Progress Towards Biological Control of Ragwort in Australia

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Abstract
In Australia, biological control of ragwort, Senecio jacobaea, commenced in Victoria in 1930 with the release of the cinnabar moth, Tyria jacobaeae, and later, in the 1950s, a seed fly, Pegohylemyia jacobaeae. Neither of these insects established despite at least 16 seasons of release of the former up until 1982. In 1979 the first flea beetles, Longitarsus sp., were released in Victoria and Tasmania. The origins of the several hundred thousand beetles that have been laboratory reared and released include the original introduction of L. jacobaeae, from Annanay in France, (although specimens in Victoria and Tasmania were subsequently found to more closely resemble L. flavicornis) and seven colonies of L. flavicornis from Spain. The Annanay introduction constituted all releases up until 1985 with substantial establishment and control of ragwort over small areas occurring in both Victoria and Tasmania. Since 1986 the Spanish strain of L. flavicornis have been laboratory reared and released at 28 locations in Victoria with first generation establishment occurring at many sites. During 1987 in Victoria, releases began of L. jacobaeae which had been imported from Italy via the USA and New Zealand. Releases of the leaf and crown boring moth Cychlis ariacapitana also began in 1987 with over 80,000 eggs seeded directly into field infestations of ragwort and onto potted plants for distribution into the field. Since the commencement of flea beetle releases, and more recently the release of C. ariacapitana, the prospects of substantial control of ragwort in Australia have improved dramatically.

Introduction
Ragwort, Senecio jacobaea L. (Asteraceae), was introduced to Australia about 100 years ago and by 1907 was proclaimed as a noxious weed in Victoria (Ewart 1909). By the early 1900s ragwort had also become a serious pasture weed in many areas of Tasmania (Hyde-Wyatt and Morris 1980). Ragwort is now established in the high rainfall areas of Victoria, Tasmania and the south-west of Western Australia (Parsons 1973). It infests highly productive dairy land, sheep and beef farms and pine and eucalypt plantations, in southern Victoria. The plant contains liver damaging alkaloids and although ragwort is grazed by sheep, it is not readily eaten by cattle. Chemical control is expensive and difficult to undertake, particularly on steep terrain and, as a consequence, many farmers have resorted to sheep grazing where they would have otherwise grazed cattle.

Ragwort was one the first weeds in Australia, along with St. John’s wort Hypericum perforatum L. (Clusiaceae), to be addressed as a target for biological control. Projects on these weeds followed soon after the successful establishment of Cactoblastis cactorum (Berg) (Lepidoptera: Pyralidae) on prickly pear, Opuntia stricta (Haworth) (Cactaceae) in the 1920s. Regular attempts have been made to establish insects on ragwort in Victoria but it was not until the 1980s that some prospects for control became evident.

This paper reports on recent progress towards biological control of ragwort in Australia and summarises earlier attempts at control with the cinnabar moth, Tyria jacobaeae (L.) (Lepidoptera: Arctiidae) and the seed fly Pegohylemyia jacobaeae (Hardy) (Diptera: Anthomyiidae).

