Biological Control of Invasive Species, a Personal Perspective

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Introduction

As a biologist trained in an academic program that had little scientific appreciation for the traditional method of classical biological control, I find it very instructive that I now oversee one of the largest U.S. Department of Agriculture (USDA) biological control facilities in the United States.

Through years of experience working in pest-management systems of all types, I have become a believer, supporter, and advocate for biological control when practiced scientifically and systematically. Time and experience have made me aware of the highly powerful and beneficial tools available in the form of biological control introductions and establishments, especially to combat invasive pest species. It is my sense, however, that it takes either detailed scientific study to do this job correctly or a large dose of good luck.

Although good luck may have carried us into the field of biological control more than 100 years ago (Coulson et al. 2001), I do not believe that we can depend on luck (good or bad) any longer. Because so many factors must come into proper alignment to allow safe and successful biological control to be realized, I strongly support the assembling of multidisciplinary teams to investigate the need for biological control programs for pests of agricultural and natural areas and to oversee their development and successful implementation. As pointed out by Hoddle (2004 [this issue]) such an approach has worked well for other countries such as Australia and New Zealand (McFadyan 1998), and a comprehensive effort is long overdue in the United States (Carruthers & Petroff 1997; Carruthers 2003).

When safe and effective biological control programs are developed, they can be extremely impressive, being environmentally beneficial, economically viable, and highly sustainable—thus justifying the resources needed to support the entire field of science required to conduct such efforts. Hoddle cited the beneficial attributes and economics of such programs, listing a cost-benefit ratio of 1:145. Although these exact figures can be debated, it is clear that successful programs are extremely cost-effective.

My commissioned goal with this paper was to assess and respond to items brought to our attention by Hoddle and to provide further commentary on associated issues. I agree, however, with the primary points made by Hoddle and thus hope to take this consideration a little deeper into some of the issues that face us as a community of scientists considering, debating, and acting out species introductions in real life. I do this as an individual scientist, not as a representative of the U.S. Department of Agriculture or my supporting agency, the Agricultural Research Service (ARS). With that in mind, I provide my perspectives rather than a highly documented argument based on a long string of citations. In taking this approach, I hope the following discussion stimulates thought and builds bridges rather than barriers because together we have many important hurdles to cross in the fight to contain invasive species.

Invasive Species Management: We Must Take Action

First, invasive species are a horrific and increasing problem, causing difficulties too numerous to outline here. Hoddle and others have covered this territory well (Office of Technology Assessment 1993; National Audubon Society 1994; Enserink 1999; The Nature Conservancy 1999; Pimentel et al. 2000). Clearly, human intervention is required to limit many invasive species (Van Hook 1994), and the USDA-ARS has invested heavily in addressing

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these issues using a wide range of tactics (Carruthers 2003), including biological control. The traditional approach to classical biological control requires the further introduction of additional exotic organism into the local environment. This approach has stirred controversy because undesirable side-effects can and have been induced in nontarget populations (Louda et al. 1997; Follett & Dunn 1999; Pearson & McKelvey 2000). Such negative consequences are possible, yet the overall safety record of classical biological control is exceedingly high (Van Driesche 1994; Pemberton 2000).

Tied to the question of introducing additional exotic biological control agents, we must consider that ecosystems and environmental conditions have been altered radically over the past 200 years, largely through human activities. Over vast areas of the world, extensive changes have significantly altered the operational biological components (species), the physical environment in which they exist, their interactions, and thus, potentially, overall ecosystem functions. In most cases, we cannot go back to preexisting states; even if we could, it is unclear which state from the past we would aspire to. The problem is that the speed at which this change is progressing and the associated damage is increasing at an alarming rate.

Ecosystems and their component species are changing too fast everywhere, and invasive species are one of the main causes of this problem. On the surface, adding more exotic organisms to the mix seems only to exacerbate the problem. Hoddle suggests that the addition of a few "well-selected" additional organisms—biological control agents—holds the potential to return a portion of these systems to a more reasonable balance. This balance would not necessarily be a natural state, but it would have more positive ecological value than those primarily dominated by invasive species. This seems a reasonable goal, based on our knowledge of population dynamics, community structure, and dynamic ecosystem processes; however, it should be pursued with care to conserve other desired ecosystem attributes, including beneficial exotic and native organisms.

