

## The Biological Control Programme Against *Parthenium hysterophorus* in Queensland

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### Abstract

Between 1979 and 1983 seven species of insects were imported from Brazil and Mexico for the biological control of *Parthenium hysterophorus* (Compositae) in Queensland. Detailed testing on six of these showed them to be host-specific and field releases were made between 1980 and 1984. So far, three species have established: a stem-boring weevil, *Listronotus setosipennis* (Coleoptera: Curculionidae); a leaf-feeding chrysomelid, *Zygogramma bicolorata* (Coleoptera: Chrysomelidae); and a stem-galling moth, *Epiblema strenuana* (Lepidoptera: Tortricidae), but only the last is having any impact on the weed. In the 18 months since initial release, this moth has increased and spread dramatically, and there are excellent prospects for substantial biological control of parthenium weed. The closely related weeds *Ambrosia artemisiifolia* (Compositae) and *Xanthium strumarium* (Compositae) are also attacked, and substantial control of these may also be achieved. The implications of the use of insects capable of attacking several related weeds are discussed.

### Programme de Lutte Biologique Contre *Parthenium hysterophorus* à Queensland

Dans le cadre d'un programme de lutte biologique contre *Parthenium hysterophorus* (Composée) à Queensland, sept espèces d'insectes ont été importées du Brésil et du Mexique entre 1979 et 1983. D'après les essais exhaustifs, six espèces n'adoptent qu'un unique hôte, et des lâchers sur le terrain ont été effectués entre 1980 et 1984. Jusqu'à présent, trois espèces se sont établies, à savoir un charançon perce-tiges *Listronotus setosipennis* (Coleoptera: Curculionidae), une chrysomèle se nourrissant de feuilles *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) et un lépidoptère provoquant la gale des tiges *Epiblema strenuana* (Lepidoptera: Tortricidae), mais seule la dernière espèce influe de façon notable sur la plante nuisible. Au cours des 18 mois qui se sont écoulés depuis l'introduction initiale, les populations de lépidoptères ont augmenté et se sont disséminées de façon marquée, et cet insecte semble être très prometteur pour la lutte biologique contre la plante nuisible *Parthenium*. Le lépidoptère s'attaque également aux plantes nuisibles étroitement apparentées *Ambrosia artemisiifolia* (Composée) et *Xanthium strumarium* (Composée), contre lesquelles il constituera sans doute un excellent agent biologique. Le rapport traite des conséquences de l'utilisation d'insectes pouvant s'attaquer à plusieurs plantes nuisibles de la même famille.

### Introduction

Parthenium weed, *Parthenium hysterophorus* L. (Compositae), an annual herb native to the neotropics, has become a serious weed in many parts of the world (Towers *et al.* 1977). It was first collected in Australia in 1955 from the upper Brisbane valley in Queensland but in 1964 was recorded from the Central Highlands of this State where it was established from contaminated grass seed imported from Texas (S. Everist, unpubl. rept, 1976). The weed spread rapidly and now infests thousands of square kilometres in Queensland (Auld *et al.* 1983). It is still spreading with over 100 small infestations recently reported in New South Wales.

In 1975 parthenium weed was declared a noxious weed in Queensland and in 1976 a programme of biological control was initiated at the same time as a containment scheme to control spread to new areas (Haseler 1976). An entomologist from the Alan Fletcher Research Station went to south-west Brazil from 1977–81, and from 1978–83 the Commonwealth Institute of Biological Control was contracted by the Queensland Department of Lands to investigate possible biological control agents in Mexico (McClay 1985).

### Insects Introduced

Only preliminary host testing was carried out in both Brazil and Mexico, against 9 to 10 plants in the tribe Heliantheae of the Compositae, with particular emphasis on sunflower (*Helianthus annuus* L.) and guayule (*Parthenium argentatum* Gray), two closely related plants of economic importance. Suitable species were then sent to Queensland for detailed testing in quarantine against a list of about 50 economic plants in 27 families (McFadyen and McClay 1981). Between 1979–80, seven species were imported into quarantine. A root-feeding weevil, *Thecesternus hirsutus* Pierce (Coleoptera: Curculionidae), was not successfully reared in quarantine and host testing was never completed; the other six species proved sufficiently host specific and were subsequently field released. The seed-feeding weevil, *Smicronyx lutulentus* Dietz (Coleoptera: Curculionidae), was released between 1980–83 but failed to establish. The sap-sucking bug *Stobaera concinna* (Stål) (Hemiptera: Delphacidae) and the leaf-mining moth *Bucculatrix* sp. D (Lepidoptera: Lyonetiidae) were first released in September 1983 and January 1984, respectively, and establishment has not been confirmed. The remaining three species have established. *Listronotus setosipennis* (Hustache) (Coleoptera: Curculionidae), a stem-feeding weevil from Brazil which has been released since January 1983, appears to have established; however, the population levels in the field are very low and the impact on the plant negligible. *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), a leaf-feeding beetle released from December 1980 to May 1983 (McFadyen and McClay 1981), has established in some areas but appears to be restricted by poor survival if rain is delayed till late in the year, as is common in central Queensland.

