Application for the approval of a host test list for the Leaf beetle *Gonioctena olivacea*, a potential biological control agent for Scotch broom, *Cytisus scoparius* subsp. *scoparius*

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1. Information on the target species *Cytisus scoparius* subsp. *scoparius*

1.1 Taxonomy

Order: Fabales
Family: Leguminosae
Subfamily: Papilionoideae
Tribe: Genisteae
Sub-tribe: Cytisinae
Genus: *Cytisus* Desf.
Species: *scoparius* subsp. *scoparius* (L.) Link

Synonyms:
Cytisus scoparius var. *sulphureus* Goldring
Cytisus scoparius f. *sulphureus* (Goldring) Rehder
Cytisus scoparius var. *prostratus* (C.Bailey) F.Hanb. ex A.K.Jacks.
Cytisus scoparius var. *andreanus* (Puiss.) Dippel
Genista andreana Puiss.
Sarothamnus bourgaei Boiss.
Sarothamnus oxyphyllus Boiss.
Sarothamnus scoparius (L.) W.D.J. Koch
Sarothamnus scoparius var. *prostratus* C.Bailey
Sarothamnus scoparius (L.) Wimm. ex W.D.J.Koch
Sarothamnus vulgaris Wimm.
Spartium scoparium L.

Common names: Scotch broom, English broom.

Scotch broom is treated as *Cytisus scoparius* (L.) Link (Australian Plant Name Index, (APNI) http://www.anbg.gov.au/cgi-bin/apx?taxon_id=46707) and treated as *Cytisus scoparius* subsp. *scoparius* in NSW and the ACT. A second subspecies, *Cytisus scoparius* (L.) Link subsp. *maritimus* (Rouy) Heywood is native to Corsica, France, Denmark, Germany, Great-Britain and Ireland (http://www.ildis.org/LegumeWeb?version~10.01&LegumeWeb&tno~6453), but is not present in Australia. *C. scoparius* belongs to the section *Spartopsis* Dumort. of the genus (Cristofolini and Troìa 2006) which includes about 60 species distributed from Morocco to southern, western and central Europe (Cristofolini and Troìa 2006). The highest species diversity occurs around the Mediterranean Sea (Cristofolini and Troìa 2006). The section *Spartopsis* contains five species mainly distributed in the Iberian peninsula with the exception of *C. scoparius* which is widely distributed throughout Europe.
Some confusion has existed for some time in regard of which valid name to use for the legume family. The nomenclature presented here is the one where Leguminosae is accepted at the family level (Table 1) with three subfamilies: Papilionoideae, Mimosoideae, Cesalpinioideae (Klitgaard and Bruneau 2003; Lewis *et al.* 2005). However the name Fabaceae was kept when used in publications cited here.

Table 1. Accepted nomenclature for the legume family (Lewis *et al.* 2005).

Family	Sub families
Leguminosae	Papilionoideae, Mimosoideae, Cesalpinioideae
Fabaceae	Faboideae (= Papilionoideae), Mimosoideae, Cesalpinioideae
Fabaceae (= Papilionaceae)	Mimosaceae, Cesalpiniaceae

1.2 Description

Scotch broom occurs in the cooler areas of temperate Australia at an altitude generally higher than 600 m. It is an erect, perennial, leguminous shrub, generally growing up to two meters high but occasionally reaching up to four meters (Hosking *et al.* 1998). Plants have multiple dark-green five ribbed alternate twigs. Photosynthesis occurs both through leaves, twigs and stems. In south eastern Australia, plants begin flowering in October-November producing yellow flowers until January. Pea-like pods mature from December until February. Red and yellow broom flowers have been observed in the field and these are considered to be *C. scoparius* cultivar *Andreanus* or C. scoparius cultivar *Andreanus aureus* (Rowell 1991). Scotch broom reproduces only by seeds which are further dispersed by water, animals, agricultural and forestry machinery. When ripe, pods explode and expel most of the seeds to a distance up to seven meters (Malo 2004). Germination is promoted by vegetation removal caused by fire and large Scotch broom seed banks translate in extensive seedling recruitment. Once established, Scotch broom fixes nitrogen and dominates vegetation forming dense thickets and preventing re-establishment of native species. Broom provides shelter for pest animals such as rabbits, foxes and feral pigs.

1.3 Native range and probable centre of origin

Cytisus scoparius subsp. *scoparius* originates from western, southern and central Europe, northwards to southern Sweden and eastwards to west central Ukraine.

