# Redistribution of the gorse soft shoot moth, *Agonopterix umbellana* (Fabricius), for the biological control of gorse in Australia

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**Summary** The gorse soft shoot moth, *Agonopterix umbellana*, was released at Lake Tiberias near Jericho, Tasmania, in 2007 for the biological control of gorse. By December 2011, the presence of high larval densities enabled the site to be used as a nursery to collect and redistribute the agent. In Tasmania, the only suitable collection times for *A. umbellana* are in early summer (December) when 4–6th instar larvae are active and in February and March when adults are active. Two collection techniques were used, the first involved the harvesting of new gorse growth infested with larvae and a second used a bee smoker to flush sheltering, newly emerged adults from within gorse bushes into a collection tent. These two techniques maximised the limited collection opportunities imposed by the univoltine life cycle of *A. umbellana*. Preliminary surveys indicated that establishment was achievable from open releases of either 200 adults or 500 larvae during summer. However, the collection of larvae was far less labour intensive and easiest for redistribution programmes involving landholders and Landcare groups. Four agents, including *A. umbellana*, have now been released for the biological control of gorse in Australia and none are, by themselves, lethal to mature gorse plants. No additional agents are currently available. Further research will be required to determine the combined effect that the available guild of agents have on annual seed production, whether they have sub-lethal effects on plant age and whether they increase the susceptibility of gorse to fungal attack. Formulating an appropriate integrated management strategy using these agents will also require additional research.

**Keywords** Redistribution, biological control, *Agonopterix umbellana*, gorse.

## INTRODUCTION

Gorse, *Ulex europaeus* L., is a Weed of National Significance and one of the most invasive weeds in south-eastern Australia. The annual cost of gorse management to Australian agricultural and forest industries in 2000 was estimated at $7 million (Anon. 2006). The difficulty and expense in controlling gorse by conventional means has resulted in biological control options being investigated. Four agents, originally of European origin, have now been released in Australia. These are the gorse seed weevil, *Exapion ulicis* (Forster) released in 1939, the gorse spider mite, *Tetranychus lintearius* Dufour released in 1998, the gorse thrips, *Sericothrips staphylinus* Haliday released in 2001 and the gorse soft shoot moth, *Agonopterix umbellana* (Fabricius), released in 2007 (Ireson *et al.* 2013). The gorse seed weevil and the gorse spider mite have become widely established across south-eastern Australia and the gorse thrips is now widely established in Tasmania and starting to spread in Victoria and South Australia following a succession of redistribution programmes (Ireson and Davies 2012). Recoveries of *A. umbellana* in Tasmania as well as in Victoria and South Australia suggest that the species will also become widely established (Ireson *et al.* 2013). In Tasmania, *A. umbellana* has become well established at its first release site in the midlands on the western edge of Lake Tiberias near Jericho, where high larval densities have been recorded since December 2011 (Ireson *et al.* 2013). The Lake Tiberias site can now be used to collect and redistribute this agent, thereby accelerating its establishment across south eastern Australia. Studies that were conducted at Lake Tiberias between October 2011 and February 2013 showed that the life cycle was univoltine (Ireson *et al.* 2013). Larvae first commenced hatching in October and mature (6th instar) larvae were present by December. Adults emerged in high densities by the beginning of February but did not commence egg laying until late winter (Ireson *et al.* 2013). It was therefore evident that the best options to redistribute *A. umbellana* were to collect and re-release larvae that were approaching maturity and let them complete their pupation and overwinter as diapausing adults, or collect and redistribute newly emerged diapausing adults.

The earliest field releases that had resulted in the field establishment of *A. umbellana* in Tasmania consisted of caged releases of either 200 larvae or *c.* 100 adults (Ireson *et al.* 2013). As cages would not be available to supply a large scale redistribution programme, more information was needed on the number of larvae or adults that could result in field

establishment from open releases and the best way to collect them from field nursery sites.

This paper details the methodology that can be used for the collection and redistribution of *A. umbellana* and the results of preliminary establishment assessments following releases conducted during the summer/early autumn of 2012/13. Factors affecting establishment, release strategies and the potential impact of *A. umbellana* in combination with the three other agents released for the biological control of gorse in Australia are discussed.

## MATERIALS AND METHODS

Larvae approaching maturity are easily seen and collected because they form webbed shelters near the branch tips of new gorse growth. During summer 2012/13 at Lake Tiberias (42.41331 S, 147.3496 E), high larval densities resulted in nearly all the new growth on the bushes around the central release point being infested and there were often several larvae on each branch. This enabled *c*. 500 larvae to be collected by one person in about 15 minutes. Branches containing undisturbed larvae were removed from gorse bushes using a pair of secateurs. To reduce larval activity, infested branches were placed in large insulated plastic containers ('Eskies') containing freezer blocks and transported to the new release site within two days of collection. Larval collections/releases were conducted between 12 December 2012 and 2 January 2013 and *c.* 500 larvae released/site.