Species additions, whether accidental or purposeful, are only one dimension of currently changing ecosystems. In California alone, it is estimated that over 1000 exotic species are free-living and reproducing as added components to operational ecosystems. For example, California rangelands are now almost totally dominated by non-native grasses (D'Antonio & Vitousek 1992). Not everyone would typify these grasses as pests, but many pest plants, grasses, and herbaceous species affect the biology of these rangelands. The core primary producers of this system have been altered; thus, little of the past remains the same and nearly all higher trophic levels have been affected in some way. Such changes are now commonplace and must be considered a reality of our current situation.

More important, the overall dynamics of these ecosystems and the key goods and services they provide to the environment may have been altered. Invasive species (and other factors) are driving many of these changes at rates faster then we can understand them, much less predict their trajectory and impact. Fire dynamics is one such example, in which exotic species such as *Bromus* spp. in upland areas and *Tamarix* spp. (saltcedar) in riparian zones are increasing fire frequency and thus harming or eliminating many native species that were once abundant (Young & Allen 1997; Dudley et al. 2001). Fire is only a single issue within this multidimensional problem area. We could also discuss water utilization, competitive exclusion, nutrient depletion, carbon dioxide alteration, and other elements of change linked to invasive species. Without massive scientific undertakings we will never know the implications of the current state of many of our ecosystems before they have changed into something else altogether. Thankfully, efforts such as Cooperative Ecosystem Study Units have been initiated (Anonymous 2000).

Decision-Making and Biological Control in a Risky World

In the short term, however, we are required to act responsibly to manage agricultural and natural ecosystems and their associated native and exotic species. To accomplish this we will have to make decisions without complete knowledge, which brings risk into the picture. The no-action alternative often represents greater environmental risk, however, by allowing known invasive pest species to continue their negative impact relatively unchecked. What I believe is required is an open, science-based decision-making process that provides the best possible choice with currently available knowledge. Such an approach requires cooperation, detailed planning, and follow-up. In addition, we must realize from the start that neither the outcome of such decisions nor the decision to do nothing will always be correct.

In the area of biological control, risk analysis is gaining respectability on a global scale (McEvoy & Coombs 2000; Pemberton 2000; Lonsdale et al. 2001). Others have conducted retrospective studies to provide guidance to those having to make critical biological control decisions (Ewel et al. 1999; Louda et al. 2003). It will take a combination of these two approaches and many other specific assessments to move us forward in positive ways. Where non-biological control alternatives are available and biological control is considered too risky, we should use other tactics to control invasive species. We need to consider such decisions carefully, however, before eliminating biological control as a primary alternative.

Through my exposure to numerous-species problems from insect pests of crops and forests to exotic weeds invading grasslands and riparian areas, I have witnessed areas of severe infestation and devastation on one hand,

to amazing feats of control and recovery on the other. The recoveries were more impressive than the invasive-species damage. It is encouraging that we can gain control of these problems if we confront the issues in a cooperative and integrated fashion. Although a variety of methods have been used to combat invasive species, the most spectacular and sustainable methods I have observed have been those involving natural enemies, either naturally occurring or induced through active biological control efforts. This technology has significant potential to successfully combat major infestations of many invasive species (e.g., Huffaker & Kennett 1959; Hajek et al. 1996; Coulson et al. 2002).

On the other hand, I am the first to admit that the prerelease assessment and predictions of biological control efforts are far from perfect and may even be untenable in some situations. Yet the economic and environmental benefits still encourage the application of biological control in both agricultural and natural areas. Risk of nontarget damage by such programs is possible, and it is true that the insertion of any organism into the environment may alter existing relationships. The questions, however, are to what degree these systems are naturally conserved and what the implications are if further alterations by invasive species are left unchecked. Is it clear that negative change will be avoided if biological control interventions are delayed or avoided? I don't believe so. The question becomes whether the potential benefits are worth the risks?

