
Will Expected and Unexpected Non-Target Effects, and the New Hazardous Substances and New Organisms Act, Cause Biological Control of Broom to Fail in New Zealand?

S. V. FOWLER¹, P. SYRETT², and P. JARVIS²

¹Landcare Research, Private Bag 92170, Auckland, New Zealand

²Landcare Research, P.O. Box 69, Lincoln, New Zealand

Abstract

Two biocontrol agents, broom seed beetle, *Bruchidius villosus* (F.), and broom psyllid, *Arytainilla spartiophila* (Förster), have been released against broom, *Cytisus scoparius* L. (Link)(Fabaceae), in New Zealand since 1981. Risks to non-target plants have, in part, caused this slow progress. Host-range testing of biocontrol agents for broom has often been difficult, or yielded equivocal results, particularly with tagasaste, *Chamaecytisus palmensis* (Christ) Bisby et K.Nicholls, and tree lupin, *Lupinus arboreus* Sims. These two alien plants are closely related to broom, and are valued by interest groups in parts of New Zealand. Recently, broom seed beetle has unexpectedly attacked tagasaste seed in New Zealand. Ecological studies on broom in its native range make us optimistic about the long-term potential for biological control, provided that sufficient agents are introduced. To date, the impact of herbivorous insects on broom in New Zealand is insufficient to ameliorate its weed status significantly or prevent its continuing spread. The new Hazardous Substances and New Organisms Act demands rigorous assessment of risks, costs, and benefits for introductions of new organisms into New Zealand. In response, the applications for release of new biocontrol agents against broom are being delayed, and better information on the costs and benefits to New Zealand of broom and the non-target plants at risk is being gathered, but this process is time-consuming, expensive, and fraught with difficulties or uncertainties. The level of public consultation prior to applications for release is being increased, and further laboratory and field safety-testing with potential agents are being conducted. The broom biocontrol programme will suffer further delays, and prospects for eventual success are more uncertain.

Keywords: Weed biological control agents, cost-benefit, safety, host-range testing

For over 18 years, one of the longest running biological control programmes in New Zealand has targeted broom, *Cytisus scoparius* L. (Link.), a weed of European origin. Only two biological control agents have been deliberately introduced into New Zealand to attack broom since the programme started in 1981. In this paper we review the reasons for this slow progress, and illustrate some of the problems that the programme has faced. We also discuss the benefits gained from the large number of ecological studies of the plant and its herbivorous insects in its native range and elsewhere. These studies include pioneering work by entomologists at Silwood Park in the south of England, in the 1950s, 60s and 70s (Waloff 1968, Waloff and Richards 1977), and more recent studies in the UK, France, Australia and New Zealand (Paynter *et al.* 1996, Memmott *et al.* 1997). Although these studies provide encouraging evidence for the impact of herbivorous insects on the

population dynamics of broom in its native range, approval for the introduction of some of these insects may now be even more difficult because of new rules and regulations in New Zealand. We present a summary of the requirements of the new Hazardous Substances and New Organisms (HSNO) Act in New Zealand, including the increased costs imposed by the Environmental Risk Management Authority (ERMA) in processing applications. We review the information on economics and risk to non-target plants used in a recent application to release the chrysomelid beetle, *Gonioctena olivacea*, that was declined by the Ministry of Agriculture and Forestry (MAF), and summarize our attempts to obtain new information according to ERMA guidelines. Finally we assess the likely overall impact of all these problems and legislative developments on the broom biological control programme in New Zealand.

Reviewing Progress with Biological Control of Broom in New Zealand

Searches for classical biological control agents against broom have been undertaken in its native range, which is Western Europe, from Portugal and Italy in the south to Scotland and Scandinavia in the north (Syrett *et al.* 1999). There is an extensive literature on the natural enemies of broom in its native range (reviewed in Syrett *et al.* 1999), and considerable ecological studies of broom and its insect herbivore fauna have been made, particularly at Silwood Park in southern England (Waloff 1968, Waloff and Richards 1977).

Although the biological control programme against broom in New Zealand has been operating for 18 years, only two biological control agents have been introduced: the broom seed beetle (*Bruchidius villosus* (F.)) in 1987, and the broom psyllid (*Arytainilla spartiophila* (Förster)) in 1993. One very promising species, the broom twigminer (*Leucoptera spartifoliella* Hübner), was already present in New Zealand before the programme commenced. In total 20 insect species and 2 fungi have been investigated or tested during the course of the entire broom programme, both in Europe and after importation into quarantine in New Zealand.