### The Stem-galling Moth *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae)

The only species to have reached damaging numbers is *E. strenuana*. The biology of this moth is described by McClay (*in press*). Eggs are laid singly on the underside of leaves, and larvae bore into stem tips or axillary buds. The plant swells to form a fusiform gall, inside which the larva feeds until full size, about 10 mm long. Pupation occurs in the gall and the adult emerges through a thin-walled 'window' cut by the larva. In summer, the life cycle from egg to adult is about 5 wks and moths in the laboratory in Queensland lay up to 250 eggs each. *E. strenuana* is widely distributed throughout North America where it is recorded from *Ambrosia trifida* L., *A. artemisiifolia* L., *A. psilostachya* DC. (Compositae), *P. hysterothorus*, and *Xanthium commune* Britton (Compositae) (McClay, *in press*).

### Establishment and Spread

The first field releases of *E. strenuana* were made in December 1982, and by February 1984 a total of 35,000 pupae had been released at 36 sites, mainly in the central highlands of Queensland, where the largest infestations of parthenium weed occur.

Initially, conditions were very dry in this normally summer-rainfall area, until in April–May 1983 there was widespread heavy rain with resulting germination of parthenium weed. Most areas then experienced an exceptionally wet, mild winter and spring, and sufficient summer rain for continued growth of parthenium weed. Of the earlier releases, three established well from the outset, with large populations present by August 1983 (spring). By January 1984, at these three sites there were 500–800 galls m<sup>-2</sup> over several ha of dense parthenium and collection and distribution of field material began soon after. By May 1984, the moth was present over most of the 120,000 km<sup>2</sup> affected by parthenium weed, and had reached damaging levels over at least 25% of this area. Travelling with the prevailing winds, in 12 months the moth in one place was present 160 km from the nearest release, crossing a low range of hills en route.

This phenomenal increase was aided by two factors: first, the very favourable weather conditions from April 1983 on; and second, the fact that the moth also attacks Noogoora burr, *Xanthium strumarium* L., which is a widespread weed over most of the State. In many instances, *E. strenuana* has spread on Noogoora burr into areas where parthenium weed occurs only as isolated patches. Furthermore, although Noogoora burr is also an annual, in central Queensland it tends to germinate longer after rain than does parthenium weed, and to remain green much later. Thus the moth has continued to increase in Noogoora burr at times when no suitable parthenium weed was present.

#### *Mortality Factors*

One of the most striking features of the increase of *E. strenuana* in Queensland has been the almost total absence of mortality in larvae and pupae. Mortality in adults and eggs has not been estimated, but must be very low in favourable conditions with abundant suitable plants, as increases of nearly 100 fold in each generation have been observed. Presumably if adults have to search over long distances for suitable plants, adult mortality would be substantial. Among small larvae, the only significant cause of mortality is drought stress in the plants. Females will only lay on plants in good condition, but if severe wilting occurs over the next 2–4 wks, which is not uncommon in summer, many small larvae die *in situ* or after leaving the wilted plant.

In large larvae and pupae, there is virtually no mortality. Predation is extremely rare, as the gall is closed. Large larvae usually survive water stress in the plant, sometimes feeding down into the stem where they successfully complete development. If plants die from other causes, such as excessive numbers of galls, larvae will leave galls and transfer successfully to adjacent plants. In the field this is quite common at high population levels, in contrast to the situation in Mexico (McClay, *in press*).

Parasitism is also very low, in contrast to the Americas (McClay, *in press*). Five parasites have been recorded: *Bracon* sp. (Hymenoptera: Braconidae); *Apanteles* sp. (Hymenoptera: Braconidae); an undetermined species (Hymenoptera: Eupelmidae) from the larvae; *Glabridorsum* sp. (Hymenoptera: Ichneumonidae); and *Antrocephalus* sp. (Hymenoptera: Chalcididae) from the pupae. The greatest total parasitism so far recorded was 10% at Sherwood, Brisbane, in February 1984. In the Central Highlands, an ecologically less-diverse region, no parasites have yet been found.

