AN OVERVIEW OF THE ESTABLISHMENT, DISTRIBUTION AND EFFICACY OF BIOLOGICAL CONTROL AGENTS FOR RAGWORT, *SENECIO JACOBAEA* L., IN TASMANIA

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Summary Ragwort, *Senecio jacobaea*, is a serious pasture weed in Tasmania. Biological control is now providing a solution to the problem. The ragwort flea beetle, *Longitarsus flavicornis*, was first released in Tasmania in 1979 and has reduced ragwort density by up to 95% at many sites. The spread of *L. flavicornis* has been accelerated by collecting nearly 2 million adults from the field and transferring them to 879 new sites. About 88% of these collections have been carried out in summer since 1993. *L. flavicornis* is now common throughout southern Tasmania and was estimated to have spread over at least 90% of the major infestations in the north by February 1999. *L. flavicornis* has been an effective control agent in many localities, however, its efficacy has been restricted in some pastures. Mortality resulting from the use of herbicides and pugging of wet ground by cattle, particularly in heavily stocked pastures, could be key factors. Additional biological agents have also been released. A second species of flea beetle, an Italian biotype of *Longitarsus jacobaeae*, was released in 1988. Its current distribution is unknown but it has been recovered from only 5 sites and is not believed to be widespread. Releases of the cinnabar moth, *Tyria jacobaeae*, have been carried out annually in spring since the introduction of this species from New Zealand in 1993. However, there is still no evidence that it is permanently established, possibly due to the effects of predation. In localities where the impact of *L. flavicornis* has been restricted, two other species, the introduced ragwort stem and crown boring moth, *Cochylis atricapitana*, and a native moth, the blue stem borer, *Patagoniodes farinaria*, could be useful complementary agents. *C. atricapitana* has now been permanently established at sites in Tasmania from releases that commenced in 1995. *P. farinaria* is common on ragwort in parts of northern Tasmania and its life cycle and feeding habits are similar to those of *C. atricapitana*. We expect that the integration of biological agents with traditional control measures that enable agent survival will ultimately provide cost effective control of ragwort throughout Tasmania.

INTRODUCTION

In Tasmania, ragwort is a serious weed of pastures in high rainfall areas (>800 mm per year). Annual production losses to the dairy and beef industries have been estimated at *ca*. $3 million in some years. The first attempt at biological control of ragwort in Tasmania began in 1963 with the release of a consignment of the ragwort seed fly *Botanophila jacobaeae* (Hardy) (previously referred to as *Pegohylemia seneciella* Meade) which failed to establish (Ireson and Terauds 1982). A French biotype of the ragwort flea beetle, *Longitarsus flavicornis* (Stephens), was introduced to Tasmania in 1979 (Cullen and Moore 1981). Multiple releases of glasshouse reared adults and a redistribution programme has resulted in its widespread establishment (Ireson and Terauds 1982; Ireson *et al*. 1999). Some of the Spanish biotypes of *L. flavicornis* that were introduced to Australia between December 1984 and January 1986 (Field 1989) became established in Tasmania from releases that commenced in 1986. A second species of flea beetle, an Italian biotype of *Longitarsus jacobaeae* (Waterhouse), which was imported to Australia via Oregon (USA) and New Zealand (Julien and Griffiths 1998), was first released in Tasmania in 1988 and also successfully established.

Two additional agents of European origin, the cinnabar moth, *Tyria jacobaea* (L.), and the ragwort stem and crown boring moth, *Cochylis atricapitana* (Stephens), are also now being investigated in Tasmania as possible complementary agents to the *Longitarsus* spp. Several previous attempts to establish *T. jacobaeae* in Victoria carried out between 1930 and 1982 were unsuccessful (Bornemissza 1966; Field 1989). Attempts to establish *T. jacobaeae* in Tasmania commenced in 1993 with the introduction of rearing stock from New Zealand where it has been established since its release in 1929 (Miller 1929).

A Spanish biotype of *C. atricapitana* (Stephens) was first released in Victoria in 1987 (McLaren 1992) and introduced to Tasmania in 1994. Studies have also been

carried out on a native species of pyralid moth, the blue stem borer, *Patagoniodes farinaria* (Turner), whose larvae attack ragwort (Ireson and McQuillan 1984; McQuillan and Ireson 1987).

The aim of this paper is to summarise the outcomes achieved in Tasmania from work carried out on the biological control of ragwort since the introduction of *L. flavicornis* in 1979.

STUDIES ON THE RAGWORT FLEA BEETLES, *LONGITARSUS* SPP.