Problems with agents attacking tagasaste (tree lucerne), *Chamaecytisus palmensis* (Christ) Bisby and K. Nicholls, and some other members of the tribe Genistae, which includes broom, were identified early in the programme. The first agent selected for testing in the 1980s, the chrysomelid beetle, *Gonioctena olivacea* (Förster), was initially abandoned because of potential risk of attack on tagasaste and tree lupin (*Lupinus arboreus* Sims). However, interest was renewed in this species after observations of the levels of damage it inflicted on mature and seedling broom in Europe. An Impact Importation Assessment (IIA) was submitted to the Ministry of Agriculture and Forestry (MAF) in New Zealand in 1997, as a test case to see whether concerns about non-target attack, on tagasaste in particular, would be an issue. This application for release of *G. olivacea* was declined on two grounds: (1) there was insufficient information on the scale of the broom problem in New Zealand relative to the value of tagasaste, and (2) that the risk the beetle posed to tagasaste had not been assessed sufficiently. We return to these issues in more detail below.

Several other potential biological control agents for broom have been difficult to test and/or yielded equivocal results from testing. The weevil, *Sitona regensteinensis* (Herbst), with larvae that attack the root nodules of broom, was difficult to rear. Tests with larvae of two moths, *Chesias legatella* (Denis and Schiffermüller) and *Agonopteryx assimilella*

(Treitschke), gave some equivocal results with non-target plant species in the tribe Genistae. Oviposition tests with adults of these moths failed because of their abnormal behaviour in cages (e.g., laying eggs on the cage mesh a long distance from the nearest plant), despite the use of a 128 m³ cage. Field tests, augmenting numbers of these insect species, have been tried with mixed success. Overall, it seems that a suite of potential biological control agents for broom in New Zealand, while sufficiently host specific to be a negligible threat to native plants, may represent a risk to certain non-target plants in the same tribe as broom. Native New Zealand plants in the Fabaceae, as well as economically important plant species, are essential components of host-range testing carried out for all prospective agents. Agents are rejected if they fail these tests. For example, the promising stem-mining weevil, *Pirapion immune* (Kirby) was rejected from further consideration as a biological control agent by Landcare Research because tests revealed a risk of attack on the native plant, kowhai *Sophora microphylla* Ait. (Syrett *et al.* 1995).

In 1999, twelve years after its release, the broom seed beetle was discovered attacking the seed of tagasaste in New Zealand. This was not predicted by the host-range tests, and is likely to lead to concern over the reliability of the testing procedures. Our current explanation for this failure to predict attack on a closely related non-target plant species is that the tests carried out were oviposition choice tests (with the normal host plant, broom, always present). In the field it appears that the beetles are exposed to a no-choice situation: tagasaste flowers much earlier in spring than broom and, contrary to our expectations, the beetles may be emerging early from overwintering and becoming reproductive after consuming tagasaste pollen. Normally the ovaries of the female beetles develop fully only after they start to consume broom pollen, but clearly tagasaste pollen is an acceptable substitute. We had good evidence from the field in Europe that the broom seed beetle avoided several other *Cytisus* spp. and *Chamaecytisus hirsutus*. Furthermore, the beetle has never been found attacking the seed of gorse, *Ulex europaeus*, in Europe despite the fact that adults are known to feed on the flowers of this shrub, which appear earlier in spring than those of broom. In future, we will ensure that both choice and no-choice tests (i.e. without the normal host plant) are carried out. We are also carrying out a field trial in Europe, using tagasaste planted experimentally adjacent to broom. These trials will be time-consuming and expensive because tagasaste can be difficult to grow in areas where broom will grow because of its lack of frost tolerance. Nevertheless, these trials are necessary to obtain reliable and convincing evidence of the level of risk to tagasaste from potential biological control agents for broom in New Zealand.

Despite all these problems, there is good evidence that the population dynamics of broom in its native range is strongly influenced by its natural enemies (see below), so these problems with host-range testing and related non-target plants (themselves aliens in New Zealand) are frustrating.