Releases of Cinnabar Moth, 1930-82
All releases of T. jacobaeae have occurred in Victoria, most in the Strzelecki Ranges of Gippsland. Details of the releases are given in Table 1.
<table>
<thead>
<tr>
<th>Year</th>
<th>Source</th>
<th>Number released</th>
<th>Site</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930-31</td>
<td>England via New Zealand</td>
<td>400 L, 200 E</td>
<td>Morwell Road, South Gippsland</td>
<td>Gone December 1931 (1)</td>
</tr>
<tr>
<td>1931-32</td>
<td>England via New Zealand</td>
<td>200 L</td>
<td>Morwell Road, South Gippsland</td>
<td>No trace following year (1)</td>
</tr>
<tr>
<td>1935-36</td>
<td>England via New Zealand</td>
<td>210 A, 200 L, 100 E</td>
<td>Mirboo North, South Gippsland</td>
<td>Gone following year (1)</td>
</tr>
<tr>
<td>1936-37</td>
<td>England</td>
<td>55A, 2100 L, 6000 E</td>
<td>Beech Forest</td>
<td>Predation from Harpobitacus; gone February 1937 (1)</td>
</tr>
<tr>
<td>1937-38</td>
<td>England</td>
<td>20 A, 5000 L, 1000 E</td>
<td>Toora, South Gippsland</td>
<td>Predation from Harpobitacus; gone January 1938 (1)</td>
</tr>
<tr>
<td>1955-56</td>
<td>Italy</td>
<td>184 A</td>
<td>Mirboo North</td>
<td>Died out in first season (2)</td>
</tr>
<tr>
<td></td>
<td>England</td>
<td>1372 A</td>
<td>South Gippsland</td>
<td>Survived until winter 1957 (2)</td>
</tr>
<tr>
<td>1956-57</td>
<td>England</td>
<td>2834 A</td>
<td>Mirboo North, South Gippsland</td>
<td>No survival in next season (2)</td>
</tr>
<tr>
<td>1957-58</td>
<td>England</td>
<td>1285 A</td>
<td>Mirboo North, South Gippsland</td>
<td>Some survival to next season (2)</td>
</tr>
<tr>
<td>1958-59</td>
<td>England</td>
<td>2691 A</td>
<td>Mirboo North, South Gippsland</td>
<td>Some survival to 1961-62 (2)</td>
</tr>
<tr>
<td>1960-61</td>
<td>England</td>
<td>&gt; 6000 A</td>
<td>Seven sites in southern Victoria</td>
<td>Disease caused heavy loss of larvae; three sites survived to the following year and two sites survived for 3 yrs (3)</td>
</tr>
<tr>
<td>1962-63</td>
<td>Mulhouse, Switzerland</td>
<td>not specified</td>
<td>Jumbuk, South Gippsland</td>
<td>Pupae harvested and released in 1963-64 (3)</td>
</tr>
</tbody>
</table>

Vienna, Austria
<table>
<thead>
<tr>
<th>Year</th>
<th>Source</th>
<th>Number released</th>
<th>Site</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963-64</td>
<td>Mulhouse and Basle, Switzerland</td>
<td>not specified</td>
<td>Five sites in South Gippsland</td>
<td>Colonies existed at all sites in 1965 but all had become extinct by 1968 (3)</td>
</tr>
<tr>
<td></td>
<td>Vienna, Austria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978-79</td>
<td>ex Switzerland &amp; Sweden via Nova Scotia, Canada</td>
<td>2500 L, few A</td>
<td>Several sites at Yarram</td>
<td>Emergence at one site only (4)</td>
</tr>
<tr>
<td>1979-80</td>
<td>As above</td>
<td>not specified</td>
<td>Yarram, Meeniyan</td>
<td>Field establishment at Meeniyan until 1983 (4)</td>
</tr>
<tr>
<td>1980-81</td>
<td>As above</td>
<td>&gt; 1000 P</td>
<td>Yarram, Meeniyan, Beech Forest</td>
<td>Some emergence at Meeniyan only</td>
</tr>
<tr>
<td>1981-82</td>
<td>As above</td>
<td>2334 L, 3045 L</td>
<td>Cape Schanck, Calligne South</td>
<td>No establishment</td>
</tr>
</tbody>
</table>

1 A = adults; E = eggs; L = larvae; P = pupae.
2 (1) = Currie and Fyfe (1938); (2) = Bomemia (1966); (3) = Schmidl (1972); (4) = Schmidl (1981).
The first releases of *T. jacobaeae* began in December 1930 following an introduction by the Council for Scientific and Industrial Research (CSIR) in 1929 from England via New Zealand (Currie and Fyfe 1938). Further introductions came from New Zealand prior to direct introductions from England in September 1933 which resulted in larger scale releases in 1936-37 and 1937-38 (Currie and Fyfe 1938). Disease prevented large numbers of *T. jacobaeae* being reared and of those released, none established for more than a year. This poor survival was attributed mainly to predation from a scorpion fly, *Harpobittacus* sp. (Mecoptera: Bittacidae).