***L. flavicornis* (French biotype)** Studies on the biology and efficacy of *L. flavicornis* were carried out at two established sites (Lachlan in the south and Mayberry in the north) from 1985-1989 (Ireson *et al.* 1991). *L. flavicornis* was released at both sites in 1979 and by May 1989 (*ca*. 9 years after its release) had reduced ragwort densities by *ca.* 90%.

High densities of *L. flavicornis*, and corresponding reductions in ragwort densities, have occurred over the same time scale recorded by Ireson *et al.* (1991) in all the major ragwort infested regions of the state (Ireson 1993; Ireson 1995). Population dispersal has been accelerated by a successful redistribution programme (Ireson *et al.* 1999). This has involved the field collection and transfer of around 2 million adults to 879 new sites, 80% of which were carried out during a six year period from 1993-1999. By February 1999, it was estimated that *L. flavicornis* had spread throughout all the ragwort infestations in southern Tasmania and about 90% of the major infestations in the north (Fig. 1) (Ireson *et al*. 1999).

On many dairy properties in northern Tasmania the impact of *L. flavicornis* has been restricted, probably by unfavourable site conditions and incompatible management practices. For instance it is suspected that the pugging of wet ground by cattle is causing high larval mortality at some sites (Ireson *et al*. 1999). The use of boom sprayed herbicides could also be a major factor restricting *L. flavicornis* population increases (Boersma 1996). Further studies are now being undertaken on factors affecting *L. flavicornis* densities in these areas. This should enable the production of a comprehensive integrated management plan for farmers. Many farmers are already being encouraged to improve their control programmes by utilising chemical and mechanical control methods and grazing strategies that promote the survival of *L. flavicornis*.

***L. flavicornis* (Spanish biotypes)** Biotypes of *L. flavicornis* collected from locations in Spain (Albares de la Ribera, Sancti Spiritus and Sarria) (Field 1989) were released at 8 sites in Tasmania between August 1986 and March 1989. Establishment was confirmed at 6 sites (two in the north and four in the south) (Ireson unpubl. data). The Spanish biotypes of *L. flavicornis* released in Tasmania behave similarly to the French biotype (Field 1989). It is therefore not possible to distinguish the field populations of the Spanish biotype now that the release sites have since been overlapped by the spread of the French biotype.

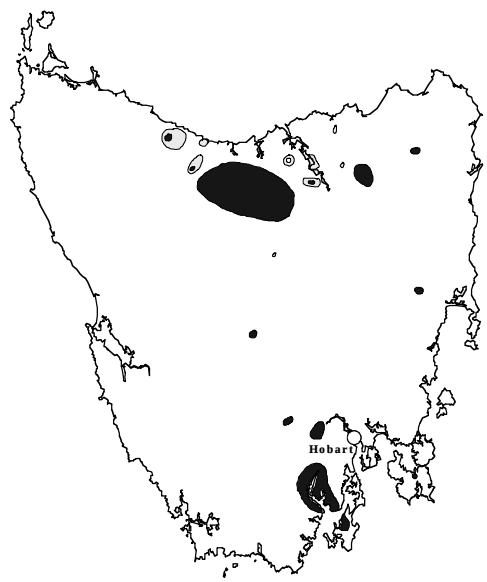

Figure 1. Estimated distribution (by autumn 1999) of the ragwort flea beetle, *Longitarsus flavicornis*, (dark grey), in relation to the main ragwort infestations in Tasmania. Ragwort infested areas where *L. flavicornis* has not yet established are indicated in light grey.

***L. jacobaeae* (Italian biotype)** Glasshouse reared adults of the Italian biotype of *L. jacobaeae* were released at 26 sites between October 1988 and July 1990. Surveys have indicated that it has survived at only 5 sites in northern Tasmania. Two of these sites are small, isolated infestations of *ca*. 1-2 ha. and at the other 3 sites its distribution has overlapped with *L. flavicornis*, which has spread from neighbouring release sites. A detailed study is therefore required to confirm the identity of *L. jacobaeae* at these 3 sites and accurately

determine its distribution and phenology. The species is pre-adapted to survive hot dry summers (Frick and Johnson 1973) and could be expected to perform better than *L. flavicornis* at some locations in Tasmania (Ireson *et al*. 1999). However, because *L. flavicornis* has generally performed well in Tasmania, it is unlikely that any further work with this species will be undertaken, at least in the short term.

INVESTIGATIONS ON OTHER BIOLOGICAL CONTROL AGENTS

Release and monitoring of the cinnabar moth, *T. jacobaeae* In January 1993, *ca*. 1600 larvae were imported from North Canterbury, New Zealand into quarantine at New Town Research Laboratories near Hobart. Progeny from this stock were used for the mass rearing and annual field release of *T. jacobaeae* that was carried out in Tasmania between November 1993 and December 1997. During this period over 250,000 larvae and over 2,000 adults were released at 36 sites. Adult releases ranged from 300-500 per site. The number of larvae released per site ranged from 1,000-42,500 (mean 8,000).