Ecological Studies on Broom and the Prospects for Biological Control

A total of 243 phytophagous insect and mite species are found associated with broom in Europe, and 69 have been considered as possible classical biological control agents for New Zealand (Syrett *et al.* 1999). Less is known about the potential for classical biological using pathogens of broom from its native range, but there has been some preliminary host-range testing with two species (*Uromyces sarothamni* Guyot and Massenet, and *Pleiochaeta setosa* (Kirchn.) Hughes).

Several of the insect herbivores attacking broom were studied in detail by Waloff and co-workers during the 1950s and 60s (Waloff 1968), and Waloff and Richards (1977) report on a large-scale, but unreplicated, application of insecticides to broom at Silwood Park for 11 years. The unsprayed bushes had higher numbers of herbivores, did not attain full growth, and had higher mortality compared with the sprayed bushes. The total seed yield of unsprayed broom was also reduced by 75%. However, although these results show a severe impact of insect herbivores on broom plants, seed-banks and the recruitment of seedlings into the next generation were not studied, so an impact on the population dynamics of broom cannot be unequivocally demonstrated. From 1991-8, replicated ecological experiments were carried out UK, France, Australia, and New Zealand to examine other aspects of the ecology of broom including: size and decay of broom seed-banks, intraspecific and interspecific plant competition, natural enemies of seedling broom (both vertebrate, invertebrate, and fungal), seed and microsite limitation (by seed-sowing and various cultivation treatments). A simulation model was developed by Rees and Paynter (1997) to predict the proportion of sites with broom under a variety of scenarios of disturbance, herbivory etc.

The overall conclusions can be summarized:

- Moderate levels of disturbance, creating reduced levels of intraspecific and interspecific plant competition are key factors in the creation of broom stands in Europe.
- Invertebrate herbivory on broom seedlings in the native range was not significant, but in places vertebrate herbivory caused 100% death.
- The modeling indicated that reduced longevity and seed production of broom plants could have a major effect on the population dynamics of broom.
- The model highlighted the importance of whether broom stands self-replace (as they appear to do in some areas where broom is weedy in New Zealand and Australia, but do very rarely in its native range in Europe).

Overall, the results of these ecological studies on broom suggest that the prospects for classical biological control are good. Insect herbivory does reduce longevity of broom in Europe. Seed-feeders should reduce the rate of invasion of broom into new habitats (Paynter *et al.* 1996), and the model predicts that they could reduce broom cover in frequently disturbed areas such as braided rivers (Rees and Paynter 1997). Chronic effects of insect herbivores and plant pathogens on broom stands may also allow competing plants, especially perennial grasses, to persist in these stands, and then they can outcompete broom seedlings once the mature broom senesces, preventing a second generation of broom at the site.

Biological control agents may become more abundant when introduced without their own natural enemies, so it is possible that impacts could be higher than predicted from studies in the native range. An example is the broom twigminer, *L. spartifoliella*, which was first reported in New Zealand in the 1950s. The twigminer is having a substantial impact on broom (Memmott *et al.* 1997). Currently, we cannot predict how much worse a weed problem broom would be in New Zealand in the absence of the twigminer, but even with its presence broom remains a major weed and is still spreading. If successful amelioration of the broom weed problem in New Zealand is possible through biological control, it will need the introduction of further species of agents, and these will now have to be approved by the new Environmental Risk Management Authority (ERMA).

The Hazardous Substance and New Organisms Act, and the Environmental Risk Management Authority

The Hazardous Substances and New Organisms (HSNO) Act (1996) established a new statutory body, the Environmental Risk Management Authority (ERMA), to replace the Ministry of Agriculture and Forestry (MAF) as the authority making decisions on whether to allow the importation of new organisms into New Zealand. Here we summarize the requirements and assumptions of ERMA, which are based on the HSNO Act (HSNO 1996; HSNO (Methodology) 1998). The key changes are that proposals to introduce new organisms into New Zealand will require more detailed risk identification and analysis, and a greater level of consultation with the New Zealand public.

