strawberry guava (*Psidium cattleianum* Sabine) enemy was delayed by public opposition. Raising awareness about invasive species in Hawaii is the purpose of the Hawaii Invasive Species Council Public Outreach Working Group (POWG). POWG organized statewide biocontrol educational activities. For Big (Hawaii) Island Invasive Species Committee (BIISC) outreach staff, biocontrol issues became particularly important with the strawberry guava proposal. One vocal Big Island activist raised public concern against biocontrol using a variety of tactics (described in Warner and Kinslow, 2011). BIISC outreach strategy focused on responding to issues that resonated with many members of the population. Key issues raised by the public to outreach staff revealed: the lack of agreement that strawberry guava is a problem that needs biocontrol (the tree has food value and natural area impacts are unseen); the public is primarily aware of examples of disastrous introductions and unaware of the extent and successes of biocontrol releases in Hawaii; the fear of rapid evolution of biocontrol agents to new hosts is pervasive; the lack of understanding of insect biology and genetics contributes to fear of rapid evolution; and, the public does not understand the selection process, research and testing protocols, and the regulatory process involved in classical biological control. A long-term education program with basic curricula plus materials on each species released would help agencies build public support for future releases.

Introduction

Biocontrol has a long history in Hawaii, with almost 800 species introduced, 300 established, complete control of approximately 40 insect species and substantial control of approximately 150 insect species, and successful control of approximately 10 weed species (Funasaki et al., 1988; Culliney and Nagamine, 2000; Culliney et al., 2003).

However, many people are familiar only with the famous mistakes (mongoose, cane toad) and not at all familiar with the extent or successes of other biocontrol releases. Biocontrol history in Hawaii commenced under the leadership of King Kalakaua. This last king, revered for his leadership in preserving Hawaiian culture, also passed laws (1890) to prevent immigrant insect pests from entering Hawaii. The first biocontrol release (1890) was the vedalia beetle (*Rodolia cardinalis* Mulsant), which successfully controlled the cottony cushion scale (*Icerya purchasi* Maskell). After the reign of Queen Liluokalani, Albert Koebele was hired as entomologist and biological control expert for the Republic of Hawaii. In the early period, attention was focused on agricultural pests and the general public had little knowledge of biocontrol.

One might characterize the 20th century in "biocontrol eras", beginning with a long period of introductions to address agricultural pests with little review, then an era euphoric about pesticide efficacy,

and next an era impressed with biocontrol. With the greater ecological consciousness of the 1970's and entomological research, awareness of non-target impacts began to increase. However, there was also developing interest in the idea of using natural enemy introductions to slow the spread of weeds in conservation areas. Concurrently, the regulatory review process became increasingly strict, with committees of specialists reviewing proposals, and requirements for NEPA documents.

Still, most biocontrol proposals were not widely noticed by the public until an activist became concerned about proposals to introduce a scale insect to control strawberry guava (*Psidium cattleianum* Sabine). This vocal Big Island resident activist raised public concern against biocontrol using a variety of tactics. His tactics have been described in Warner and Kinslow (2011) and were familiar to BIISC, as he has opposed numerous other projects to control coqui, mangrove, and invasive species work in general.

Methods

Raising awareness about invasive species in Hawaii is the primary purpose of the Hawaii Invasive Species Council Public Outreach Working Group (POWG). Core members of the group include the outreach staff of the invasive species committees (ISC) on each island. In 2009 four focal topics were identified as outreach priorities, one of which was biocontrol. POWG organized several biocontrol educational activities, including a documentary video, a biocontrol communications conference held March 2010, and a general brochure (produced collaboratively with the Hawaii Department of Agriculture) for public and legislator education (distributed at Ag Day at the Capital). Several video segments about biocontrol were shown on Outside Hawaii (an audience of 20,000 every week on TV alone, plus viewers at the website). The video focused on the recovery of the native wiliwili tree after a successful biocontrol effort. There were also some interviews about the impacts of strawberry guava and the need for biocontrol as a separate segment (http://www.oc16.tv/shows/32) A website was posted about strawberry guava biocontrol specifically to assist with the EIS public review process (http://www.hear.org/strawberryguavabiocontrol/).