*T. jacobaeae* was reintroduced by CSIRO from England and released over four consecutive summers from 1955-56. Although some colonies survived for three seasons, predation from *Harpobittacus nigriceps* (Selys) and disease eventually eliminated all colonies (Bornemissza 1966). The Victoria Department of Crown Lands and Survey (DCLS) introduced *T. jacobaeae* from England in 1959 and from Switzerland and Austria in 1961 and 1962 (Schmidl 1972). Those from England were severely affected by disease and died in the first season. Those from central Europe were mainly disease-free and colonised release sites for up to three seasons before disappearing, although apparently not due to predation from *H. nigriceps* (Schmidl 1972).

The most recent attempt to establish *T. jacobaeae* was made by the DCLS with the importation of three shipments of the insect from Nova Scotia, Canada (Schmidl 1981). Releases began in 1978-79 and continued each season until 1981-82. Although one colony persisted until 1983 at Venus Bay (Meeniyan) no other release sites established for more than one year. Environmental factors, rather than disease and predation, were considered to be the main reasons for non-persistence of the colony at Venus Bay but *H. nigriceps* was present at other release sites.

The failure of *T. jacobaeae* to establish in Victoria can be at least partially attributable to disease in imported stocks and predation in the field, mainly from the scorpion fly *H. nigriceps*. However there were some years where apparently healthy stock suffered little predation from *H. nigriceps* and yet failed to persist. More consideration to the selection of a biotype suited to the Victoria ragwort areas may have improved survival. Certainly the winter climates of central Europe, England and Nova Scotia are colder than the snow free ragwort areas of southern Australia. These strains may, however, have had a better chance of establishment in the colder areas of Tasmania but releases were not made in that State.

No further attempts to establish *T. jacobaeae* are currently being considered, however if other insects now under investigation fail to satisfactorily control ragwort, *T. jacobaeae* could be reconsidered, particularly for the colder ragwort areas in Tasmania where scorpion flies are not common. For these situations, importation of *T. jacobaeae* from New Zealand, where it is now well established in the North Island (Syrett 1983), would be suitable and would overcome life cycle asynchrony problems that exist with importations of this insect from the northern hemisphere.

**Releases of the Ragwort Seed Flies, Pegohylemyia species**

The seed flies *P. jacobaeae* and *P. seneciella* (Meade) were first introduced into Australia in the 1930s from New Zealand and England (Wilson 1960, Delfosse and Cullen 1982). Because of difficulties in rearing the flies, no releases from these introductions were made. Another introduction in 1958 (Bornemissza 1966), was of pupae of *P. jacobaeae* collected from the North Island of New Zealand. Releases from this importation have been referred to as *Hylemyia seneciella* (Hoy 1958, Schmidl 1981, Ireson and Terauds 1982) but Colless (1983) determined the voucher specimens in the Australian National Insect Collection to be *P. jacobaeae*. Releases were made in the Strzelecki Ranges of Victoria and Tasmania (Ireson and Terauds 1982). There has been no evidence of establishment of *P. jacobaeae* in either State.

The reintroduction of seed flies should be reconsidered for Australia's programme of biological control of ragwort as reproduction through seeding is the major concern facing farmers trying to stop the spread of the weed from forestry areas.
Releases of Flea Beetles, *Longitarsus* Species, 1979-88

*Longitarsus jacobaeae* Waterhouse (Coleoptera: Chrysomelidae) was introduced from Annonay in France to Australia in 1977 and released in Victoria and Tasmania in 1979 (Cullen and Moore 1981). However, specimens sent to New Zealand, from a site in Victoria (Calligee South) where the beetle had become well established, were identified as more closely resembling *Longitarsus flavicornis* Stephens (Sytrett P., pers. comm. 1985). The Annonay strain of this species appears to have no adult or egg aestivation. Adults emerge in southern Victoria in December and January and oviposition commences within 3 wks. During hot weather egg hatching occurs two weeks later. In Tasmania, Ireson and Terauds (1982) also reported adult emergence in December and January from releases that had made 8 to 13 months earlier.

