Rhinocyllus conicus -- Insights to Improve Predictability and Minimize Risk of Biological Control of Weeds

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Abstract

A review of information on the release of *Rhinocyllus conicus* to control of *Carduus* spp. thistles in North America suggests at least 8 lessons for future biological control efforts. These lessons include the need for: 1) better *a priori* quantification of the occurrence and ecological effects of the weed; 2) improved incorporation of ecological criteria to supplement the phylogenetic information used to select plants for pre-release testing; 3) increased assessment of plausible direct and indirect ecological interactions when an agent looks promising but feeding tests suggest it is not strictly monophagous, including ecological factors determining host use and limiting population growth; 4) quantitative evaluation of the efficacy of the proposed biological solution, including evidence the agent can reduce persistence and regeneration of the weed; 5) more evidence on alternative control methods; 6) expanded review, both prior to release and periodically afterward; 7) addition of post-release evaluations and redistribution control; and, finally, 8) a rethinking of the situations that qualify for the use of biological control releases.

Keywords: ecological risk, biocontrol, integrated control, Curculionidae, environmental policy

Current evidence of significant ecological effects by *Rhinocyllus conicus* on native thistles and their inflorescence insects (Louda *et al.* 1997, 1998, Louda 1998, 2000) presents both a challenge and an opportunity. The challenge is to demonstrate that current protocols will produce effective solutions while preventing nontarget impacts on native species. The opportunity is to use this case history to improve or reinforce the criteria for the development of effective biological control programs, including the detection and quantification of possible nontarget effects.

Evaluation of potential nontarget effects is often viewed either as (i) sufficient using present protocols or (ii) impossible. However, the situation appears to be intermediate between these two extreme views. Present protocols clearly provide an important foundation for risk assessment (McEvoy 1996, Thomas and Willis 1998). However, additional, feasible ecological studies are required to increase the likelihood of detecting the potential for significant nontarget effects in biological communities (Secord and Kareiva 1996, Arnett and Louda 1999, Gassmann and Louda 2000).

Finally, it is clear that both the effectiveness of weed control and the minimization of risk associated with the importation and deliberate release of non-native species will be maximized by focusing the research and implementation programs on the most pervasive, environmentally-damaging invasive species, particularly those where no feasible alternative control methods exist.

***Rhinocyllus*-Native Prairie Thistle Interactions.** *Rhinocyllus conicus* Fröl., an inflorescence-feeding weevil, was introduced into the USA 30 years ago to control Eurasian thistles (e.g. *Carduus* spp). Although *R. conicus* was known to feed on some *Cirsium* spp., reports of feeding, oviposition, and successful larval development on at least a third of the native *Cirsium* spp. examined to date are greater than expected, but perhaps not so surprising. However, significant direct and indirect ecological effects were unanticipated. According to Zwölfer and Harris (1984), the weevil's strong preference for *Carduus* spp., its greater larval performance on *Carduus* spp. compared to *Cirsium* spp., and the relatively low densities of native thistles would prevent a host range expansion of any significance. So, the weevil was released into Canada in 1968, and into the USA in 1969, after exploration and initial testing in Europe. And, research on its biology and interactions was done once it was brought into North America (see Zwölfer and Harris 1984).

Hindsight now demonstrates that, although the logic and reasoning were clear, the conclusion that *Rhinocyllus* was unlikely to have any major ecological effects was incorrect. The case suggests that more information was needed in order to make an accurate prediction of the level of use of species such as Platte thistle, *Cirsium canescens* Nutt., the species that I have studied since 1984 with the aim of understanding the influence of insects on native plant population density and dynamics.