The biocontrol communications workshop brought agency staff, researchers, land managers and outreach specialists together to talk about challenges and approaches to communicating about biocontrol. Since then, the biocontrol working group was convened for one meeting. The Maui Invasive Species Committee (MISC) worked with their county council to pass a resolution supporting the use of biocontrol. The Big Island County Council, in response to the strawberry guava controversy, passed a resolution against biocontrol. A site visit to a public forest infested by dense strawberry guava convinced the participating council members of the need for biocontrol, but not all council members chose to or were able to attend.

BIISC outreach strategy, particularly with regards to the strawberry guava proposal, focused on responding to biocontrol issues that resonated with many members of the public. The BIISC program participates in an average of one public outreach event per week, often in the form of information booths at varied festivals, plant sales, farmers markets, or spoken presentations to public or school groups. The BIISC outreach specialist presented an oral presentation on the history and successes of biocontrol in Hawaii at the 2009 Hawaii Conservation Conference. Presentations were also developed to educate and intrigue the public on the biology and importance of insects. Better understanding of insects will help the public to assess risk.

Results

Key issues raised by members of the public to outreach staff revealed that: the public generally is aware of one or two examples of disastrous failed introductions and is totally unaware of the extent and successes of biocontrol in Hawaii; fear of rapid evolution of the host to new targets is pervasive; a lack of understanding of insect biology and genetics contributes to the fear of rapid evolution; and the public does not understand the quarantine testing, regulatory process and limits on biocontrol releases. Through discussions and exhibits, many individuals expressed relief that biocontrol introductions were not as haphazard and uncontrolled as they had thought them to be. Most significantly, other

biocontrol releases have not been met with much opposition, before, during, or since the strawberry guava biocontrol issue came to a head.

The public's view of the invasive species considered for biocontrol affects whether or not a project receives support. For example, in the case of the wiliwili tree decimated by an accidently introduced wasp, people saw the trees die and understood the gall wasp was a problem. Biocontrol of the gall wasp was not opposed. People do not see the watershed, do not see the full extent of the strawberry guava invasion, and therefore, they do not understand the impact (on groundwater, on cultural values, and on native species). Strawberry guava is not a recently introduced species and so has social familiarity and is perceived as a useful tree. Because it has some food value, attempts to control strawberry guava were portrayed as attempts by government to control the food supply, which is linked to fears of genetically modified foods. The relationship of strawberry guava fruit in promoting damaging fruit flies is not well understood by the public.

Discussion

Agencies may give undue weight to public opposition to biocontrol projects if that opposition is based on misinformation which can be corrected. Public opinions can change rapidly when a broader context of history, methods, successes, and regulation is described. Biocontrol is an important management tool for the threats facing Hawai'i. For biocontrol to be successful, agencies must be committed to and have the resources necessary for the research, development and education necessary before a release. This strong agency support and education will help the public in supporting this tool. Limited support runs the risk of achieving neither conservation goals nor reducing public concern with risk.

It is recommended that agencies and resource managers in Hawaii devote significant resources to produce educational materials to publicize biocontrol methodology and successes in Hawaii. Basic curricula should educate and intrigue the public on the biology and importance of insects. A discussion of genetics and reasons for host specialization is also important. Good guy and bad guy cards, identification cards, and the current fascination with forensic anthropology may be useful lures. Another interesting possibility would be to engage citizen groups in rearing of approved biocontrol agents, as has been done elsewhere in the world. Future biocontrol projects should evaluate public attitudes towards the particular species, and plan outreach accordingly, while building general awareness and support.

Other current limitations for the state are the shortage of adequate quarantine facilities for testing. Public support for biocontrol proposals would help convince policy makers that these facilities should be funded.