Importations into quarantine facilities

The new procedures apply both to introductions into secure quarantine facilities and to introductions into the New Zealand environment. Introductions into quarantine facilities do not need to be notified to the public, and so are relatively streamlined. Nevertheless, ERMA requires a full risk analysis even for introductions into MAF-certified quarantine facilities. The Authority regards risk analysis as comprised of two elements: an identified adverse effect, and a probability of that adverse effect occurring. It requires that both the magnitude and the probability of risks be described in all cases. Applications to import into quarantine thus need to describe in detail the impact that an escaped organism would have on the New Zealand environment. Applications to introduce a new organism into containment are expected to take an average of 72 hours of ERMA staff time for a decision to be reached. The total ERMA cost for such an application is now NZ\$10,676 (approx. US\$5,600) (although currently reduced by a government subsidy of NZ\$3,150).

Risk identification and assessment for full releases

The Hazardous Substances and New Organisms Act (HSNO 1996) requires ERMA to take a “precautionary approach” in managing adverse risks where there is scientific and technical uncertainty about those effects. For the most recent application for a release of a biological control agent for a weed in New Zealand (mist flower gall fly, *Procecidochares alani* Steyskal), the risks were identified and assessed according to ERMA protocols. Given knowledge of the biology of the agent concerned, its weedy host, and the New Zealand environment, risks, costs and benefits to the following areas were identified (as required by the HSNO Act, and taken from the annotated methodology published by ERMA (1998a)):

- (1) the life supporting capacity of air/water/soil/ecosystems;
- (2) the capacity of people and communities to provide economic social and cultural well-being and the reasonably foreseeable needs of future generations;
- (3) the sustainability of all native and valued introduced flora and fauna;
- (4) the intrinsic values of ecosystems;
- (5) public health;
- (6) the relationship of Maori and their culture and traditions with their ancestral lands, water, sites, wahi tapu (sacred places), valued flora and fauna, and other taonga (treasures);
- (6) the economic and related benefits to be derived from the use of a new organism;
- (7) New Zealand’s international obligations.

Applicants are expected to identify all reasonably foreseeable risks to the environment and the health and safety of people and communities. Significant risks will then be needed to be assessed quantitatively or qualitatively, using methods that can be justified, e.g., accepted science, common practice. The degree of accuracy required is related to the level of risk proposed. The Authority will be more cautious and risk averse where the following risk characteristics apply (ERMA 1998a):

- (1) exposure to the risk is involuntary;
- (2) the risk will persist over time;
- (3) the risk is subject to uncontrollable spread and is likely to extend its effects beyond the immediate location of incidence;
- (4) the potential adverse effects are irreversible;
- (5) the risk is not known or understood by the general public and there is little experience or understanding of possible measures for managing the potential adverse effects.

All of these apply to classical biological control: agents are intended to spread and maintain persistent populations, and the process is generally regarded as irreversible. Furthermore, there is often a lack of public awareness of biological control, and ecological science is not currently able to make accurate predictions of adverse effects in ecosystems let alone manage them.

Public consultation and hearings

All applications for the release of a new organism in New Zealand will be publicly notified in major newspapers and on the ERMA website. Anyone in New Zealand is allowed to make a submission in writing to ERMA, and this must include details of decision sought, reasons, and whether a hearing is requested. The HSNO Act requires the authority to “arrange a public hearing for a notified application if the applicant or any submitter requests it, or if we (ERMA) consider it necessary” (ERMA 1998b). There is a possibility of a pre-hearing if ERMA deems it useful. A safeguard against possible unjustified, or even frivolous, demands for public hearings is provided by the following rule: “in certain cases when a submitter requests a hearing without exhausting all other avenues, they may be held liable for a part of the Authority’s costs” (ERMA 1998c).

Cost recovery and ERMA fees

Present New Zealand Government policy is to require cost recovery and thus ERMA charges substantial fees (although there is a partial government subsidy at present). Recent ERMA cost/time estimates are presented below (taken from ERMA 1999). The assessment and decision-making on an application to release a new organism into the New Zealand environment will take ERMA a total of 255 hours of staff/contractor time. With notification costs, the final cost to the applicant is NZ\$30,669 (approx. US\$16,800). Note that this includes a government subsidy of NZ\$6,300. Should a public hearing be required, then these charges will increase substantially. In the past, the costs of the regulatory process operated by MAF was borne by the New Zealand taxpayer. Although this cost was not separately itemized, it seems clear that the much simpler procedures in place then (see below) would not have required the same resources. With a process such as classical biological control, that can have potential benefits to a wide range of the New Zealand public, it can be argued that targeting applicants for full cost recovery is inappropriate.