In Victoria, between the summers of 1978-79 and 1984-85, over 47,000 adults and over 26,000 eggs were released at a total of 86 different sites (Table 2). The average number of adults released per site rose from 330 during 1978-79 to at least 1,000 for each of the last 17 releases. In Tasmania, between December 1979 and March 1981, 6 caged and 46 uncaged sites received releases of ovipositing adults. The numbers released at uncaged sites ranged from 100 to 750 (mean = 250) (Ireson and Terauds 1982).

<table>
<thead>
<tr>
<th>Year</th>
<th>Average number (range/site)</th>
<th>Number of sites</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-79</td>
<td>330 adults (239-500)</td>
<td>3</td>
<td>Establishment at one site</td>
</tr>
<tr>
<td></td>
<td>1000 eggs</td>
<td>2</td>
<td>Some recoveries for only 2 yrs</td>
</tr>
<tr>
<td>1980-81</td>
<td>488 adults (230-1000)</td>
<td>47</td>
<td>Major establishment at 10 sites</td>
</tr>
<tr>
<td></td>
<td>2844 eggs (2466-3240)</td>
<td>5</td>
<td>Some recoveries for only 2 yrs</td>
</tr>
<tr>
<td>1981-82</td>
<td>425 adults (100-500)</td>
<td>6</td>
<td>No recoveries the following year</td>
</tr>
<tr>
<td></td>
<td>1695 eggs (1155-2000)</td>
<td>6</td>
<td>No recoveries the following year</td>
</tr>
<tr>
<td>1983-84</td>
<td>1161 adults (1000-2000)</td>
<td>16</td>
<td>Establishment at 10 sites</td>
</tr>
<tr>
<td>1984-85</td>
<td>2000 adults</td>
<td>1</td>
<td>Adults recovered after 2 yrs</td>
</tr>
<tr>
<td></td>
<td>500 larvae</td>
<td>1</td>
<td>No recoveries</td>
</tr>
<tr>
<td>Total releases: 86 sites; 26,390 eggs; 500 larvae; 47,057 adults</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In both Victoria and Tasmania (Ireson, J.E., pers. comm. 1987) the beetles have become well established at a number of sites with, in some cases, a dramatic decline in the density of *S. jacobaeae* occurring. However, the rate of spread has been slow with the best sites in Victoria taking eight years for control of *S. jacobaeae* to occur over 5 ha. Establishment has not occurred in the warmer, drier coastal areas of Victoria where most release sites have been on cattle or sheep grazed properties. However, those sites inland near the top of the Strzelecki Ranges, which are in pine forests or on ungrazed pasture, have proved to be highly suitable for establishment of this biotype of this *Longitarsus* species.
Efforts to introduce other biological control agents continued with the CSIRO Division of Entomology being contracted by the DCLS (now Department of Conservation, Forests and Lands; DCFL) to collect and undertake host specificity tests on species found in southern France and in Spain.

Between December 1984 and January 1986 three shipments involving seven populations of *L. flavicornis* were received into quarantine (Table 3). Although populations from northern Spain (Sarria, Hospital de Orbigo and Albares de la Ribera) appear to have no adult or egg aetivation, populations from further south (Salamanca, Trujillo and Mérida) may exhibit delayed oviposition under long day lengths. Further studies are currently underway to determine the physiological responses of these populations under differing photoperiods and temperatures.

Releases of these Spanish populations of *L. flavicornis* began in late 1985 and with the advent of improved laboratory mass rearing technique using hydroponically grown *S. jacobaea*, over 70,000 adults were released in Victoria in three years (Table 4). Recoveries of adults have been made from many sites but permanent establishment will require verification over the next few years.

*L. jacobaeae* was also imported from New Zealand in April 1986 and was first released in Victoria in April 1987. This biotype had been imported into New Zealand from Oregon, USA (originally from Italy) (Syrrett 1983), and has a facultative adult aetivation period (Frick and Johnson 1973). Mass rearing of this species is now underway and flea beetle releases in Victoria over the next few years will concentrate on widely distributing this species in the drier coastal infestations of *S. jacobaea*.

