Research reports

Leucoptera spartifoliella Hübner as a biological control agent for broom in New Zealand

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Summary
The present distribution of the twig-mining moth *Leucoptera spartifoliella* in New Zealand is almost the same as that of its host plant, broom (*Cytisus scoparius*). The moth spreads readily under New Zealand conditions, with a rate of spread through Southland of 45 km in seven years. Numbers of eggs laid per female averaged 99 (se 9.3), comparable with maximum mean fecundity reported from England, as was the median longevity of 13 days for adults. The peak of adult emergence occurred during the first two weeks in December, with the peak for males 2–3 days earlier than for females. The ratio of males to females varied (1:0.8 and 1:1 in the two seasons measured). Mortality during the pupal stage was 26% lower than the rate observed in England and attributable to the absence of parasitism that contributes significantly to mortality in English populations. The large populations of *L. spartifoliella* achieved in New Zealand give this moth the potential to be an effective biological control agent of broom here, and its relatively rapid rate of colonization indicates that it should multiply and spread equally well in Australia.

Introduction
The self-introduced broom twigminer, *Leucoptera spartifoliella* Hübner (Lepidoptera: Lyonetiidae, now indexed by CAB under Elachistidae (Zhang 1994)), a moth of European origin, was first collected in New Zealand from Taupo in 1950–51 (Scheele and Syrett 1987). Its identification here in 1981 coincided with our initiation of a programme for biological control of broom (*Cytisus scoparius* (L.) Link.), its main host in Europe (Emmett 1988). Broom is an aggressive shrubby weed in New Zealand, where it disrupts agricultural production and forestry operations and is increasing its abundance on conservation lands. Broom is also a serious weed in the United States and Australia (Mountjoy 1979, Smith and Waterhouse 1988, Bossard 1991), and *L. spartifoliella* has been introduced into the United States as a biological control agent for broom (Parker 1964). Approval to proceed with a biological control programme in New Zealand was gained after preparation of an Environmental Impact Assessment (Syrett 1987).

Preliminary information on the moth, its life cycle and distribution in New Zealand, and its impact on broom has been published by Scheele and Syrett (1987) and Syrett (1989), respectively. The moth is univoltine and adults (Figure 1) appear in the field during December and January. Large numbers of moths can occur, so that when branches are shaken the white moths fly off giving the appearance of a shower of small snowflakes. Eggs hatch from mid-summer, and developing larvae feed under the surface of green twigs, forming characteristic raised mines (Figure 2). Larvae continue to develop during the winter, then leave their mines in the final instar in October to spin pupal cocoons, usually on the underside of branches (Figure 3). When a large proportion of green material has been mined, complete branches and even whole bushes die, a common and visually obvious consequence in broom stands in New Zealand but rare in Europe. For the first time in summer 1992–93, we observed several locations where large numbers of broom plants had died after high levels of larval mining by *L. spartifoliella.*

Figure 1. Adult moth, *Leucoptera spartifoliella* Hübner (Lepidoptera: Lyonetiidae).

Figure 2. Mining by *Leucoptera spartifoliella* larvae in twigs of broom, *Cytisus scoparius*.

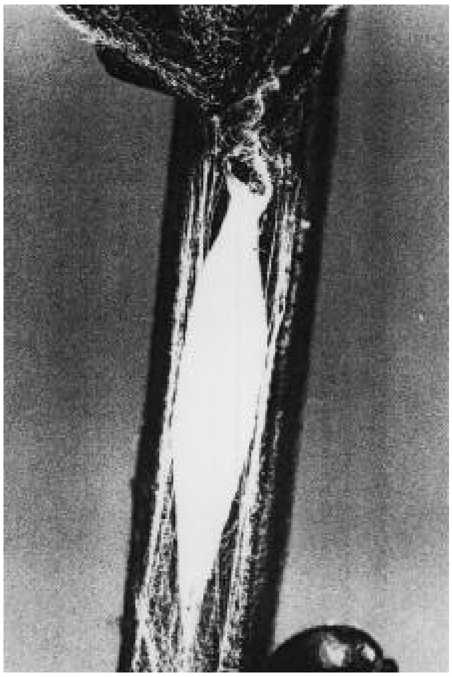

Figure 3. A pupa of *Leucoptera spartifoliella* attached to a broom twig.