Acknowledgements

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The Role of Implementation in Weed Biological Control in South Africa

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Abstract

Biological control of weeds was initiated in South Africa in 1913 with the introduction of the cochineal insect *Dactylopius ceylonicus* (Green) (Hemiptera: Dactylopiidae) on the invasive cactus *Opuntia monacantha* Haw. (Cactaceae) (Moran et al., 2011). Since that time some 113 agent species have been released against 48 weed species with varying levels of success (Klein 2011). The implementation of weed biological control agents has historically been neglected and there is very little research on this topic (Grevstad 1999, Memmott et al., 1998). In South Africa, initially agents were mass-reared and released by the researchers and a few landowners. In 1996 with the advent of the Working for Water Programme biological control implementation officers were appointed in each province of the country to serve as a conduit between the research scientists and the landowners (Gillespie et al., 2004). The role of the implementation officers was to mass-rear, release and monitor for establishment of the agents and redistribute, where necessary. Key to the success of this programme was record-keeping and the ensuring that information regarding releases and establishment of agents was provided to the researchers. This was achieved through the establishment of biannual technical liaison committee meetings and annual weed biological control workshops. More recently the task of mass-rearing has been outsourced to a commercial facility, which has greatly improved the quantity and more importantly the quality of agents being released. In the last five years weed biological control implementation has been rolled out to a number of schools and this has facilitated the incorporation of weed biological control into the National School Curriculum. Further, a programme that trains physically challenged individuals to mass-rear and distribute weed biological control agents around South Africa has been highly successful.

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"Of Miconia and Men": The Story of a Scientifically and Socially Successful Biological Control Program in Tahiti, French Polynesia

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Abstract

Many biological control programs against invasive plants have failed or have been abandoned because of negative human perceptions or strong conflicts of interests, *e.g.*, the fear of introducing alien predators or pathogens (the so-called "pathophobia", Warner, in press), the potential threats for related species of economic or conservation value, and the uncertainty of successful control (see e.g. Louda & Stiling, 2004). In this regard, biological control scientists often appear as sorcerer's apprentices. This talk describes how a biological control program against the invasive tree *Miconia calvescens* (Melastomataceae), a formerly popular ornamental plant species, was successfully conducted (1997-2010) on the island of Tahiti (French Polynesia, South Pacific) using a fungal pathogen (Meyer et al., 2008; Meyer et al., in press), despite the very bad reputation of past "biological control experiments" in the region (carnivorous snails introduced to control the Giant African snail, myna birds for wasps, raptors for rats, *etc.*). This case-study tries to demonstrate that rigorous scientific (pre- and post-release) studies are necessary but not sufficient for the acceptance of biological control by human society. Information and education at all levels (from public to politicians), consultation process including all stakeholders, and communication involving different media are equally important to avoid that "*The best laid schemes of mice and men go often askew*" (inspired by Robert Burns' famous poem written in 1785). Paradoxically, biological control projects provide excellent opportunities to explain basic ecological processes and the methodology of science to the general public and schoolchildren in particular.

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Russian Olive – a Suitable Target for Classical Biological Control in North America?

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Abstract

Projects to develop biological control solutions against invasive plants are mid- to long-term endeavors that require considerable financial support over several years. Discussions of concerns and potential conflicts of interests often occur when biological control agents are first being proposed for release into the environment. Such late discussion, which in some cases results in delays or in the halt of ongoing biological control programs, has led to uncertainty, confusion and frustration among the various stakeholder groups, including the biological control practitioners. Russian olive (*Elaeagnus angustifolia* L.), a small tree or multi-stemmed shrub native to south-eastern Europe and Asia, was introduced to North America in the late 19th century as a horticultural plant. It has since spread into the environment, particularly along river courses where it now occupies similar habitats as tamarisk. To date, Russian olive has become a declared noxious weed in four US states. Because of the perceived benefits of planting Russian olive in some regions, developing a classical biological control program against Russian olive could give rise to a conflict of interests. To address and discuss potential conflicts of interests right at the onset of this new biological control initiative, we recently created a platform to collect, analyze and disseminate science-based information on Russian olive. Particular emphasis is being put on the following questions: 1) what are the economic, environmental or social impacts caused by Russian olive in North America or in other parts of the invaded range, 2) what are the goals of Russian olive management, and 3) is classical biological control a useful and feasible way to achieve these management goals? We will present first results of our data analysis and propose a way forward to reach common ground among key stakeholders regarding under which conditions Russian olive is a suitable target for biological control.