Cost-benefit Information on Broom, and the Potential Release of the Chrysomelid *Gonioctena olivacea*.

Information was presented in an environmental impact assessment of broom in New Zealand (Syrett 1987) and also in the importation impact assessment for *G. olivacea* (Syrett *et al.* 1997). This existing information on broom and on the next agent for potential release is reviewed here, before we discuss the need for further information to satisfy the requirements of the HSNO Act.

The first environmental impact assessment for broom

The original environmental impact assessment for broom, used in the application to MAF for the release of *G. olivacea*, included the most recent data available on the distribution of broom from the New Zealand Land Resources Inventory (NZLRI)(NWASCO 1979) and from Bascand and Jowett (1981). As part of the development of the assessment, a summary of the intended biological control programme was sent out to 58 organizations and submissions received in reply from 45. Views were mixed as to the importance of broom as a weed (30 replies regarded broom as a weed, 15 were unsure and/or highlighted beneficial aspects of broom). Thirty-two replies supported the broom biological control programme (some even when broom was not a problem in their region) and only 8 submissions were clearly opposed to the programme. Conflicts of interest with the biological control of broom were also identified:

- (1) possible damage to ornamental brooms;
- (2) the value of broom pollen to beekeepers;
- (3) the role of broom in reducing soil erosion;
- (4) the potential of broom for forage;
- (5) the aesthetic value of broom.

Potential damage to tagasaste was recognized as a problem, but at that time agents that could not be shown by host-range testing to be no threat to tagasaste were being rejected by researchers, so the value or otherwise of tagasaste was not discussed in the assessment.

The assessment included a discussion of the overall success rates of classical biological control against weeds, and discussed the evidence from the work of Waloff and co-workers that prospects for impact of agents against broom were good (Waloff 1968, Waloff and Richards 1977). There was a simple economic analysis of the costs of broom to farmers (based on the subsidy paid for herbicides for broom control) and the likely benefit should biological control succeed (based on the increased carrying capacity of stock). Costs to forestry were assumed to be about 20% of those for gorse (from a survey by Sandrey 1985). It was noted that environmental losses caused by broom could not be quantified. No economic value was placed on the potential of broom as a forage plant or on the uses of ornamental brooms. It was argued that potential losses to beekeepers, or the reduction in the value of broom used for erosion control, were insignificant or could be prevented by the use of alternative plants. As with environmental damage caused by broom, any perceived environmental benefits, e.g., enhancement of succession of native scrub, are impossible to quantify. The overall cost-benefit analysis produced an annual cost of broom to New Zealand of about NZ\$2.8m/yr versus the cost of the complete biological control programme estimated as NZ\$1.7m (1987 figures).

Importation impact assessment for the proposed release of *Gonioctena olivacea*

As part of the application for permission to release *Gonioctena olivacea* in New Zealand an importation impact assessment was prepared. This referred to the environmental impact assessment for broom (Syrett 1987) for an environmental and economic analysis of broom in New Zealand, but also addressed the issues of potential impact on tagasaste and tree lupin as non-target plants which were not covered in the original assessment. No economic data was available for tagasaste in New Zealand, and thus the cost of possible damage to this plant could not be compared against the costs of broom to New Zealand. The application to release *G. olivacea* was declined by MAF on the basis that the economic cost-benefit analysis for the biological control of broom was insufficient, and the risk to non-target plants, particularly tagasaste, had not been adequately assessed. Work to fill these data gaps for a new application for release of *G. olivacea* has started and results/problems to date are summarized below.

Recent economic analysis of the impact of broom in New Zealand

The following summary has been taken from a draft report (Jarvis 1999) of the economic analysis of broom and tagasaste in New Zealand.

Available data on the distribution of broom in New Zealand are all over 20 years out of date. Broom as a weed is still spreading, so this data will be conservative. However, different sources of data did reveal reasonably consistent estimates of the land area of New Zealand affected by broom (Table 1) (Jarvis 1999). The MAF survey (Bascand and Jowett 1981) also indicated that broom was ranked as the 4th most serious weed (behind barley grass, gorse, and nodding thistle) to farmers in the South Island where broom is a much more serious problem.