We first observed *Rhinocyllus* eggs (recorded as "scales"!) in 1993. We then found adults on plants, and larvae and pupae within our sample of flowerheads. Population growth has been rapid (Louda 1998), and the consequences for seed production of the plants chosen are severe (Louda *et al.* 1997, Louda 2000). For example, in 1996 at our longest-running site (Arapaho Prairie, Arthur County, Nebraska) this weevil reduced the number of viable seeds matured and released by flowerheads of Platte thistle by more than 80%, and that was in only the fourth year after the initiation of its population growth at our site (Louda *et al.* 1997, 1998). Such effects have persisted (Louda 2000).

The numbers of eggs laid on wavyleaf thistle (*Cirsium undulatum* Nutt.) are also high and continuing to increase (Louda and Arnett, this volume). The high levels of use are variable but continuing; and, population growth on wavyleaf thistle, which we missed initially, is accelerating. In addition, the significant interactions are not confined to the direct effects of the weevil on native thistles. We have suggestive observational evidence and more definitive experimental evidence for a significant negative relationship between the density of a native tephritid fly, *Paracantha culta* Wiedeman, and the density of *R. conicus* within a flowerhead (Louda 2000, Louda and Arnett, this volume). So, the indirect effects are evident, unanticipated, and larger than expected. I conclude that this is a type of failure, from which we can and should learn.

The data on the impact of *Rhinocyllus conicus* on Platte thistle (*Cirsium canescens* Nutt.) may be important for the increased protection of rare native species. For example, Pitcher's thistle (*Cirsium pitcheri* [Torr.] Torrey and Gray), a close relative of Platte thistle, is already threatened by habitat destruction (Pavlovic *et al.* 1992) and negatively impacted by some of the same native insects that feed on Platte thistle (Louda and McEachern 1995, Stanforth *et al.* 1997, Bevill *et al.* 1999). Based on the close phylogenetic relationship and the data available, it is likely that Pitcher's thistle reproductive success and population density will decline further if *R. conicus* is added to its inflorescence-feeding guild (S.M. Louda, A.E. Arnett and A. McClay, unpub. data). And, even smaller populations would increase the plant's chance of extinction. There is enough evidence to suggest that this biological control agent should not be moved into the region surrounding the Great Lakes.

So, what can be learned from this case for future biological control efforts? Our results to date and my review of the documentation supporting the release *R. conicus* for musk thistle control leads to eight suggestions. All of these suggestions involve a re-examination of some of the most fundamental assumptions of biological control. Others have also concluded such a re-examination is needed (e.g., Howarth 1991, Simberloff and Stiling 1996, 1998, Thomas and Willis 1998). These assumptions include: (i) the target weed species poses major economic and environmental problems, (ii) no less risky alternatives exist, (iii) control by introduced natural enemies is predicted, (iv) significant harm to native species is unlikely, and (v) release involves known risks acceptable to the public (Louda *et al.* 1998, Louda 2000).

Examination of the history of this case suggests that the applicability of each of these must be better-quantified in the future. Besides demonstrating the value of re-examining the basic assumptions in each control project, this case suggests that in the future we need: (1) better quantification of the problem; (2) further incorporation of ecological criteria into pre-release testing; (3) evaluation of plausible ecological interactions; (4) quantitative data supporting the likely efficacy of the proposed biological solution to justify the risks; (5) comparable evidence on alternative control methods; (6) enhanced peer and public review; (7) institution of post-release reviews and redistribution regulations; and, finally, (8) re-evaluation of the situations in which releases of exotic species for biological control are considered a viable option.

1) Enhanced Problem Definition. The need for better quantification of the weed problem is obvious with hindsight. For musk thistle, the data that were taken initially are not adequate to determine current or cumulative costs and benefits of the biological control program.

The best study of economic costs, which was done after release (Dunn 1976), relied on anecdotal information applied on an inappropriate county-by-county, spatial scale. Counties are large enough to heterogeneous in terrain, land use, and weed densities. Using presence/absence on this scale to quantify the density of a patchy weed, such as musk thistle, is like deer hunting with a cannon; it greatly overestimates the scale of the problem (Louda *et al.* 1998). Also, Dunn (1976) defined a county as having a "*serious economic threat*" if "one or more pesticide applications had been used or would have been used if funds were available", and as having a "*potential economic threat*" if "the weed occurred but was not considered a problem." This method also contains an over-estimate bias. Although such estimates are still used, better economic evaluations can be made and should be required now.