#### *Phenology*

In McClay (*in press*) it is clear that in Mexico the population is strongly seasonal, overwintering as pre-pupal larvae from October to February inclusive. In Queensland, overwintering appears to be more flexible. Readiness to enter pre-pupal diapause must

be initiated by shortening daylength, as diapause does not occur in summer. However even after the autumn equinox (March in Australia), diapause requires the additional stimulus of either low temperatures (minima below about 10°C) or senescence of the plant. Thus in Brisbane in 1984 pupation continued until early May when, following a cold period of several days, pupation ceased. In central Queensland, where temperatures were still very high at the end of May, pupae were present as long as the plants were actively growing; i.e. where moisture was available. In senescing plants, only diapausing pre-pupal larvae, but no pupae, were found in April and May.

This flexibility is ideally suited to conditions in central Queensland, where a prominent feature of the climate is extreme variability from year-to-year. In general, winters are cool and dry, with frosts in June and July. However, in some years high temperatures persist well into June, frosts are almost absent, and rainfall is sufficient to maintain plant growth throughout. Thus in many areas *E. strenuana* was able to breed continuously from early August 1983 to the end of May 1984, probably passing through seven or eight generations. There was no evidence of separate generations after the first spring generation (moths emerged and laid eggs end of August, pupae abundant middle of October).

#### Damage Caused

*E. strenuana* attacks plants of all sizes from rosette to mature, if green leaves are present. A single gall on a small rosette plant may prevent all further growth, or even kill the plant. On larger plants, damage depends on the number of galls present, and 5–10 galls in a large plant effectively prevents seed production. In the best field sites, an average of 5–10 galls/large plant (2 galls/plant including seedlings, 400–800 galls m<sup>-2</sup>) was reached by January 1984 and maintained since. Over several ha at these sites very little seed was produced, parthenium stands were reduced from 150–200 cm to only 20–30 cm high, and there was a very noticeable increase in grass production. By May 1984, a similar level of attack on the few plants still actively growing was present over large areas, perhaps a quarter of the approximately 120,000 km<sup>2</sup> involved. Over much of the rest of this area, galls were present at levels varying from 1 gall/large plant (40 galls m<sup>-2</sup> in dense parthenium) to 1 gall/20 plants. At this level, the effect is negligible; however if favourable conditions continue the population could increase 10–100 fold in one generation.

#### Attack on Other Plants

Both the known host range in the Americas and the results of laboratory tests showed that *Ambrosia* and *Xanthium* species were likely to be attacked. As these genera are present in Australia only as introduced, declared-noxious weeds, subject to control measures wherever they occur, this was regarded as beneficial rather than otherwise. *X. strumarium* occurs throughout Queensland as scattered plants in moist places, becoming more abundant in the west when rainfall is adequate. *X. spinosum* L. is also widespread but less common (Kleinschmidt and Johnson 1977) and both also occur widely in New South Wales. *A. artemisiifolia* is confined to the southeast corner of Queensland (Fig. 1) where, however, it is increasing rapidly (McFadyen 1984). *A. psilostachya* and *A. (Franseria) confertiflora* DC. occur only as very limited infestations, though the former is more common in New South Wales (Whittet 1968).

Attack on *X. strumarium* and *X. spinosum* by *E. strenuana* was first observed in January 1984. *X. spinosum* is not common in central Queensland where the first releases were made, and although some galls were found, there seems to be little attack on

this species. *X. strumarium* is common throughout along creeks and riversides, in low-lying areas after flooding, and around waterholes and dams. By May 1984, *E. strenuana* galls were present in most patches of plants over at least 60,000 km<sup>2</sup>. In most of this area the density was low, 1–5 galls/large plant, at which level damage is minimal. However in some localities over 50% of seedling plants were heavily galled.