Table 1.
Estimates of the area infested by broom in New Zealand (Jarvis 1999, using data extracted from the references in the table).

Source of analysis	Resulting statistic
Blaschke <i>et al.</i> (1981)	38,300 ha dominated by broom
Jarvis 1999	54,000 ha with broom cover >10%
Bascand and Jowett (1982)	61,000 ha of South Island farmable land affected by broom

Individuals in the main sectors of New Zealand affected by broom (forestry companies, farming sector, beekeepers, Department of Conservation (DoC), Transpower, local authorities) were consulted to determine the nature and extent of the costs and benefits (Jarvis 1999). For farmers, resources were not sufficient for a survey, so historical data on distribution (see above) and control-cost data have been used. Summarized costs and benefits are shown in Table 2 (from Jarvis 1999).

The above analysis is for all of New Zealand, but this masks the disparity in the scale of the broom problem between the South Island and North Island. One of the estimates of

farming productivity increases can be divided between the two islands, with the gains in the South Island from broom control being over 10 times greater (7.66 NZ\$/year compared with 0.67 NZ\$/year) (Table 2). Thus it is not surprising that responses to the application to release *G. olivacea* varied so greatly, and that it was 3 North Island regional councils that objected to the proposed release. The issue of the potential value of tagasaste is also more significant for the North Island (see below).

The figure of NZ\$m 4.33-12.13 per year represents the net gain to New Zealand if broom is controlled completely by biological means. The figure does not consider either the costs of the biological control programme (either for a single agent, or in total), or

Table 2.
Provisional costs (a) and benefits (b) for broom in New Zealand,
and notes on the methods used to assess them.

The totals from (a) and (b) can be subtracted to give the balanced benefit (c) to New Zealand of broom being successfully controlled biologically (i.e. not requiring any further control costs and not causing any significant losses.) Note that the net benefit (c) assumes broom ceases to be a weed completely, and does not consider the costs of the biological control programme itself. Further details in text.

(a) Sector and type of cost/loss	Methods used to estimate cost or benefit	NZ\$/year (figures adjusted to 1999 value)
Farming - control costs	Data from last year of government subsidy	1.61
Farming - increased productivity (two methods presented)	NZLRI and increased carrying capacity for stock (less other development)	8.33 (used as upper bound figure). Divides as South Island (7.66) and North Island (0.67). costs for the land).
	Differences in land values with/without broom (annualized)	0.56 (used as lower bound figure)
Councils – control costs	Telephone survey	0.56
Forestry - saved control costs	Telephone survey	1.31
Forestry - increased production in dry areas	Land area in dry zone plus model increase in rotation of 2 years	0.62
DOC – cost of control	Survey	0.53
Land Information New Zealand (LINZ) – managing broom on Unoccupied Crown Lands	Discussions with LINZ	0.4
Transpower - control costs to maintain access to lines	Discussions with Transpower	0.03
Transit NZ - roadside control costs	Discussions with Transit NZ	0.2
Threats to indigenous biota from broom	Information from DOC	Non-quantifiable but some substantial threats
Total costs of broom (potential gain from biological control) 5.8 – 13.6		5.8 – 13.6

(b) Sector and type of value	Methods used to estimate cost or benefit	NZ\$m/year (figures adjusted to 1999 value)
Beekeeper – value of pollen	Sandrey (1985) data for gorse reduced to 40% (relative importance of broom v. gorse in Sandrey survey)	0.87 (for a 50% reduction in broom flowers: only costs of providing pollen alternatives considered)
Broom use as forage on farms or for soil conservation		Negligible?
Damage to tagasaste (loss in its potential use for fodder)	Costs of pesticide needed to control <i>G. olivacea</i>	0.45
Damage to tagasaste (loss in its use for soil conservation)	Cost of using more expensive, alternative plant species	0.15
Aesthetic value of broom or tagasaste		Non-quantifiable
Total losses of benefit from broom and tagasaste		1.47
(c) Balance of benefit of complete suppression of broom as a weed in New Zealand		4.33 –12.13 NZ\$m/year (figures adjusted to 1999 value)

whether the biological control programme might achieve only partial suppression of broom. Annualized costs of the biological control programme against broom have not been calculated, but will be very small compared with this net gain.