Furthermore, environmental costs were not evaluated and appear unlikely to be high. Musk thistle is a fugitive species, susceptible to competition with grasses, that becomes a weed in disturbed areas and overgrazed pasture. Thus, I concur with Thomas and Willis (1998) that more precise evaluations of a pest problem should be expected and carried out.

2) Expanded Incorporation of Ecological Criteria. This case clearly demonstrates that, while host preference and performance tests are necessary, they are not a sufficient basis on which to project environmental protection and safety (Second and Kareiva 1996, McEvoy 1996, Thomas and Willis 1998, Arnett and Louda 1999).

For example, in this case ecological criteria, such as flowering phenology, should have been added to the criteria used to select the native species to test. Phenological synchrony is known to be an important factor in host plant use, including for *R. conicus* (Klein 1986, Zwölfer and Romstock-Volkl 1991, Louda 1998). Thus, it is not surprising that tests that focused primarily on one, later-flowering, iterocarpic North American thistle, *C. undulatum* (Zwölfer and Harris 1984), did not make a strong prediction of nontarget ecological impacts. Studying species in which flowering was phenologically synchronized with the *Rhinocyllus* oviposition period would have had a higher probability of identifying the potential for serious nontarget effects, such as observed for Platte thistle (Louda 1998). The effects of *R. conicus* on native plants and dependent fauna also suggest that it is difficult to anticipate the outcome of new interactions and the long-term consequences of introductions. Improving these predictions requires some information on the dynamics of interactions, the activity of already introduced agents, and the consequences of invasions.

3) Increased Quantification of Potential Ecological Interactions. The case lends direct support to those who have argued for increased study of plausible ecological interactions before release (Simberloff and Stiling 1996, Thomas and Willis 1998). Information on the population dynamics of related non-target species, in this case the dependent herbivores of native thistles, could be used to anticipate potential environmental side effects and to develop more ecologically-realistic estimates of cost/benefit ratios.

In this case, pre-release data suggested flowerheads of *Cirsium* spp. could be used by *Rhinocyllus*. Yet, no data were collected on the conditions under which this might be expected, nor on the outcome if various degrees of nontarget host use occurred. We should be asking not only, will the proposed agent utilize native North American species, but also which species could be vulnerable and what would happen if they were used? Although gathering such data is labor-intensive, limiting the number of projects (and doing each more thoroughly) would make such data collection feasible.

One way to limit the number of projects to a manageable number for more intensive study is to restrict the number of projects to the most promising candidate agents for control of the most invasive damaging weeds. Currently, without thorough ecologically-sound investigations, we lack a solid basis from which to predict the numerical consequences of deliberate introductions on indigenous biodiversity.

4) Improved Assessment of Potential Efficacy. More focused research, including better quantitative evaluation of the factors contributing to probable success/failure of specific biocontrol agents, would increase project efficiency while substantially reducing both risk (Thomas and Willis 1998, Louda 1999) and interference among agents released.

McEvoy and Coombs (1999) make a cogent case for their suggestion that the most rational biocontrol strategy entails the introduction of the fewest, most effective agents that have the lowest probability of nontarget effects. To do this, we need better prediction of control efficacy. For musk thistle, even early evidence for control by R. conicus was equivocal. Decreases in Musk thistle density after the release of R. conicus in test plots occurred only where Musk thistle was in a competitive context (Zwölfer and Harris 1984). Subsequent studies have confirmed the importance of grass competition for thistle control (e.g., Austin *et al.* 1985, Hamrick and Lee 1987, Popay and Medd 1990). Since every introduction of an exotic species entails some risk, common sense suggests that the pre-release data should demonstrate a high probability of control to justify taking the risk.