The collection of adults was far more labour intensive. A self-supporting mosquito tent not impregnated with insecticide. (2.1 × 1.5 × 1.0 m) (length × width × height) was placed over gorse bushes. The tent was purchased through Australian Entomological Supplies (2012). Adults were noticeably active at the time of first emergence in February and March, with activity declining with the onset of cooler weather later in autumn. They were easily flushed out from their shelter within and beneath the bushes and into the tent using a bee smoker. This collection technique required two people, one to hold the tent in place and the other to operate the bee smoker. As the tent was light it could be re-positioned over a different bush or groups of smaller bushes depending on adult densities. At Lake Tiberias, flushing of adults into the tent usually continued until *c.* 200 had been collected. The tent was then placed on flat ground and entered by up to two people through a zipped opening in the side. Moths were then collected manually from the sides of the tent in ventilated tubes (11 × 4.2 cm) (height × diameter). Usually, between two and six moths could be collected in each tube. Once collected from the tent, the moths in each tube were counted and placed into clear ventilated plastic containers (29 × 20 × 18 cm ) (length × width × height) through a stoppered circular hole cut into the lid. Two hundred moths were placed in each container and kept cool in an 'Eskie' with freezer blocks until release within two days of collection. At Lake Tiberias, during February and March 2013, 800 adults were collected in about one hour. Adult collection/releases were conducted between 15 February and 27 March 2013 and 200 adults released/site

From 10–18 December 2013, eight larval release sites and 14 adult release sites were assessed for the presence of larvae by conducting 10 minute searches of the release points.

## RESULTS

Larval activity was noted at five (62%) of the larval release sites and at 10 (71%) of the sites where adults were released. The number of larvae observed during the 10 minute searches at each site ranged between two to nine at the larval release sites and between two and six at the adult release sites. This was indicative that population densities at all sites were low, as would be expected close to the completion of only one field generation.

## DISCUSSION

The early summer collection of late instar larvae is easy and can readily be utilised by landowners and Landcare groups for any *A. umbellana* redistribution programme. However, as the opportunity to collect sufficient numbers of mature larvae is limited to a period of *c.* four weeks in Tasmania, the additional collection of adults using a bee smoker and tent trap is a method that could be employed to extend the collection period.

The preliminary survey results indicate that establishment is achievable through either the open release of 500 larvae/site or 200 adults/site. However, as the population densities were still low, it is too early to be certain whether the numbers of adults or larvae arbitrarily chosen for release will result in permanent field establishment. Furthermore, although larvae were recovered from 67% and 71% of larval and adult releases respectively, it is still possible that sites where no larvae were recovered may have a surviving population that could establish permanently, as surviving larvae may not have been observed during assessments, because of the low population density. It is also possible that, because of low population density, populations may not survive at the sites where larvae were recovered. As *A. umbellana* is univoltine (Ireson *et al.* 2013) at least two to three field generations will be required to determine whether permanent field establishment has occurred from these releases and this could vary between sites depending on the conditions

prevailing during the years after release. Densities high enough to harvest for redistribution did not occur at Jericho until five years after release and, in New Zealand, *A. umbellana* field populations were difficult to locate until the presence of high density populations were located 15 years after release (Hill *et al.* 2008). A number of factors can affect the field establishment and population density of a biological control agent. These can vary from site to site and include the prevailing weather conditions at the time of release, climate, the presence of parasites and predators, host plant quality and release strategy which also involves choosing a suitable number of the agents for release (Day *et al.* 2004, Spafford *et al.* 2008).

Increasing the success of establishment at individual sites may be achievable by increasing the number of larvae or adults released per site. It would be easy to increase the number of larvae released per site when they are present in high densities at the nursery site, as the larvae are so easy to collect. However, as the collection of adults is more labour intensive, an open release of 100 to 200 adults per site would be considered optimal if it results in field establishment. In New Zealand, open releases of 100 adults or larvae ranging from 500–1000 per site have resulted in field establishment (H. Gourlay pers. comm. 2012).

Determination of the optimal number for field release of any agent is best determined by trialing different sized releases at the start of a release programme thereby determining the minimum number of an agent required for establishment (Shea and Possingham 2000). Agent establishment has been shown to be an increasing function of release size (Memmott *et al*. 1998, Grevstad 1999, Ireson *et al.* 2008). However, a point may be reached beyond which an increase in the release size does not increase the chance of establishment (Ireson *et al.* 2008). Determination of the minimum number of an agent required to achieve establishment may increase the effectiveness of a release strategy by enabling releases at more sites. A large number of small releases as opposed to a small number of large releases is perhaps the best strategy to maximize geographical coverage and counter the possible loss of some release sites (Ireson *et al.* 2008). This is an important consideration with an agent such as *A.umbellana* whose establishing populations are initially slow to increase and disperse (Ireson *et al.* 2013), even though there is evidence that larger releases of an agent can initially increase population growth rates (Day *et al.* 2004, Ireson *et al.* 2008).

European investigations have shown that there are no additional invertebrate species that are considered suitable as biological control agents for gorse (Sheppard and Thomann 2005) and there are no suitable fungal pathogens available (Jourdan 2009). A submission to obtain permission for the release of a fifth agent, the gorse pod moth, *Cydia succedana* (Denis & Schiffermüller), was rejected by quarantine authorities due to concerns about its host specificity (Department of Agriculture 2104). The individual impacts of *A. umbellana*, *E. ulicis*, *T. lintearius* and *S. staphylinus*, which are the full complement of agents currently available for the biological control of gorse in Australia, are not known to be lethal to mature plants. However, accelerating the dispersal of *A. umbellana* across south eastern Australia should be considered the next priority. The combined impact of this guild of agents, whether it be sub-lethal effects on plant age, increasing susceptibility to fungal attack, or their possible use as part of an integrated management programme can then be determined (Hill *et al*. 2008, Ireson *et al.* 2013).

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