For the current discussion, the net gain needs to refer only to the extent of broom suppression that the addition of one agent, *G. olivacea*, will achieve. This is extremely difficult to predict with any reliability or accuracy, and is an especially difficult issue with biological control agents that have never been used before in any part of the world, such as *G. olivacea*. All we can say currently is that there are natural “outbreaks” of the beetle in the UK that cause very substantial damage to localized broom stands (appearing to massively reduce growth and seed production for at least 1-2 years, or until the population of beetles declines) (Syrett *et al.* 1997, Fowler unpublished observations). Adult beetles and larvae attack both the leaves and, more importantly, the green stems of broom. The beetles are good dispersers, and colonize new broom patches in the UK within a few years, and sometimes much sooner. In the UK, we have observed a solitary, 1-year-old broom plant, attacked by larvae of *Gonioctena olivacea* (presumably from eggs laid by one dispersing female beetle). Virtually all above-ground plant parts were consumed, killing the plant. However, the beetle has only one generation per year, so populations take a few years to increase. Natural enemies in the native range may be significant in comparison to the predation and parasitism the beetle may suffer from after release in New Zealand. There are other potentially critical aspects of the life cycle of the beetle that we know little about, such as the overwintering requirements of the adult beetles. Doing ecological studies and impact experiments with one agent would be prohibitively expensive and time-consuming, but we are now planning a multi-year, field host-specificity trial in

southern France that may provide some further information.

Perhaps the only viable approach is to present several scenarios, e.g., 10%, 50%, or 90% control. There are cases worldwide where single agents (chrysolids even) have exerted high levels of control, but also instances where they have failed to establish or had little or no impact. The scenario chosen for the likely level or levels of eventual broom suppression exerted by *G. olivacea* has a major bearing on the discussion of likely damage to tagasaste, particularly if there is evidence that the damage to tagasaste will be similar to that to broom.

Risk Assessment for Non-Target Plants

A number of plant species in the tribe Genistae are at risk from several of the potential biological control agents for broom. Ornamental varieties of broom and the various hybrids and varieties are not usually a concern, because it is common practice in the nursery industry to apply chemicals to control plant pests, and these pesticides should readily eliminate the proposed biological control agents for broom. Consequently, the two major non-target plants at risk are tagasaste (tree lucerne), *Chamaecytisus palmensis*, and tree lupin, *Lupinus arboreus*. Tree lupin has been used by the forestry industry to stabilize sand dunes and fix nitrogen, assisting with the early establishment of commercial conifer plantations. However, the usefulness of tree lupin has declined markedly after a disease appeared in New Zealand. In this paper we consider only the role and value of tagasaste in New Zealand.

Perceptions of tagasaste vary widely between various interest groups and also geographically across New Zealand. As part of the follow-up to the declined application to MAF for the release of *G. olivacea*, a visit was made to the three regional councils in the North Island who had objected to the release, and also to AgResearch where research into the potential use of tagasaste as a dry-region fodder plant is being carried out. Other information has been taken from Department of Conservation publications, surveys of beekeepers, forestry companies, and other regional councils. All the available information on the perceived value or otherwise of tagasaste has been summarized into an overall environmental balance sheet for tagasaste in New Zealand (Table 3). Unfortunately it is difficult to assess the relative importance of the factors listed in Table 3, and availability of information has been a problem. Some of these risks are impossible to quantify (e.g., benefit to establishment of native bush, provision of a winter food source for native birds).

Table 3.
An environmental balance sheet for tagasaste in New Zealand.

Benefit/potential benefit of tagasaste to New Zealand	Negative/potential negative effects of tagasaste to New Zealand
Stabilizing eroded slopes/soil conservation.	Naturalized in some areas; not currently a pest but could have potential.
Encouraging more rapid return of native bush, and reducing fire risk (e.g., of areas dominated by bracken).	
Providing a food source for native birds in winter when other sources are scarce.	
Riparian plantings.	
Potential use as a dry region fodder crop.	
Value to beekeepers.	

The assessment of some other risks requires the prediction of future value or loss (e.g., potential use as a fodder plant especially if new varieties prove useful, or potential to be an environmental weed in the future). Nevertheless an attempt is being made to put figures on these potential losses wherever possible, using the same scenarios that will be used for predicting a reduction of the broom problem as a result of the introduction of *G. olivacea* (i.e., 10%, 50%, or 90% loss of the value of tagasaste).