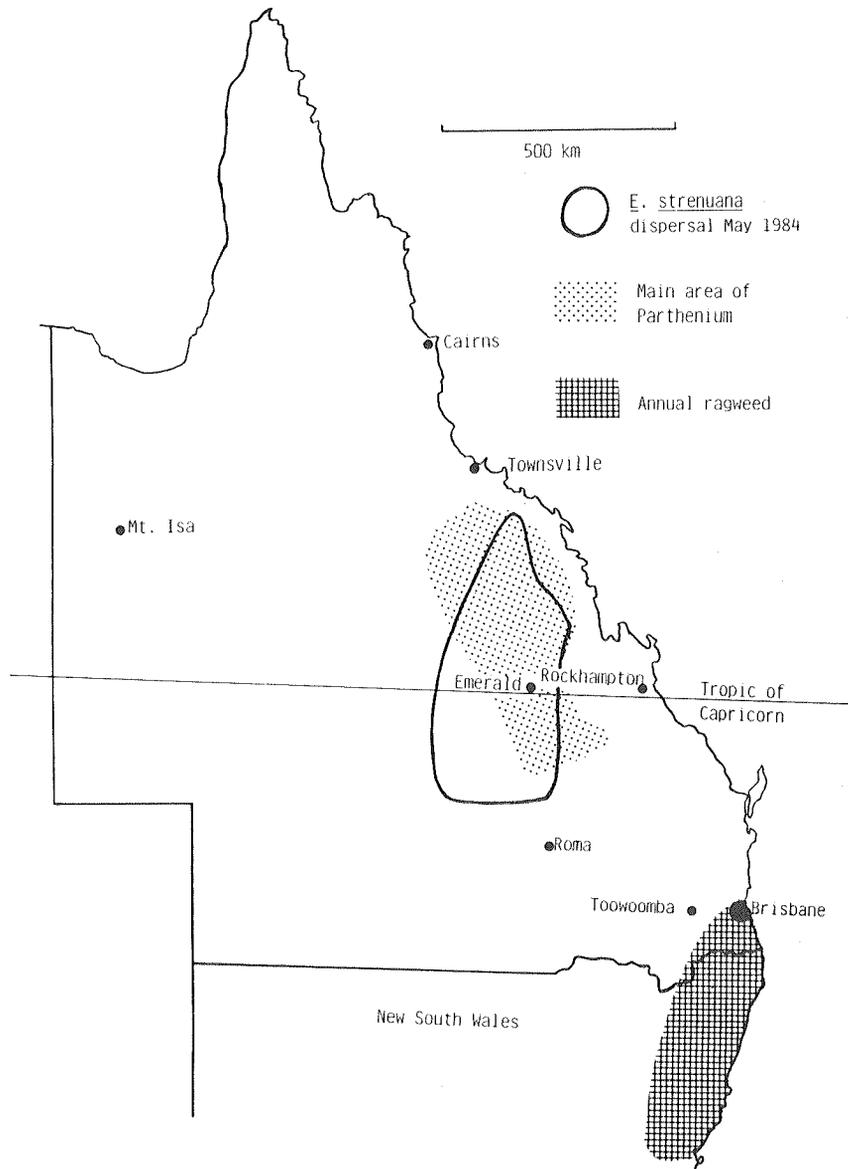


Fig. 1. Distribution of parthenium (*Parthenium hysterophorus* L.) and annual ragweed (*Ambrosia artemisiifolia* L.) in Queensland.

Field attack on *A. artemisiifolia* was first observed in Sherwood in January 1984, and in February and March releases were made on this species south of Brisbane. The moth has established, but the population is still low, and further increase and spread will be delayed until spring (August–September 1984).

### Future Prospects

After field releases over 18 months, *E. strenuana* is already present in most of the 120,000 km<sup>2</sup> affected by *P. hysterophorus* (Fig. 1), and further distribution will only be necessary in some isolated areas, or where very dry weather in 1983–84 limited increase. The degree of control obtained in the 1984–85 summer will depend entirely on rainfall, as *E. strenuana* will probably be less successful in dry conditions, even though a reasonable population persists on plants occurring in moist situations. Indeed, initial establishment and spread took place in January–April 1983 at the end of a severe 3-yr drought. Increase to damaging levels nevertheless probably needs widespread rain. However, as drought conditions also restrict seed production in these annual weeds, it now appears likely that adequate control of *P. hysterophorus* will be obtained in the long term. As *P. hysterophorus* is not poisonous, it is only a problem because at high densities and producing enormous quantities of seed, it is an aggressive invasive weed of pasture and crops. If restricted to small areas along creeks, in cattle yards, etc., *P. hysterophorus* would no longer be a problem. Whether this degree of control is reached in 3–5 yrs, or 10–15 yrs, depends in my opinion entirely on the climate, with *E. strenuana* favoured by wet years. Heavy rain in eastern Australia in late July 1984 should ensure favourable conditions this spring.

Control of *X. strumarium* is more problematical for two reasons. First, in central Queensland *X. strumarium* is already fairly well-controlled by the rust *Puccinia xanthii* Schw. (Uredinales) (Julien *et al.* 1979), and only occurs as relatively small patches. It is a problem even at this low density because the seedlings are poisonous to livestock (Everist 1974), and the burrs become entangled in wool, lowering its value. Second, in the west where the rust is ineffective and *X. strumarium* is still common, rainfall is both lower and more unreliable, so that *E. strenuana* could be expected to be less effective. However, overall *E. strenuana* attack must reduce vigour of this species to some extent, and further releases are planned for summer 1984–85 in western Queensland and northern New South Wales where *X. strumarium* is a problem.