The moth has now been released in Australia (Smith 1994), the founder population of cocoons having been collected from Hanmer Springs, North Canterbury, and shipped to Australia in December 1990. New Zealand moths were preferred over European ones because the New Zealand population is unparasitized and the moths are already synchronized to southern hemisphere conditions. This paper summarizes the information available on *L. spartifoliella* in New Zealand and identifies some of the factors that might allow it to be a successful biological control agent of broom here.

Materials and methods

Distribution and dispersal

Records of sightings of *L. spartifoliella* on broom were compiled and mapped from field observations made from 1983–94.

A survey in 1983 showed that the moth was not present in parts of the south and west of the South Island (Scheele and Syrett 1987). Several hundred moths and cocoons were released at Otautau, Southland, in December 1987 to investigate whether *L. spartifoliella* was able to survive in the area. The site was revisited in December 1990 and broom bushes up to 200 m from the point of release were inspected for evidence of *L. spartifoliella.*

All but one of the original 1983 survey sites were re-checked in 1990. Areas of mature broom (at least 1.2 m high) visible from the road, at least 20 km apart, and with a minimum of five bushes growing within a few metres of each other were examined for larval mining and cocoons. If no evidence of *L. spartifoliella* was apparent after 10 minutes the moth was recorded as absent as wherever larval mining and/or cocoons were identified, they were discovered within 2 minutes of searching, and usually within 30 seconds.

Fecundity and longevity

Broom twigs bearing cocoons of *L. spartifoliella* were collected from Hoon Hay valley, Christchurch (altitude 375 m), in early November 1987 and from Hanmer Springs, North Canterbury (altitude 300 m), in late October 1988. The twigs were cut into short lengths and stored in transparent ventilated plastic containers (height 200 mm, diameter 190 mm) at room temperature. Male and female adult moths were collected as they emerged several weeks later and placed in pairs in plastic containers lined with filter paper (five for the 1987 experiment, 10 for the 1988 one). Each container was provided with a 90–100 mm long broom shoot in a 150 mL conical flask of water plugged with cotton wool and a 50 mm diameter petri dish containing two cotton dental rolls soaked in a weak honey-water solution. The shoots and dental rolls were replaced weekly, and the dental rolls were re-moistened with water every two days. Dead moths were removed. Containers were held under fluctuating ambient temperatures (mean 21°C) in the laboratory. After shoots were removed from the container any eggs that had been laid on them were counted under a dissecting microscope. The experiment ceased after 25 days in 1987 and after 31 days in 1988 when all females had died.

Information on longevity was obtained in 1988, when 86 adults newly emerged from cocoons collected near Hanmer Springs were placed in five containers identical to those used in the fecundity experiment above. The containers were held in the same conditions and looked after in the same manner except that eggs laid on shoots were not counted.

Adult emergence and pupal survival

Cocoons of *L. spartifoliella* were collected in November from Hanmer Springs (971 in 1988 and 1368 in 1990), placed in containers as above, then stored in an insect-rearing room with a maximum temperature of 21 ± 2°C and a minimum temperature of 17 ± 2°C. Relative humidity ranged from 60–90%. Adult moths were collected and sexed daily once emergence started. After emergence had ceased, remaining entire cocoons were dissected to determine the fate of the pupae.