Table 3. Introductions of *Longitarsus flavicornis* Stephens from Spain, 1984-6.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Province</th>
<th>No. Eggs</th>
<th>No. Larvae</th>
<th>No. Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1984</td>
<td>Hospital de Orbigo</td>
<td>León</td>
<td>508</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Albares de la Ribera</td>
<td>León</td>
<td>116</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sancti Spiritus</td>
<td>Salamanca</td>
<td>1132</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sarria</td>
<td>Lugo</td>
<td>326</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Apr. 1985</td>
<td>Hospital de Orbigo</td>
<td>León</td>
<td>42</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Albares de la Ribera</td>
<td>León</td>
<td>45</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sancti Spiritus</td>
<td>Salamanca</td>
<td>95</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sarria</td>
<td>Lugo</td>
<td>2440</td>
<td>302</td>
<td>-</td>
</tr>
<tr>
<td>Jan. 1986</td>
<td>Sarria</td>
<td>Lugo</td>
<td>-</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Salamanca</td>
<td>Salamanca</td>
<td>-</td>
<td>-</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>Trujillo</td>
<td>Cáceres</td>
<td>-</td>
<td>-</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Mérida</td>
<td>Badajoz</td>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
</tbody>
</table>

Releases of the Crown Boring Moth, *Cochylis atricapitana* (Stephens) (Lepidoptera: Cochylidae)

Larvae of *C. atricapitana* cause damage to *S. jacobaea* by mining from the leaf petioles into the crown or stem of the plant. They may prevent flowering and, in sufficient numbers, can
cause death of the plant. This insect was collected by CSIRO at Annonay in France and at Salamanca in Spain (Table 5). Following host specificity studies in France, C. atricapitana was approved for release in Australia in 1987 and releases began in November of that year. Within three months over 80,000 eggs had been distributed at 24 release sites in Victoria and by mid-January adults from the first releases had begun to emerge and commenced ovipositing in the field. It is likely that up to four generations of C. atricapitana will be completed each year before the final instar larvae diapause in silken cocoons within the crown. C. atricapitana causes extensive damage to S. jacobaea in the laboratory and if it becomes common in the field it would complement damage caused by the Longitarsus spp.

Table 4. Releases of adult Longitarsus flavicornis Stephens (ex. Spain) in Victoria, 1985-88.

<table>
<thead>
<tr>
<th>Year</th>
<th>Average number and (range)/site</th>
<th>Number of sites</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>1548 (885-2703)</td>
<td>3</td>
<td>Establishment doubtful.</td>
</tr>
<tr>
<td>1986-7</td>
<td>2624 (919-4448)</td>
<td>21</td>
<td>Recoveries at two-thirds of the sites the following year.</td>
</tr>
<tr>
<td>1987-88</td>
<td>2795 (2034-3572)</td>
<td>4</td>
<td>No check made on establishment.</td>
</tr>
</tbody>
</table>

Total releases: 70,926 adults; 28 sites.

Table 5. Introduction of Cochylis atricapitana (Stephens) 1985-86.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Number of eggs</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1985</td>
<td>Extremadura, Spain</td>
<td>3605</td>
<td>Not released.</td>
</tr>
<tr>
<td>May 1985</td>
<td>Extremadura, Spain</td>
<td>1100</td>
<td>Not released.</td>
</tr>
<tr>
<td>May 1986</td>
<td>Annonay, France</td>
<td>900</td>
<td>Not released.</td>
</tr>
<tr>
<td></td>
<td>Salamanca, Spain</td>
<td>1250</td>
<td>Released Nov. 1987.</td>
</tr>
</tbody>
</table>

Conclusions

Only since the release of two Longitarsus species, and more recently the release of C. atricapitana, has the prospect of substantial control of S. jacobaea in Australia become a reality. Neither T. jacobaeae nor P. jacobaeae have established, but further efforts to
establish the latter should be encouraged, particularly to prevent the spread of seed from ungrazed land onto grazed pastures.

References


