

Benefit-cost analysis for biological control of *Echium* spp. (Paterson's curse and related species) in Australia, 1972–2050

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Summary Based on the timing and location of 400 successful releases of insects from 1993 to 2000 specifically targeting *Echium* species (Paterson's curse being the most important representative), and estimates of insect attack and spread rates according to dates of weed germination, a benefit/cost analysis is developed for a biological control research and development program begun by CSIRO in 1972. Australian meat and wool industries have also contributed funding to the program, in addition to in-kind contributions of the NSW, Victorian, South Australian and Western Australian state departments, and, since 1995, the Weeds CRC. The total of these R&D expenditures by CSIRO and these partners reached \$14 million by 2001. Annual benefits in terms of increased productivity of grazing lands are projected to rise from near-zero in 2000 to some \$75 million by 2015, based on a value of \$8 DSE⁻¹. These sums do not include savings due to reduced spray costs as offsetting expenses will arise with management practices required to maximise the success of biocontrol agents, and to limit reinvasion by other pasture weeds. The discounted (5%) net present value (NPV) of the benefit-cost stream from 1972 to 2015 is projected at \$287 million, for a B/C ratio of 14:1. Because lower attack and spread rates of the insects are observed in regions with late autumn breaks, a slow build-up of benefits is expected to continue over many years. The discounted NPV for the 1972–2050 period is estimated to be \$1074 million, with a B/C ratio of 50:1 and an internal rate of return exceeding 19%.

Keywords Biological control, benefit cost analysis, Paterson's curse, *Echium* spp., weed, pasture.

INTRODUCTION

Echium plantagineum L. is an introduced winter annual pasture weed of Mediterranean origin. Free of native Mediterranean plant and insect communities, it has become one of the dominant pasture weeds of temperate Australia. Other introduced *Echium* species (*E. vulgare* L., *E. italicum* L., and *E. simplex* L.) also occur as weeds in Australia (Parsons and Cuthbertson 1992). Keeping in mind that *E. plantagineum* is the most important Australian pasture weed in the genus, henceforth in this paper we refer to the four species

collectively as '*Echium*'. Although relatively nutritious in terms of digestible nutrients, and valued as a pasture plant in some places, *Echium* contains pyrrolizidine alkaloids that are poisonous to livestock, reducing weight gain and wool clip and in severe cases leads to death. *Echium* is estimated to occur on over 30 million hectares in Australia (Industries Assistance Commission, IAC, Report 1985).

Echium was first suggested as a candidate for biological control at the Australian Weeds Council in 1971. CSIRO Entomology started surveys in its native range in 1972 from its base in Montpellier, France. Of the hundred or more insect species recorded on *Echium*, eight were selected as possible biological control agents, with the first imported into quarantine, Canberra, by 1979. In 1980, a small group of graziers and apiarists lodged an injunction in the Supreme Court of South Australia to stop the biological control program as they considered the loss of *Echium* a threat to their livelihoods. *The Biological Control Act 1984* established procedures for assessing and authorising biological control programs in Australia (Cullen and Delfosse 1985); a subsequent inquiry and benefit-cost analysis was conducted by the IAC, which concluded with the judgment that a biological-control program on *Echium* should go ahead (IAC Report 1985).

The Supreme Court injunction was eventually lifted and the importation of insects into Australia resumed. Since then six insect species have been successfully released: a leaf mining moth, *Dialectica scariella*, crown and root weevils, *Mogulones larvatus* and *Mogulones geographicus*, a root beetle, *Longitarsus echii*, a stem boring beetle, *Phytoecia coerulescens*, and a pollen beetle, *Meligethes planiusculus*. Of these insects, *D. scariella* and *M. larvatus* were introduced first and have been released across the geographic range of the weed. *M. larvatus* is known to be limiting the *Echium* population at two of the earliest release sites and approaching control at many of the younger release sites.

Based on the positive population trend of *M. larvatus* and its ability to limit the weed at an increasing number of sites, the economic analysis of the IAC report was revisited so projected economic gains from

biological control could be quantified. Unlike previous cost-benefit analysis of biological control, where an insect is given an arbitrary impact and rate of spread, the current analysis incorporates observed values based on the biology and ecology of *M. larvatus* and its' weedy host, *Echium*, over the past nine years.

