# Guidelines for improving impact evaluation of weed biocontrol

Adele M. Reid[1], Louise Morin[1] and Royce H. Holtkamp[2]
Cooperative Research Centre for Australian Weed Management
[1] CSIRO Entomology, GPO Box 1700, Canberra, ACT 2601, Australia
[2] NSW Department of Primary Industries, Weed Biological Control Unit, Tamworth Agricultural Institute, 4 Marsden Park Road, Calala, New South Wales 2340, Australia
Email: adele.reid@csiro.au

**Summary** This paper discusses a set of methodologies for quantifying the direct and indirect impacts of weed biological control agents.

**Keywords** Best practice guidelines, biological control, impact, monitoring.

## INTRODUCTION

Evaluating the success of weed biological control (hereafter referred to as biocontrol) programs is essential to justify continued investment and improve efficiency and effectiveness of future programs. Impact assessments of biocontrol agents however, have not been systematically undertaken for many programs, often due to inadequate resources and funding (Syrett *et al.* 2000).

Although confirming establishment of an agent is a crucial milestone for any program, it cannot, by itself be used as a measure of program success. Genuine evaluation of biocontrol programs can only be achieved by measuring long-term impacts of the agents on weed populations and associated natural or agricultural ecosystems (Syrett *et al.* 2000). Unfortunately, past research has often only focused on assessing damage on individual plants of the target weed (Thomas and Reid 2007). Considering the goal of most programs is to reduce the impact of the weed, it is vitally important to evaluate if biocontrol leads to long-term reductions in weed populations and the recovery of agricultural yields, desirable plant species and/or ecosystem function.

There are many ways to evaluate a biocontrol program including both pre- and post-release studies and using a range of ecological, economic and social indicators (Syrett *et al.* 2000). Long-term post-release evaluation is generally necessary to demonstrate impact of agents on the target weed, against a background of environmental and temporal variability (McClay 1995).

In this paper, we outline the steps that should be considered when implementing impact evaluation studies and the pros and cons of various methods for evaluating post-release impact of biocontrol agents.

## SETTING PERFORMANCE TARGETS

Clearly defining performance targets at the onset of a biocontrol program, including the extent and timing of any impact (e.g. 25% reduction in weed cover within 10 years and corresponding increase of desirable vegetation), is necessary to provide goals against which the program can be later evaluated. Devising realistic performance targets however, requires some knowledge of the economic and ecological effects of the weed and what level of control is necessary to ameliorate these impacts (Thomas and Reid 2007). Unfortunately, this information is not always available, particularly for environmental weeds, which hinders the setting of meaningful (or quantitative) performance targets.

Costs involved in controlling a weed before biocontrol agents are introduced can be obtained from key stakeholder groups and by searching the literature. Weed impact studies (e.g. correlative and weed removal experiments) can be performed to determine the extent of ecological damages caused by the weed; however these are often beyond the scope and means of most biocontrol programs. Environmental and economic modelling can also assist in setting performance targets for biocontrol programs (Sims *et al.* 2006), although they are often limited by lack of information.

Devising an appropriate study to monitor impact of a biocontrol program should take place well before any agents are released. This includes determining the design, scale and duration of the study and the types and timing of data collection.

## CHOOSING A METHOD

A range of methods can be used to evaluate the impact of biocontrol. Some methods are more effective or suitable than others under certain circumstances, and each method has pros and cons.

**'Before and after' studies** One of the most effective evaluation methods is to monitor weed-infested sites before and after introduction of biocontrol agents.

When using this approach, it is vital to monitor multiple sites pre- and post-agent release over several years (McClay 1995, Dhileepan 2003). Base-line pre-release data collected over several years is necessary to document fluctuations in weed populations due to abiotic influences.

The downside of 'before and after' studies is the lack of appropriate control plots, where agents have not been released, for comparison. Consequently, it is difficult to ascertain that changes in weed populations are due to biocontrol agents and not to some other factors such as climate variability or land use change. It is therefore prudent to include representative sites across the weed distribution, so the effect of the agents can be examined across different climatic regions and habitats. Control sites, where agents have not been released or have been excluded (see below) can also be incorporated into before and after studies, although these sites may be short-lived if agents rapidly colonise them or exclusions cannot be adequately maintained over long periods.

**Agent exclusions** Agent exclusion experiments (which use cages or chemicals to provide agent-free plots or sites) are useful for directly relating agent attack to plant performance by comparing agent-free with attacked plots (or sites) (McClay 1995).