5) More Detailed Evidence on Alternatives. Several authors have recently called for greater consideration of alternative, potentially more manageable, biological methods for control of invasives, such as conservation biocontrol (Barbosa 1998, Newman *et al.* 1998,

Thomas and Willis 1998).

We need solutions that are scaled appropriately to the problem. Many weed problems are local, and many are subregional, in extent. Multiple, smaller-scale alternative tactics could be employed to manage pests on these spatial scales, lowering the risks involved (e.g., Newman *et al.* 1998, Thomas and Willis 1998). For example, localized, alternative strategies reported to control local infestations of Musk thistle include mechanical control by hand weeding, localized spraying, and intensified grass management (Randall 1993). Augmentation of indigenous natural enemies (Newman *et al.* 1998) remains an enticing, still developing technology for fugitive rangeland weeds.

In addition, logic argues for the implementation of the least risky options first. However, rational decisions are difficult if all the options are not equally evaluated. Optimization of weed management strategies, a technique to reduce risk, requires relatively complete information on options.

6) Expanded Peer Review and Public Input. Although expanded external review is often viewed as an "impediment to progress," this case history suggests that more perspectives would have been useful during the decision-making process on *Rhinocyllus* benefits and risks. Current T.A.G. guidelines for evaluating a proposal for agent release on a weed in the U.S.A. include an exhaustive list of things that could be considered. However, the extent to which each is addressed is not clear. Cooperative efforts to increase the transparency of the process and to insure input from the broader scientific community would enhance the process of evaluating proposed releases for both efficacy and safety. For example, within the U.S.A., open, professional workshops and round-tables could be used to develop explicit criteria for: targeting pest species for biocontrol research, providing external evaluations of proposals for release of exotic species, reviewing cost/benefit ratio calculations for biocontrol programs, identifying exotic species that appear too risky to release, and determining the safety of species redistributions among ecoregions within the country.

7) Establishment of Formal Post-Release Assessment and Monitoring. We need to know how effective agents, such as *R. conicus,* are as controls and under what conditions. Furthermore, given the impact of *R. conicus* on Platte thistle and its potential threat to the closely related, threatened Pitcher's thistle, it is clear the weevil should not be redistributed to regions with vulnerable early-flowering thistles, such as the states and provinces surrounding the Great Lakes. However, there are no systematic federal guidelines on the redistribution of an approved insect at present. No national regulations or guidelines deal with the redistribution of biological control agents among ecoregions once the organism has been approved for release within the USA.

Furthermore, periodic reviews of agent effectiveness and potential side effects are needed to help manage the risk associated with deliberate introduction and spread of new species (Thomas and Willis 1998). Development of guidelines or restrictions on movement are needed to help contain the impact of species, such as *R. conicus*, for which undesirable side effects are demonstrated after approval and initial release.

8) To Release or Not: How Do We Decide? How do we balance limited resources for research against unlimited demands for solutions to problems of all sizes? Economists argue that competing demands must be prioritized in order to make resource allocation decisions. I suggest a similar strategy is needed in weed management, especially where biological control is considered a possibility. Prioritizing weed problems, by both the magnitude of the threat and the difficulty of solution, would increase attention on the

problems where the control is needed most, and where biocontrol is likely to be effective without negative effects on native organisms and biodiversity.

Conclusion

Use of a wider range of assessment information, plus more rigorous economic and environmental assessments, should increase environmental safety in future biocontrol efforts (Louda *et al.* 1998, Thomas and Willis 1998, 1999, Louda 1999). The recent findings and the permanence of any successful biological control introduction suggest that (i) past biological control agents should be studied and thoroughly reviewed periodically and (ii) new efforts should be reserved for only the most invasive, harmful species, preferably with no native relatives, if and only if intensive efforts have shown that no reasonably effective, more local alternatives exist.

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