MATERIALS AND METHODS

Of some 1000 releases of *M. larvatus*, 400 have been confirmed successful in terms of insect survival to subsequent seasons. Of these successful releases, 189 were in NSW, 143 were in Victoria, while SA and WA had only 34 each. The rates of spread of insects and development of attack rates on *Echium*, and the rates of expected progress of geographic coverage (Figure 1) are based on field data and observations by scientists on the project, are described as functions of time. Function parameters differ according to the date of the autumn season break; both attack and spread rates are highest with an early autumn break (March) and lowest with a late break (May). This variation occurs because late breaks tend to decouple the occurrence synchrony of *Echium* and *M. larvatus*.

The present study uses the district location, grazing area, and stocking rate information supplied by the IAC (1985), updating and correcting an earlier analysis by Nordblom *et al.* (2001), overlaying the new insect release location and date data. Autumn break date classifications were assigned to districts according to the month in which greater than 25 mm median rainfall is received, based on long-term monthly median rainfall maps from the Bureau of Meteorology (BOM 2000). The projected geographic extents of insect spread over the coming three decades are illustrated in Figure 2.

We assumed for districts in which there had been more than one release, that the maximum spread of insects from each release was to the area defined as the district total divided by the number of releases in the district. This is a conservative assumption given the fact that the earliest insect releases will have spread over greater surface areas and reached greater densities than later releases, and the fact that insects are not limited by administrative boundaries. These conservative assumptions were made to limit the computational burden posed by 400 insect releases distributed over a seven-year period across 44 districts of varying size and divided into 130 sub-districts, depending on year of release. For each sub-district, year-by-year sequences of areas with partial relief were simulated, then aggregated back to the 44 districts as area equivalents with full economic loss relief.

There are several other conservative assumptions in our analysis. One is that all long-term biological control of *Echium* results only from the activity of

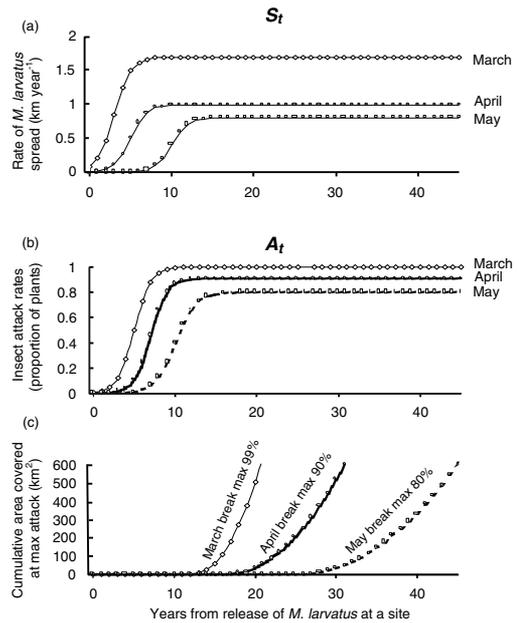
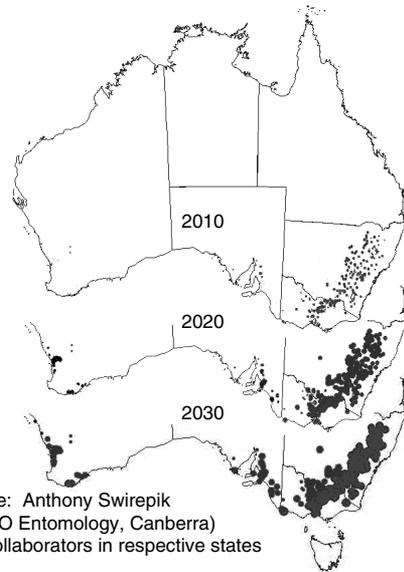


Figure 1. Spread and attack rates of *M. larvatus* on *Echium*, with subsequent geographic coverage at maximum economic control levels in three climates.