Monitoring of the 36 release sites during summer has indicated an annual decline in the size of field populations and the number of sites at which the agent has been recovered. By January 1999, surviving colonies were found at only 4 (44%) of the 1 year old sites and 1 (20%) of the 2 year old sites. No surviving colonies were found at sites 3-5 years old.

In Canada, Harris *et al*. (1971) reported that field establishment of *T. jacobaeae* followed a pattern of high mortality of laboratory reared stock during the first year after release, approximate maintenance of the larval population in the following 2 years and a 4 to 5 fold increase in the fourth and later years. In Oregon (USA) Isaccson (1973) found no significant increase in either density or spread at any release site until 5 years after release. A similarly lengthy build-up was also reported by Syrett *et al*. (1991) in New Zealand where establishment was recorded at 35% of the release sites. In Tasmania, it is evident from the consistent annual decline in the *T. jacobaeae* colonies that a similar pattern of establishment is not being followed. Furthermore, the average size of the larval populations released at the Tasmanian sites (8,000) was considerably higher than those used for releases in Canada, the USA or New Zealand where establishment has been achieved through releases of 1,000 larvae or less (Harris *et al*. 1975; Brown 1989; Syrett *et al*. 1991).

Previously unsuccessful attempts at establishing the species in Victoria between 1930 and 1982 (Bornemissza 1966; Schimidl 1972, 1981; Field 1989) were attributed to disease in imported stocks, field predation mainly by the scorpion fly, *Harpobittacus nigriceps* (Selys), and the importation of biotypes from Europe and Canada that were ill adapted to the ragwort infested areas of Victoria.

For the Tasmanian programme, the introduction of a New Zealand biotype has overcome the life cycle asynchrony and disease problems associated with the importation of northern hemisphere biotypes. However, it is possible that predation could be having a significant impact on establishing colonies of *T. jacobaeae*.

Dempster (1971) concluded that mortality of *T. jacobaeae* due to arthropod predation was low during the egg stage but was high amongst young larvae which became more immune to predation as they matured. A species of *Harpobittacus* was recorded in northern Tasmania at only 1 of the 36 Tasmanian release sites (Parkham: 41° 25´S, 146° 37´E). This species is therefore not considered to be the same threat to establishing populations in this State as was the case in Victoria, where Bornemissza (1966) noted *H. nigriceps* to be common in all ragwort infested areas. The predatory shield bug, *Cematulus nasalis* (Westwood), was observed attacking *T. jacobaeae* larvae but is unlikely to pose any significant threat as it too was only observed in low numbers at one site in southern Tasmania (Woodstock: 43° 05´S, 147° 02´E). However, other polyphagous arthropod predators are common in Tasmanian pastures (McQuillan and Ireson 1982) and were collected at the Tasmanian release sites during summer when *T. jacobaeae* larvae were active or eggs present (Ireson unpubl. data). Potential predators identified were species of carabid, staphylinid and cantharid beetles, mites, spiders, isopods (slaters), ants and the European earwig, *Forficula auricularia* L. These groups or species have been recorded as attacking either eggs, larvae and pupae of *T. jacobaeae* in overseas studies (Wilkinson 1965; Dempster 1971,1982; Harris *et al*. 1975; Isaacson 1973; van der Meijden 1979). It is therefore possible that common arthropod predators may be a key factor in preventing the establishment of *T. jacobaeae* in Tasmania.

Dempster (1971) observed that *T. jacobaeae* larvae were distasteful to vertebrate predators, which had no impact. Miller (1970) recorded 3 bird species attacking larvae in New Zealand. However, Bornemissza

(1966) failed to observe any insectivorous birds or lizards in Victoria and there was no evidence that any significant avian predation has occurred at the Tasmanian release sites.

At this stage it appears unlikely that *T. jacobaeae* will establish in Tasmania or may have a restricted distribution if it does. The waterlogging which reduces the survival of *L. flavicornis* larvae in some winter pastures would also be detrimental to the survival of overwintering pupae of *T. jacobaeae* which cannot tolerate wet soil (Dempster 1971).

Release, monitoring and establishment of *C. atricapitana* This species was originally imported from Salamanca, Spain and first released in Victoria in November 1987 (McLaren 1992). Adult *C. atricapitana* derived from this stock were imported from Victoria to Tasmania in October 1994 for mass rearing at New Town Research Laboratories. The first field releases from this culture commenced in September 1995 at Woodstock and by September 1998 the agent had been released at 27 sites.