The Economics of Classical Biological Control: A Meta-Analysis of Historic Literature and Suggested Framework for Future Studies

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Abstract

Classical biological control (CBC) programs are initiated to protect natural resources, agricultural and other human interests. CBC programs typically involve an investment of public funds and their success is often determined by welfare measures such as benefit/cost analyses. An initial review of the literature shows previous efforts at measuring program benefits in monetary terms have often been incomplete and/or misguided. This review reveals that the basic analytical challenge can be broadly traced to two areas; project benefits lacking marketable measures and confusing or under reporting of project costs and benefits. The economics of CBC projects should be analyzed within the neo-classical economic view of supply and demand. On the supply side, costs are expenses directly related to project development and implementation. These include all direct expenditures necessary to locate and test the control agent and affect its release. These costs are typically covered by public funds and justified by the public nature of the anticipated project benefits. However, cost should also include any value lost to agents as a result of the project's success. On the demand side, agents with marketable goods and services that benefit from the project will provide a direct measure of the economic gain. Furthermore, their gains will lead to an indirect benefit or ripple effect through the economy. However, there are also benefits that lack market value and include items such as improved ecological services and other non-market activities such as improved fishing, hunting, *etc*. CBC projects would benefit from a strategic approach to assessing their economic efficiency. A meta-analysis of the use of economics in historic CBC literature is conducted and an analytical framework introduced to guide future benefit/cost studies for CBC projects. The framework will help generate support for CBC programs by providing a clear guideline for their effective economic evaluation.

Biological Control of Strawberry Guava in Hawaiian Forests

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Abstract

Over the last two decades, scientists in Hawaii, Florida and Brazil have researched biological control as a new tool for managing strawberry guava, an invasive tree in Hawaiian forests. A leaf galling scale insect from Brazil, *Tectococcus ovatus* (Hemiptera: Eriococcidae), was found to be highly target-specific and has been proposed for release in Hawaii. This natural enemy is expected to slow the spread of strawberry guava into native forests by reducing growth rates and seed and fruit production over time. A State of Hawaii environmental assessment of the proposed biocontrol release included detailed data from researchers as well as inputs from stakeholders and the public in recent years. Although this project has been strongly supported by partner agencies and conservation workers in Hawaii, it has encountered substantial opposition from some quarters of the public who value strawberry guava for a variety of reasons. As a prominent and provocative target for biocontrol, the case of strawberry guava offers some important lessons on the challenges and opportunities facing biocontrol as a management tool for conservation and restoration of Hawaiian forests.

The Economic Benefits of TSA Biological Control

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Abstract

Tropical Soda Apple (*Solanum viarum* Dunal) (TSA) is an invasive exotic plant from South America that has become a weedy pest, choking pastures and afflicting Florida's beef producers. In 2007, state-wide economic losses were documented to range from $6.5 million to $16 million annually. In 2008, efforts to control TSA resulted in the release of the green tortoise beetle (*Gratiana boliviana* Spaeth) (GTB) across central and southern portions of the state. Also a native of South America, the GTB is particularly fond of TSA foliage with no alternative native hosts. Initial results indicate the beetle is spreading rapidly and significantly reducing TSA density in many areas of the state. During the summer of 2010, a survey of Florida's cattle producers was conducted to evaluate the impact of the recent TSA biological control efforts (*Gratiana boliviana* Spaeth) in central and southern Florida. A survey was mailed statewide to 3,500 members of the Florida Cattleman's Association. The survey asked participants to identify their type of cattle operation, the distribution of TSA in their pastures and their assessment of TSA density and the effort required to control this plant. Slightly more than 30% of those surveyed responded. When compared to 2007, preliminary results indicate significant declines in both TSA density and control efforts across central and southern Florida. On the other hand, northern Florida has experienced an increase in TSA density and control effort. These preliminary results support the hypothesis that the GTB has reduced TSA density and lowered control costs to cattle producers.