The prospects for biological control of *A. artemisiifolia* are much better. The only factor limiting *E. strenuana* in Queensland seems to be drought, and along the coast where this weed occurs, rainfall is both higher and more reliable. As the first releases here were only made in February and March 1984, it is still too early for results, but I would confidently expect these to be excellent. The only possible problem would be parasitism, as five parasite species have been recorded in the coastal region. However parasitism has remained very low, even at Sherwood where galls have been present in outside cages for 18 months. Releases of *E. strenuana* are planned for summer 1984–85 in ragweed areas in southeast Queensland and northern and central New South Wales.

### Discussion

*E. strenuana* is an insect that has been known for a long time, having been recorded on *X. strumarium* in the 1930s by Australian entomologists looking for biocontrol agents in the U.S.A. In eastern America, it is common and sometimes damaging on *Ambrosia* spp. (Stegmaier 1971). Nevertheless it was never considered as a potential biocontrol agent, because its host range of *Ambrosia*, *Xanthium* and *Parthenium* was considered unacceptably wide (Hilgendorf and Goeden 1983; Goeden, pers. comm., 1984).

These three genera are currently in the tribe Heliantheae of the family Compositae. In previous classifications based on floral structures, *Parthenium* was placed in the sub-tribe Melampodiinae, while *Ambrosia* and *Xanthium* were in the sub-tribe Ambrosiinae. However Stuessy (1973) included *Parthenium* in the Ambrosiinae, based on chromosome

numbers, leaf type, and particularly on presence in the plants of similar complex sesquiterpene lactones. In the tribe Heliantheae (*sensu* Stuessy) these lactones are found in only four of the 15 sub-tribes. Most species in all eight genera in the sub-tribe Ambrosiinae (*sensu* Stuessy) contain these lactones, while in the other three sub-tribes they only occur in some genera. Within the Ambrosiinae, the highly characteristic class III and class IV lactones (ambrosanolides) occur in *Ambrosia*, *Parthenium*, and *Hymenoclea*, while xanthanolides occur in *Xanthium* and *Parthenice*, and both types are found in *Iva* (Hertz 1977).

It is thus clear that the three genera *Parthenium*, *Ambrosia* and *Xanthium* are very closely related, and this grouping of *Parthenium* with *Ambrosia* is in agreement with the host range of many *Parthenium* insects. Recent studies have shown that there is a close affinity between the insects attacking *Ambrosia* spp. and those of *P. hysterophorus* (Gagné 1975; McClay 1983). Furthermore *E. strenuana* belongs to a genus of very host-specific root- and stem-galling moths, with hosts entirely in the Compositae, which suggests a long evolutionary relationship between insect and host. *E. strenuana* occurs throughout much of North America, including large agricultural areas with a wide variety of crops. Agricultural entomology in the U.S.A. is highly developed and any attack by *E. strenuana* or other *Epiblema* spp. on sunflower or other crops would have been recorded. It can thus be unwise to rely too heavily on the systematic position of plant genera, when considering insects as potential biological control agents. Systematics change, and some botanical families have not been revised for a very long time.

The other side of the coin, of course, is that *E. strenuana* is likely to attack most plants in these three genera. In Australia there are no native plants in the sub-tribe Ambrosiinae nor closely related to them, and the only representatives occurring in the country are introduced species, most of which are serious weeds. The only plant with possible economic value is guayule, *P. argentatum*, and this is not attacked by *E. strenuana* either in tests or the field (McClay, *in press*). *P. argentatum* lacks the characteristic sesquiterpene lactones (Swain and Williams 1977) and supports a very different insect complex. Consequently, Australian Plant Quarantine authorities permitted the introduction and release of *E. strenuana*, and general opinion in the country is that if the moth succeeds in significant control of *Xanthium*, *Ambrosia*, and *Parthenium*, it will be hailed as a supermoth and saviour!

In other countries the situation may be different. Biological control of *P. hysterophorus* and of *Ambrosia* spp. is being pursued by India and the USSR. These countries have native species of *Xanthium* which *E. strenuana* might well attack and this would have to be taken into account. However, *E. strenuana* is the most promising of the biological control agents currently being tried for weeds in these genera, and its introduction should be seriously considered wherever native species are not at risk.

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