Results of establishment assessments at these sites to February 1999 (Table 1) show that *C. atricapitana* has now successfully established at 4 (15%) of the sites, is surviving at 18 (67%) of the sites and has failed to establish at 9 sites. The maximum distance dispersed (200 m in 3 years) compares favourably with sites in Victoria where the maximum recorded dispersal in 3 years has been 100 m (McLaren 1992). These results suggest that the agent has the potential to spread rapidly in Tasmania.

Status of the blue stem borer, *Patagoniodes farinaria*, as a biological control agent for ragwort *P. farinaria* is believed to be endemic to Australia and New Zealand (McQuillan and Ireson 1987). In Tasmania, favoured native food plants are subspecies of *Senecio lautus* which have biological similarities to ragwort (McQuillan and Ireson 1987). Studies on the biology and taxonomy of *P. farinaria* were conducted in Tasmania because of the ability of *P. farinaria* to exploit ragwort as a larval food plant (Ireson and McQuillan 1984; McQuillan and Ireson 1987).

P. farinaria is common and widely distributed in the larger ragwort infestations in the pastures of northern Tasmania that are grazed mainly by dairy cattle (Ireson and McQuillan 1984). Although the larvae often cause severe damage to individual ragwort plants, the insect by itself appears to have limited potential as a control agent (Cottier 1931; Bornemissza 1966; Ireson and McQuillan 1984). High levels of parasitism have been recorded in field populations and this may be restricting its efficacy at some sites (Ireson and McQuillan 1984).

The larval feeding habits of this species are confined mainly to aboveground tissues and are similar to those of *C. atricapitana*. However, until *C. atricapitana* becomes more widely established and its densities start to increase it will not be known how the two species will interact. Preliminary surveys at *C. atricapitana* release sites in Tasmania (Ireson unpubl. data) and Victoria (McLaren pers. comm.), have found larvae of the two species feeding on the same plant, suggesting

Table 1. Results of assessments on the establishment and dispersal of *C. atricapitana* at Tasmanian release sites.

Period after release	6 months	1 year	2 years	3 years	Total
No. release sites assessed	4	13	6	4	27
Agent not recovered	0	7	2	0	9
Agent recovered from release site only	4	3	1	1	9
Agent at least 50m from release site		2	2		4
Agent at least 100m from release site		1	1		2
Agent at least 200m from release site				3	3
Sites where agent surviving*	4	6	4	4	18 (67%)
Sites where agent established**	0	0	1	3	4 (15%)

* Sites where *C. atricapitana* is surviving are those where it has been found within 100 m of the release site 6 months to 2 years after release. It also includes established sites.

** Established sites are those where *C. atricapitana* has survived for at least 2 years, is increasing its population and has spread at least 100 m from the release site.

that the two species are compatible. If this is so, the impact of these 2 species in combination with the root and crown feeding activities of *L. flavicornis* could be synergistic.

DISCUSSION

Successful biological control of ragwort has been achieved in western Oregon (USA) using the Italian biotype of *L. jacobaeae* in combination with *T. jacobaeae* and the ragwort seed fly, *Botanophila seneciella* (McEvoy *et. al.* 1991). Coombs *et al.* (1996) report that this has resulted in annual savings of $5 million from reductions in livestock losses, increased pasture production and reduced herbicide use. In Tasmania, control of ragwort with *L. flavicornis* has already been achieved at many sites. The number of controlled infestations should increase now that the species has become widespread and has been recorded in high densities in all the main ragwort infested areas of the state (Ireson *et al.* 1999). It is expected that the impact of *L. flavicornis* will be augmented by *C. atricapitana* or *P. farinaria*. These species will be particularly useful if they can survive well enough and place sufficient additional stress on ragwort to facilitate its control in areas where the impact of *L. flavicornis* is marginal. Other agents, such as the ragwort plume moth, *Platyptilia isodactyla* (Zeller), may also be available for future release, pending the outcome of host specificity tests (McLaren pers. comm.).

It is now possible that ragwort could cease to be a weed of major economic importance in Tasmania, perhaps during the next 10-15 years. This will, however, depend on the widespread adoption of management practices by Landholders that will complement the impact of the biological control agents, particularly on dairy farms.

ACKNOWLEDGMENTS

We thank Barry Rowe (Tasmanian Institute of Agricultural Research) and Margaret Williams (Department of Primary Industry, Water and Energy) for their comments on the manuscript. We are also grateful to Wal Ashby for technical assistance and the support. of the Meander Valley Weed Strategy. Funding support for the programme has been gratefully received from the Dairy Research and Development Corporation and the Natural Heritage Trust.

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