Exclusion experiments are not suitable for all weeds and/or situations (Paynter 2004). Exclusion treatments can affect agent or plant performance by altering abiotic (such as nutrient, light or moisture levels) or biotic conditions (by excluding pathogens, predators, parasitoids and pollinators) (Dhileepan 2003, Paynter 2004). Exclusion experiments may also be impractical for some weeds (such as large woody weeds) and environments (such as high rainfall areas) because it is difficult to continuously exclude agents. Exclusion studies are also time consuming and costly to maintain, which restricts their use over large areas and long time frames.

**Comparing sites with and without agents** In situations where an agent has already been released, but has not widely established or spread, it is possible to compare areas where the agent is present to those where it is not (Paynter 2004). However, because sites are not randomly chosen, there may be a range of reasons why an agent has not established at some sites (such as unsuitable abiotic or biotic conditions), which may confound any comparison of plant performance between the sites. Undertaking these studies over multiple sites and years will increase reliability of results, although 'before and after studies' and exclusion experiments are generally preferred.

**Correlative studies** Studies that correlate agent densities (or damage) with plant performance can be useful for quantifying biocontrol impacts on individual plants, once the agents have established, and can also be used to clarify contributions from multiple agents (Dhileepan 2003). Nonetheless, because agent and damage levels are not manipulated, any changes in plant performance may be due to some other unrelated factor (such as differences in plant vigour or microhabitat). To overcome some of these problems, correlative studies should be carried out over multiple sites and years.

**Historic comparisons** In some cases, historic material (such as published and unpublished data or aerial photos), can be used as baseline data to compare with contemporary weed populations (Paynter 2004). It is difficult however, to know if the weed population has changed over-time because of the biocontrol agent or because of some other factor (e.g. climate, land use). Confidence in this method can be improved by examining multiple sites, although it may be difficult to find historical data of equal quality to use across sites.

**Stakeholder surveys** Large scale evaluation of biocontrol agents across landscapes can be performed by surveying land managers' perceptions of the importance of the target weed (e.g. weed prevalence and problem status) before and after introduction of agents (Ireson *et al.* 2007). Such stakeholder surveys can also incorporate questions about the economic and social benefits derived from the biocontrol program. Nonetheless, weed populations and stakeholder perceptions may vary independently of the implementation of a biocontrol program, and therefore surveys should be coupled with more detailed site specific quantitative impact studies.

## COLLECTING DATA

Once an appropriate study to monitor impact of a biocontrol program has been designed, the data to be collected will depend on the performance targets set for the program and the type of weed and agent. Ideally, agent impacts should be measured at the plant, population, landscape and ecosystem levels (Table 1).

## LONG-TERM MONITORING

Continued, regular monitoring of biocontrol programs over many years is recommended because agents can be slow to build up and cause detectable changes in weed populations and associated ecosystems. Lack of resources is often a key factor that prevents continued long-term monitoring (McFadyen 1998). In such situations, long-term impacts of agents can be captured by

**Table 1.** Possible measurements to evaluate the impact of biocontrol.

| Level | Measurements |
|---|---|
| Plant | – growth (number, size and biomass of above- and below-ground parts) |
| | – reproduction (number and biomass of flowers, fruits and seeds) |
| | – survival |
| | – agent density and damage levels |
| Population | – photo references |
| | – weed density or cover |
| | – age structure |
| | – seedling recruitment and survival |
| | – viable seed bank density |
| | – weed stand size (and spread) |
| | – agent density and damage levels |
| Ecosystem | – damage from biocontrol agent on other plant species |
| | – species richness and abundance of desirable plant species |
| | – species richness and abundance of undesirable plant species (weeds) |
| | – rate of ecosystem processes e.g. nutrient cycling, decomposition |
| | – yield/profitability (of agricultural systems) |

re-assessing sites at regular intervals (ideally every 2–3 y) and comparing with data collected before and soon after releases. If no previous data has been collected, then correlative studies and agent exclusions can be performed to assess impact (Sims *et al.* 2006).

The timing and duration of long-term monitoring will depend on how fast agents build up to damaging levels, how long weed populations take to respond and the overall variability of the system. Demographic modelling can be used to estimate how long an agent may take to affect key growth parameters of a weed, and assist in planning the timeframe of long-term monitoring activities (Buckley *et al.* 2004).

## CONCLUSION

Biocontrol programs have traditionally focused on agent selection, release and establishment, with limited resources allocated to evaluating the long-term impact of agents on weed populations and associated ecosystems. The best practice guidelines presented in this paper were put together to assist practitioners develop sound plans for evaluating the impact of agents at the onset of a biocontrol program. Impact evaluation is a key activity to improve biocontrol as a discipline and document ultimate success in terms of recovery of desirable vegetation and ecosystems.

## ACKNOWLEDGMENTS

We gratefully acknowledge the contribution of participants to the CRC for Australian Weed Management workshop on biocontrol evaluation held in Brisbane in March 2006.

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