Conclusion

The broom biological control programme has made slow progress in New Zealand because of real or perceived risk of attack by many otherwise promising agents on several non-target plants in the same tribe as broom. This is unfortunate, because the extensive ecological studies and more recent modeling suggest that the prospects for achieving control of broom through classical biological control are good, provided that enough natural enemies can be introduced. We are confident that native New Zealand plants, none of which are closely related to broom, are not at risk from any of the current biological control agents being considered in the programme. The recent discovery of the broom seed beetle unexpectedly attacking the seed of tagasaste was not predicted by the host-range testing, which could be construed as casting doubt on the testing procedures. However, we believe that this is an anomalous case where very unusual circumstances led to the wrong conclusions being made from the host-range testing. The decision by MAF in 1998 to decline the application to release *G. olivacea* in New Zealand, has necessitated a re-examination of the cost-benefit data for biological control of broom in New Zealand, and a more detailed investigation of the actual and potential value of the closely related alien plant, tagasaste. The HSNO Act, which came into effect for the release of new organisms into New Zealand in July 1998, reflects the concern that the country needs to be protected from the negative effects of new introductions of alien species. Hence, the HSNO Act requires a much more rigorous risk analysis for the potential introduction of biological control agents. The new procedures have provided a useful framework for considering the risks involved in the recent application to release one agent, the mist flower gall fly (*Procecidochares alani* Steyskal), for the biological control of mist flower (*Ageratina riparia* (Regel) R. King and H. Robinson) in New Zealand. However, these procedures comes at a cost, both for the increased time needed to do the risk analysis and the pre-application consultation, and through the high ERMA fees. The applicant also faces the costs from increased consultation with ERMA and other parties, and potentially substantial extra costs should a public hearing be deemed necessary (preparation, travel, costs of legal assistance and provision of expert witnesses where necessary). The scale of these new ERMA procedures and charges could severely curtail biological control activities in New Zealand.

The next applications for broom biological control agents are being delayed because of the need for more detailed economic information on the cost of broom in New Zealand and the value of tagasaste, a more detailed risk assessment for each proposed agent, and an assessment of the likely contribution of each proposed agent to the biological control of broom. Major difficulties exist with trying to predict the impact of an individual biological control agent so that the cost-benefit analysis can be completed for a single introduction. This will be especially difficult when the biological control agent has never been used before in another country. These new requirements may stifle innovation in biological control. There are also many aspects of the costs or benefits associated with the target

weed, and non-target plants at risk, that are difficult or impossible to quantify. Some of these costs or benefits are environmental and hence hard to attach figures to, others require a prediction of, for example, the future application of current research on tagasaste as a fodder source. Getting permission to release biological control agents against broom that have a risk of attacking other closely related plant species, such as tagasaste, will certainly be much more expensive than previously, and may be more difficult if the detailed risk analysis or predictions of impact are hard to achieve. This affects not only the potential use of *Gonioctena olivacea* against broom in New Zealand, but also a set of other potential agents for which host-range testing is almost complete.

Many of the next group of potential agents for biological control of broom may pose a real threat to tagasaste in New Zealand, but some may not if factors such as their preferred climatic range mean they cannot form self-sustaining and damaging populations on tagasaste (which generally occupies warmer and drier regions than broom). Demonstrating this in laboratory tests may be impossible, and field tests in Europe will be difficult and expensive. Of course, if some of these agents are eventually released in New Zealand, this will provide important data to allow other countries to decide whether to allow a release (for example, *G. olivacea* in Australia where tagasaste is considered highly valuable in warm, dry rangeland in Western Australia).

The use of gall-forming herbivores from the native range of broom as potential biological control agents is being considered. These are more likely to be sufficiently host specific to allow us to demonstrate low risks to key non-target plant species. However, the gall-formers are relatively poorly studied and we have almost no information on their likely impact. Without good evidence for the potential benefit of introducing a biological control agent, even a low perceived risk of negative effects may be sufficient to prevent that introduction being approved. Overall, the prospects for classical biological control of broom succeeding in New Zealand look good in terms of the agents available, but because of difficulties in practice the overall chances of success are much more uncertain.

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