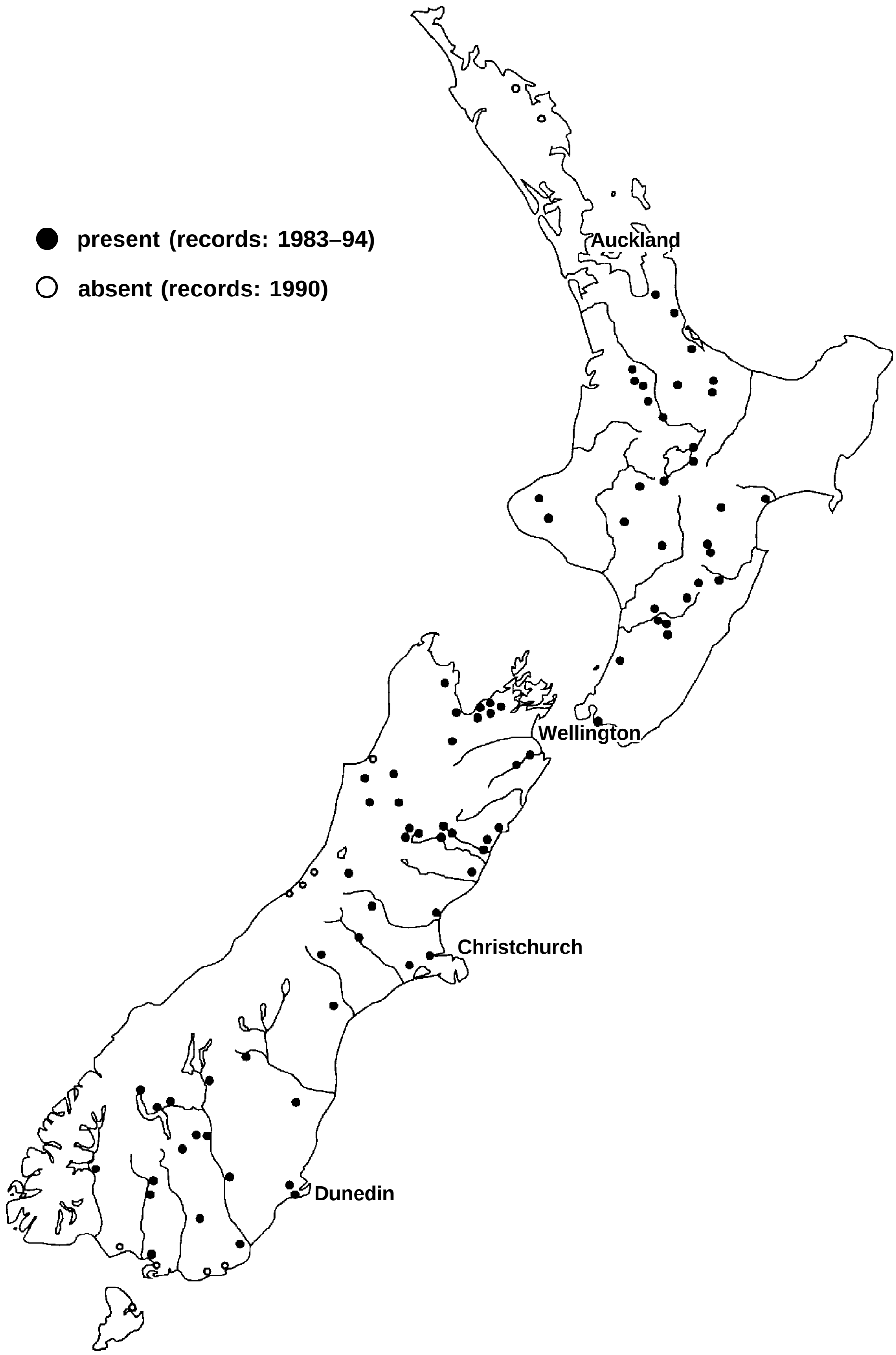

Figure 4. Distribution of broom twigminer *Leucoptera spartifoliella* in New Zealand (1983–94).

Results

Distribution and dispersal

In 1990 *L. spartifoliella* was present through most of New Zealand, including sites up to 45 km beyond the southern limit determined seven years earlier (Figures 4, 5). At Otautau, mining and cocoons were found up to 100 m from the point of release three years after moths were released.

Fecundity and longevity

There was no significant difference in fecundity between moths from the two populations (Hoon Hay valley 1987 and Hanmer 1988) (t-test, t = 1.86, df = 11). The mean fecundity of female moths under fluctuating ambient temperatures (mean 21°C) in the laboratory was 99 eggs per female (se 9.3, n=13 (1 died, 1 infertile)). The median longevity of adult moths was 13 days (range 4–31 days, n=86). The median longevity of moths in the fecundity experiment was 13 days in both years also.

Adult emergence and pupal survival

Most adult emergence occurred in the last few days of November and the first half of December (Figure 6). The peak of male emergence was earlier than that of females, by 2–3 days. The ratio of males to females of 1:0.8 in 1988 was significantly different from the 1:1 in 1990 (χ^2 = 4.46, P<0.05). Mortality in 1988 was 16% (dead larvae 5%, dead pupae 5%, dead adults not emerged from pupal skin 6%), and in 1990 it was 26% (dead larvae 9%, dead pupae 8.5%, dead adults not emerged from pupal skin 8.5%).