We can work hard to minimize most negative side effects of biological control, accepting some risk, to accomplish the primary goal of controlling dominant invaders that may be altering the function and productivity of entire ecosystems. The dilution of native diversity through the purposeful introduction of biological control agents is minute compared with the effects of other forms of species additions that have occurred and will continue to do so (Hoddle 2004). Clearly, direct and indirect negative effects should be minimized, and a number of groups have suggested potential methods that are being successfully used to accomplish this in the area of weed biological control (APHIS-PPQ 1998; Pemberton 2000; Louda et al. 2003).

Working Together to Meet the Challenge of Invasive Species

Over the years, I have developed strong feelings about the need to increase the knowledge base that will allow the development and implementation of biological control to be truly billed as a predictive science rather than an art. Some of my colleagues will be angered by this statement, but I believe that the fields of biological control and ecology are both highly challenged in the process of making knowledgeable predictions about the outcomes of species introductions and their overall implications. We are great at monitoring and telling how it "was" with sharp and critical hindsite, but we are often unable or unwilling to openly form hypotheses and test them experimentally, much less conduct such activities jointly across disciplinary lines. Certainly, we must continue monitoring and learning from both our successes and our failures, but more cooperative efforts between applied pest-management scientists, conservation biologists, and population and community ecologists are needed to assess risks and benefits and to guide management programs in advance of and in parallel with taking action.

Regardless of our predictive ability, we must make critical decisions about the use of biological control tactics here and now. Some would say don't do anything because it is just too risky; others would say doing nothing is even worse because the invasive species will only continue to cause further devastation. I believe that we need to move forward together in educated ways, collecting data as we proceed, rather than holding back to wait for the outcome of a few more case studies. In retrospect, we can find mistakes and identify areas where different decisions should and have been made. Other areas are still in need of revision of technique and technology, but both the science and our approach to the science will make it safer and more effective through time and application.

I have often heard it said that it is the responsibility of the biological control practitioner proposing a release program to ensure its safety, and this is formally true from the perspective of both regulation (APHIS-PPQ 1998) and the "Code of Best Practices" (Balciunas 2000). However, the invasive species problem is significantly larger in scope than can be met by the limited expertise and resources of existing biological control specialists. In reality, it will take many diverse talents to adequately assess and implement science-based programs to control invasive species, and I would suggest expanded partnerships to help accomplish these goals. Now is the time to work together to discuss issues, identify risks, and take collective educated actions where appropriate.

The multidisciplinary activity of the Saltcedar Biological Control Consortium is an excellent example of a project that is framed in an open and cooperative light (DeLoach et al. 1996, 2000, 2003; Dudley et al. 2001; Lewis et al. 2003). Within this program, all interested individuals and groups are welcome to participate in detailed assessments of the potential impact of biological control as a technology to help manage this pest plant. Periodic open meetings are held in which program details are discussed and debated, and those interested in contributing to the investigations and discussions can freely participate. These meetings have resulted in comprehensive assessments of the biological control effort, discussions of potential impacts on both target and nontarget species, and actual plans for assessments (both before and after

release) of the direct and indirect effects on associated organisms. The perspectives of individual scientists, laypersons, and agencies have all been solicited and discussed. The open nature of this project is one of its strengths, and even though the participants may not always agree on what should be done, the group process has provided guidance and decision-making that has safely and productively led the effort forward.

Taking the Next Steps

There are many more issues to consider and many more in-depth discussions to hold on these issues. Continuing dialog should help improve the biological control of invasive species, where it is appropriate. I challenge everyone interested in invasive species control to confront the issue in a proactive fashion and work together to assess biological control as one of several potential tools to help manage these ecological problems. By working cooperatively, we should be able to better determine where the use of biological control is safe and appropriate. Together, we should be able to use our predictive ecological abilities to better guide action programs and to focus biological control technology in ways that maximize its effectiveness while better integrating it with other methods of control. Finally, we should each look beyond our personal perspectives in an attempt to understand these issues from alternative viewpoints. It often takes diverse outlooks and compromise to develop useful solutions to difficult ecological problems.

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