Is Post Hoc Development of Risk Management in Weed Biological Control Too Late? Lessons Learned from *Cactoblastis cactorum*

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Abstract

The Argentine cactus moth, *Cactoblastis cactorum* (Berg), is renowned for its success as a biological control agent against exotic *Opuntia* spp. in many locations including Australia, South Africa and Hawaii. However, in 1957, its introduction into the Caribbean to control native *Opuntia* spp. ultimately resulted in its arrival to southern Florida where it became an invasive pest of native and rare *Opuntia* species and a threat to the *Opuntia*-rich areas of the western U.S. and Mexico. To mitigate this risk, survey and control tactics were developed in the U.S. and an awareness campaign was initiated in Mexico. A Bi-National Cactus Moth Control Program was established to facilitate risk management, which involved identifying, evaluating, selecting and implementing actions to prevent, reduce or control adverse effects of *C. cactorum*. The risk management process included comparing the risks of taking no action with the risks associated with each remedial alternative, while taking into account social, cultural, ethical, economic, political, and legal considerations. Although these risk management activities were undertaken after the initial release of *C. cactorum*, management tactics were available and used successfully to eradicate this pest when there was an incursion in Mexico. Efforts remain ongoing in the U.S. where the westward expansion of *C. cactorum* has been mitigated through regulatory and control actions. The lessons learned from *C. cactorum* in North America underscore the need to have regional involvement in the risk analysis process and in the development of risk management prior to the release of a weed biocontrol agent.

Biological Control as a Tool to Mitigate Economic Impacts of Facilitative Ecological Interactions between the Giant Reed and Cattle Fever Ticks

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Abstract

Annual domestic impacts associated with introduced weeds are conservatively estimated at $27 billion, which incorporates costs of weed management, crop losses and displacement of productive rangeland, and displacement of some environmental services. Estimating the total economic damage of invasive weeds can be difficult, especially when they impact non-market services, or when impacts are indirect. The giant reed, *Arundo donax* L., is an invasive grass infesting riparian corridors and waterways in the southwestern U.S. and northern Mexico. In addition to the economic implications of water loss in this arid agricultural area, deleterious non-market effects ascribed to giant reed invasion include riparian habitat fragmentation, biodiversity loss, stream-bank erosion, and physical and logistical obstruction for border security and enforcement. These thick swaths of giant reed are also a highly suitable habitat for the cattle fever tick, *Rhipicephalus microplus* (Say), an important vector of the protozoa causing bovine babesiosis. Survival rates, fecundity, and fertility of engorged adult female cattle fever ticks were tested in tick cohorts placed in pastures, mixed brush, and arundo stands. Ticks were more likely to lay eggs and larger egg masses in giant reed and mixed brush when compared to ticks in mixed-grass pastures where microclimatic conditions are less favorable. Animals such as cattle, horse, and white-tailed-deer traversing through nearly-impenetrable stands of giant reed create common-use corridors that in effect facilitates parasitism of suitable hosts by cattle fever ticks thriving in that habitat. Our findings document the economically significant indirect impact by giant reed as a complicating factor to keep the U.S. free of cattle fever ticks and bovine babesiosis. Such considerations should be incorporated when modeling the total economic costs associated with an invasive plant. The use of biological control agents against giant reed stands represents a sustainable strategy to mitigate the indirect economic impacts of giant reed and disrupt facilitative ecological interactions between invasive species like cattle fever ticks and giant reed in south Texas.