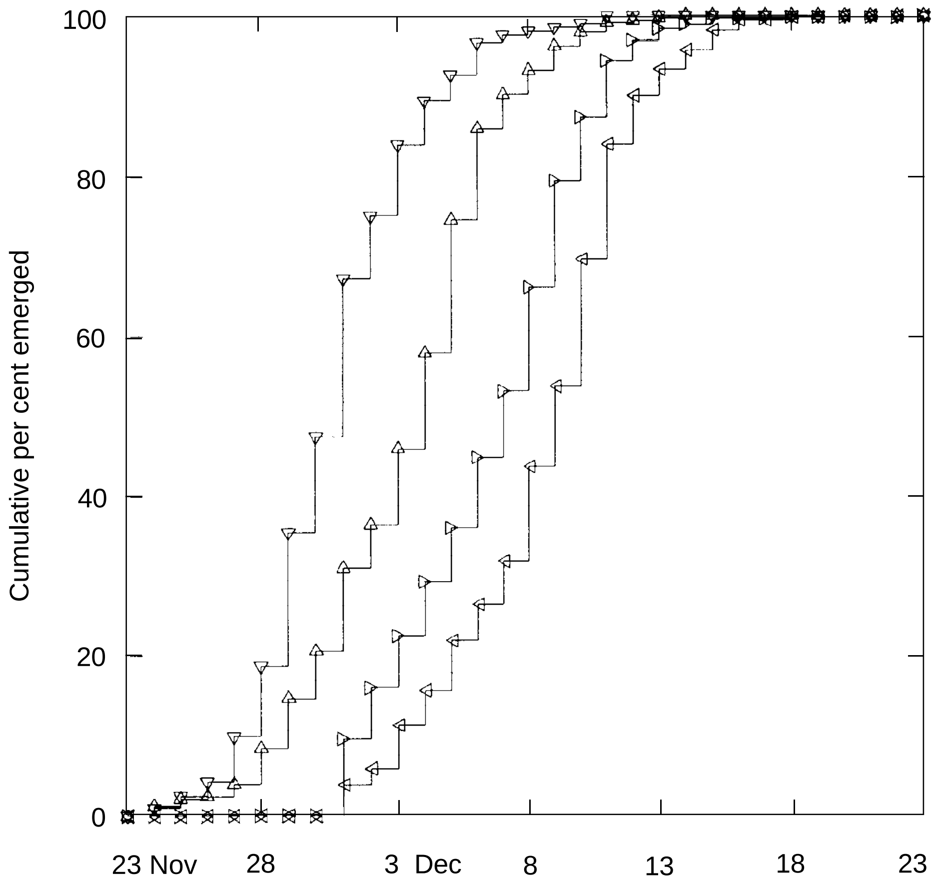

Figure 6. Emergence of adult *Leucoptera spartifoliella* from pupal cocoons, 1988 and 1990. ▽ male emergence 1988, △ female emergence 1988, ▷ male emergence 1990, ◁ female emergence 1990.

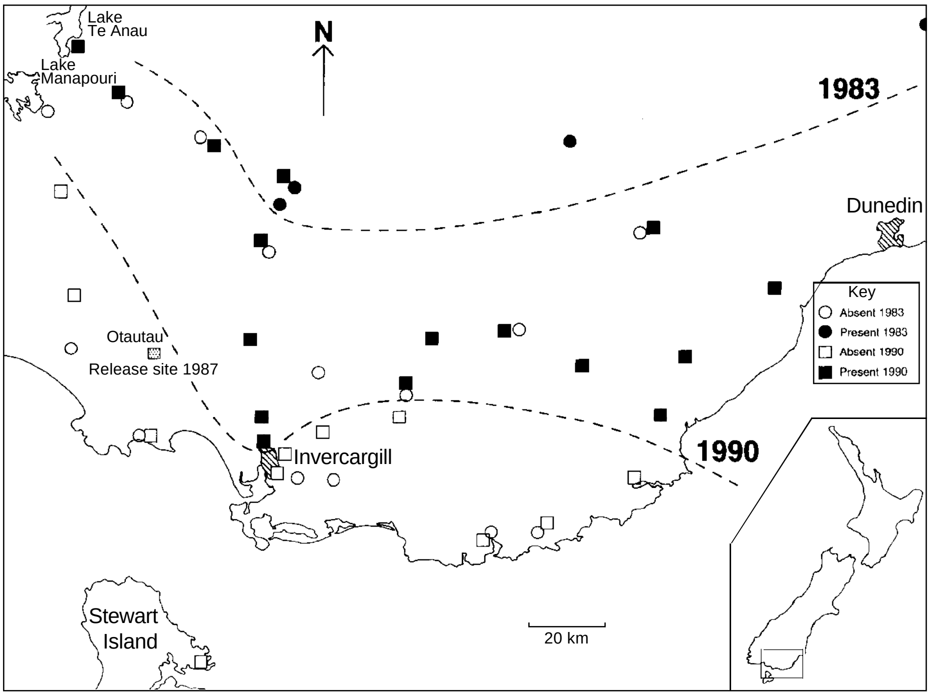

Figure 5. Distribution of *Leucoptera spartifoliella* in Southland, New Zealand in 1983 and 1990.