Source: Anthony Swirepik (CSIRO Entomology, Canberra) and collaborators in respective states

Figure 2. Simulated spreading fronts of 400 *M. larvatus* populations released from 1993 to 2000.

M. larvatus even though there is good reason to anticipate complementary successes of the other agents released against the weed. The model conservatively assumes no further releases beyond the 400; in reality,

state departments of agriculture continue to respond to farmers' requests, and the Wool Mark Company and Meat and Livestock Australia continue important support for releases of biocontrol agents against *Echium*. The model focuses on the valuation of increased pasture productivity and ignores reductions in conventional spraying costs. While reductions in pasture spray costs may be anticipated, these are likely to be replaced with the costs of measures taken by farmers to facilitate the success of the biological control agents and to limit reinvasion by other pasture weeds. The model also ignores control costs and losses attributable to *Echium* as a weed in crops, which amount only to some \$1.2 million annually (Jones *et al.* 2000) and may be assumed to continue indefinitely.

The economic damage caused by *Echium* in pastures is assumed to remain unaffected by *M. larvatus* at attack levels below 50%. Attack levels above this are assumed to result in increasing reductions in economic loss.

The attack and spread simulation model, set for the particular size, release dates and autumn break parameters of each sub-district, was used to generate a time series of areas with varying degrees of partial economic relief from *Echium*. The years required to reach these limits differed according to district size and number of releases. For each year in each district, a ratio was calculated of the (weighted) relieved area to the total area. These ratios were multiplied times the maximum proportions by which total stocking rates were assumed to be increased in the absence of *Echium* in the IAC report, district by district (these ranged from a maximum of 0.2 to a minimum of -0.1). Total stocking rates for each district were expressed as dry sheep equivalents (DSE) where 1 DSE relates to one wool sheep, 1.5 DSE for each meat sheep, 10 DSE for each beef animal and 15 DSE for each dairy cow.

In order to express the aggregate economic relief in dollar terms a conservative value per recovered DSE was wanted. The lowest gross margin per DSE in NSW is \$8.80 for wethers. A value of \$8 DSE⁻¹ was chosen as a conservative base for modelling, though values double this are recorded for sheep and cattle enterprises in NSW where the greatest infestations of *Echium* occur. The year-by-year estimates of dollar value loss relief were aggregated across districts by state.

RESULTS

The simulated time paths of the benefits for each state are projected in Figure 4. Illustrated are the projected four-state aggregate benefit streams for the case of \$8 DSE⁻¹ (undiscounted in panel 'a' and discounted at 10% in panel 'b'). The greatest benefits from biocontrol of *Echium* are anticipated in NSW, followed

by Victoria and Western Australia. Comparatively little benefit is expected for South Australia, where the late autumn breaks put *M. larvatus* at a disadvantage.

The biological control research and development program on was begun by CSIRO in 1972. Total R&D expenditures on *Echium* biocontrol by CSIRO and its partners from 1972 to 2001 has reached \$14 million (Nordblom *et al.* 2001). The sum of the undiscounted benefits (Figure 4) minus the cost stream, results in a time series of undiscounted net annual benefits. Several such series were created using a range of DSE values (\$4 to \$16 DSE⁻¹) and discounted at a range of rates (5% to 20%) to produce the results in Table 1.

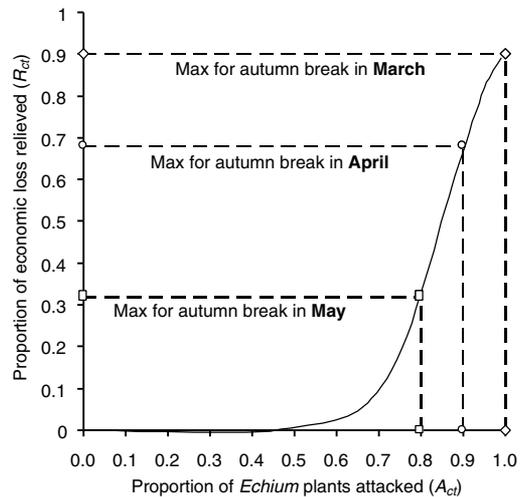


Figure 3. Proportion of pasture productivity loss recovered as a function of insect attack on *Echium*.

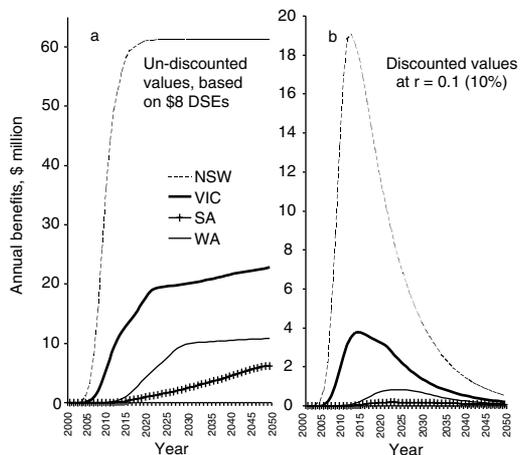


Figure 4. Projected annual benefits from biocontrol of *Echium* by state, due to insect releases in 1993–2000, \$millions, with \$8 DSE⁻¹ pasture values.

With \$8 DSEs, annual benefits in terms of increased productivity of grazing lands are projected to increase from near-zero in 2000 to some \$75 million by 2015, and \$90 million by 2025. The discounted (5%) net present value (NPV) of the benefit-cost stream from 1972 to 2015 is projected at \$287 million, for a B/C ratio over 14:1. For the 1972-2050 period, the NPV is \$1074 million for a B/C ratio of over 50:1. The internal rate of return (discount rate that drives the B/C ratio to zero) exceeds 19%.

DISCUSSION

The success story projected for biological control of *Echium* in Australia will likely be at a slower pace than envisaged by the IAC (1985). Nevertheless, the return on investments is expected to be very respectable indeed. Keeping in mind that just over \$14 million has been spent on the biocontrol program for *Echium*, the high net present values anticipated with all but the most extreme combinations of low DSE values and high discount rates (lower left corner of Table 1) give strong assurance of success.

Further analysis is needed to determine the value of additional insect releases beyond the 400 of 1993–2000 to see where there may be gaps in populations that would otherwise take many years to fill. Open to question and future revision are our assumptions on affected pasture areas in each state,

Table 1. Net present value (NPV, 2002) of the biocontrol program viewed over the 1972–2050 period, from 400 successful insect releases in 1993–2000 (\$ m).

Discount rate	Value of recovered pasture productivity (\$ DSE ⁻¹)			
	\$4	\$8	\$12	\$16
5%	526	1074	1623	2171
6%	423	871	1319	1767
7%	343	714	1084	1454
8%	280	590	900	1210
9%	229	491	753	1015
10%	186	410	634	858
11%	151	343	536	729
12%	120	287	455	622
13%	92	239	385	532
14%	67	196	325	454
15%	43	158	272	386
16%	20	122	223	325
17%	-3	88	179	270
18%	-27	54	136	218
19%	-53	20	94	168
20%	-81	-14	52	118

their ecological characteristics, livestock populations, levels of *Echium* infestation/damage and the levels of biocontrol achievable.

ACKNOWLEDGMENTS

This report corrects errors in an earlier version, which understated the contributions of *Echium* biocontrol in WA (Nordblom *et al.* 2001). It also updates the NPV estimates to a 2002 basis. The authors wish to thank David Vincent and David Pearce, of the Centre for International Economics (CIE), for raising a number of important questions over the course of the analysis. We thank those collaborating at the state level with CSIRO Entomology in releasing and monitoring biocontrol agents on *Echium*, in particular, those who provided the geo-referenced release location and date information required for this analysis: Kerry Roberts, Agriculture Victoria, KTRI, Frankston; Ross Stanger, SARDI, Entomology Unit, Adelaide; Paul Sullivan, NSW Agriculture, Tamworth; and Paul Wilson, WA Department of Agriculture, South Perth. Funding support for such work from Australian Wool Innovation and Meat and Livestock Australia is also gratefully acknowledged.

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