Discussion

Leucoptera spartifoliella has high powers of dispersal and population increase in New Zealand and is now established on broom throughout most of the country. In order to colonize and become abundant in such large areas of Southland between 1983 and 1990 (Figure 5), the rate of population increase must have been substantial.

New Zealand populations of *L. spartifoliella* are generally larger than those recorded in Europe. In Europe it is common to fail to detect *L. spartifoliella* in areas known to be within its distribution, but in New Zealand the moth is always present in areas within its current distribution wherever broom bushes are sufficiently mature and abundant. During the season of peak abundance, a 0.8 × 0.8 m beating tray collected a mean of six moths in New Zealand (Syrett 1993) but only 0.8 moths in Europe (Agwu 1974).

Reasons for larger populations in New Zealand than in Europe could include higher fecundity and lower mortality. Mean fecundity was similar in experiments conducted at 20°C in England (72 eggs/female, range 55–139, Agwu 1967) and at a mean temperature of 21°C in the laboratory in New Zealand (99 eggs per female, se 9.3), but at ambient temperatures in England mean fecundities dropped to 29–35 for caged moths in outdoor insectaries and to below 50 for a field population. As ambient temperatures in New Zealand are higher during the oviposition period than in England, fecundity may be higher here. Field oviposition data should be obtained in New Zealand, since it is most likely that fecundity exhibits a facultative response to temperature. Longevity of adult moths in England (1.5–2 weeks, Agwu 1967) is similar to that reported here.

Mortality factors in England are sufficiently influential for monitored moth populations to decline over the years (Agwu 1974). A decline in host-plant quality and parasitism, particularly of larvae by the eulophid *Tetrastichus evonymellae* Bouché, were the most important factors identified. Agwu (1974) considered mortality in eggs caused by sterility and mortality in first instar larvae caused by intra-specific competition to be mutually compensatory. In New Zealand lower levels of intra-specific competition resulting from a more abundant food resource are unlikely to account fully for the substantially higher populations occurring here. Differences in parasitism and other mortality factors acting on later life stages are more likely to contribute to differences in population densities. No larval or pupal parasitoids have been recorded in New Zealand (Scheele and Syrett 1987).

In England, late-instar larvae and pupae are vulnerable to bird predation (Agwu 1974). This occurs to a minor extent in New Zealand, where a small number of mines and cocoons show obvious signs of attack by birds. More significantly, feeding by adult *Sitona regensteinensis* Hbst. weevils caused 17% larval mortality in England. This weevil species is being considered as a potential biological control agent for introduction to New Zealand (Syrett 1992) as its larvae feed on the root nodules of broom. The possible impact of adult weevil browsing on *L. spartifoliella* needs to be considered.

It is likely that in New Zealand, populations of *L. spartifoliella* could be limited by the availability of suitable length of twig for mining larvae, judging by the often high density of eggs observed on foliage. The number of larvae dissected from mines is significantly less in September than in April (unpublished data), indicating that significant mortality occurs at this stage. However, two larvae per 150 mm length of twig are sufficient to kill the twig (Syrett 1989).

The earlier peak emergence of males than females in our study is comparable with English data. Emergence time varies slightly between years, probably in response to temperature. In England, emergence generally begins in mid June and numbers peak early in July, only slightly later than the equivalent months in New Zealand, which is probably attributable to the cooler temperatures of southern England. Sex ratio in England also varies between years (ratios in three years varied between 1:0.59 and 1:0.98, Agwu 1967), as it did in our study, and also always favours males. The reasons for this variation are not known.

Damaging populations of *L. spartifoliella* occur rarely in Europe (Parker 1964), but in New Zealand high rates of increase and dispersal and the absence of the parasitoid species that limit it in Europe give this moth the potential to be a highly effective biological control agent, both here and in Australia.

Acknowledgments

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