1.4 Australian and overseas distribution

1.4.1 Native Range

Scotch broom is native to western Europe and present in the following countries: Austria, Azores, Belarus, Belgium, Corsica, Czech Republic & Slovakia, Denmark, Estonia, former Yugoslavia, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia in Europe, Sardinia, Sicily, Spain, Sweden, Switzerland, Ukraine.

1.4.2 Introduced Range

Outside its native range, Scotch broom is naturalised in Australia, New Zealand, North America (USA: 27 states, Canada), the Chatham Islands, Hawaii, South America (Argentina, Bolivia, Chile), South Africa, Madagascar, India, the Canary Islands and Madeira (http://www.ildis.org/LegumeWeb?version~10.01#42, (Parsons and Cuthbertson 1992).

In Australia *C. scoparius* is naturalised in New South Wales, the ACT, Victoria, South Australia and Tasmania (Figure 1). In 1998, infestations in Australia were estimated at over 200,000 ha (Hosking *et al.* 1998) In Victoria, Scotch broom is present in the Australian Alps, the Dandenong and Yarra Ranges and in the region comprised between the towns of Ballarat, Castlemaine and Macedon (Figure 2) with smaller scattered infestations in the southern areas of the state. In the Australian Alps, Scotch broom has quickly re-invaded infested areas burnt during the 2003 bushfires. Potential distribution of Scotch broom in Victoria covers many climatically suitable areas in the west, centre and east of the state (Figure 3).

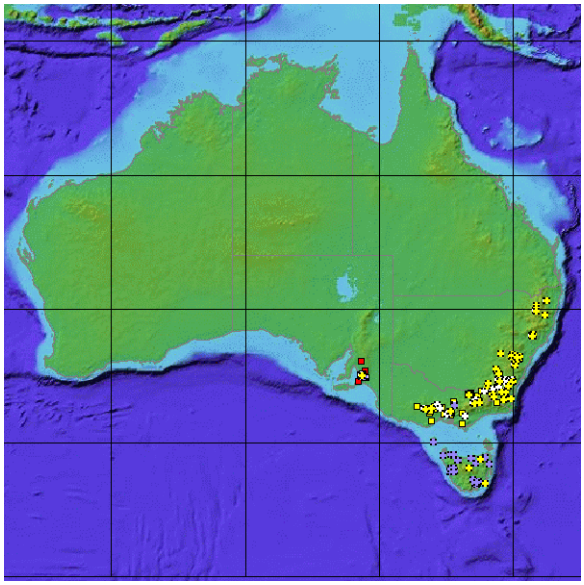

Figure 1. Australia showing current distribution of *Cytisus scoparius* (records from Australia's Virtual Herbarium).

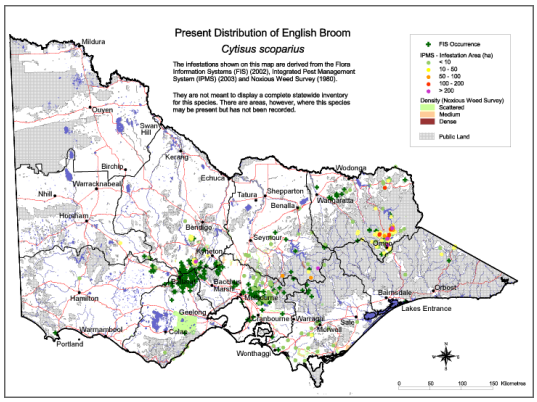

Figure 2. Present distribution of *C. scoparius* in Victoria (Data DPI).

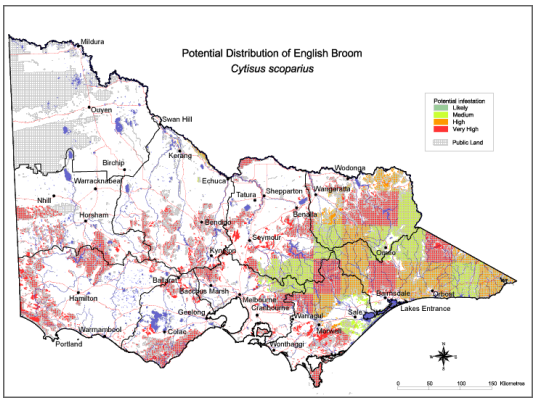

Figure 3. Potential distribution of *C. scoparius* in Victoria (Data DPI).

1.5 Native and introduced related species

C. scoparius belongs to the order Fabales, family Leguminosae, subfamily Papilionoideae, tribe Genisteae, subtribe Cytisinae. The tribe Genisteae, as defined by Polhill (Polhill 1981) has no Australian native representatives. The relationships of the different tribes and position of their genera has recently been redefined (Lewis *et al.* 2005)(Figure 4).

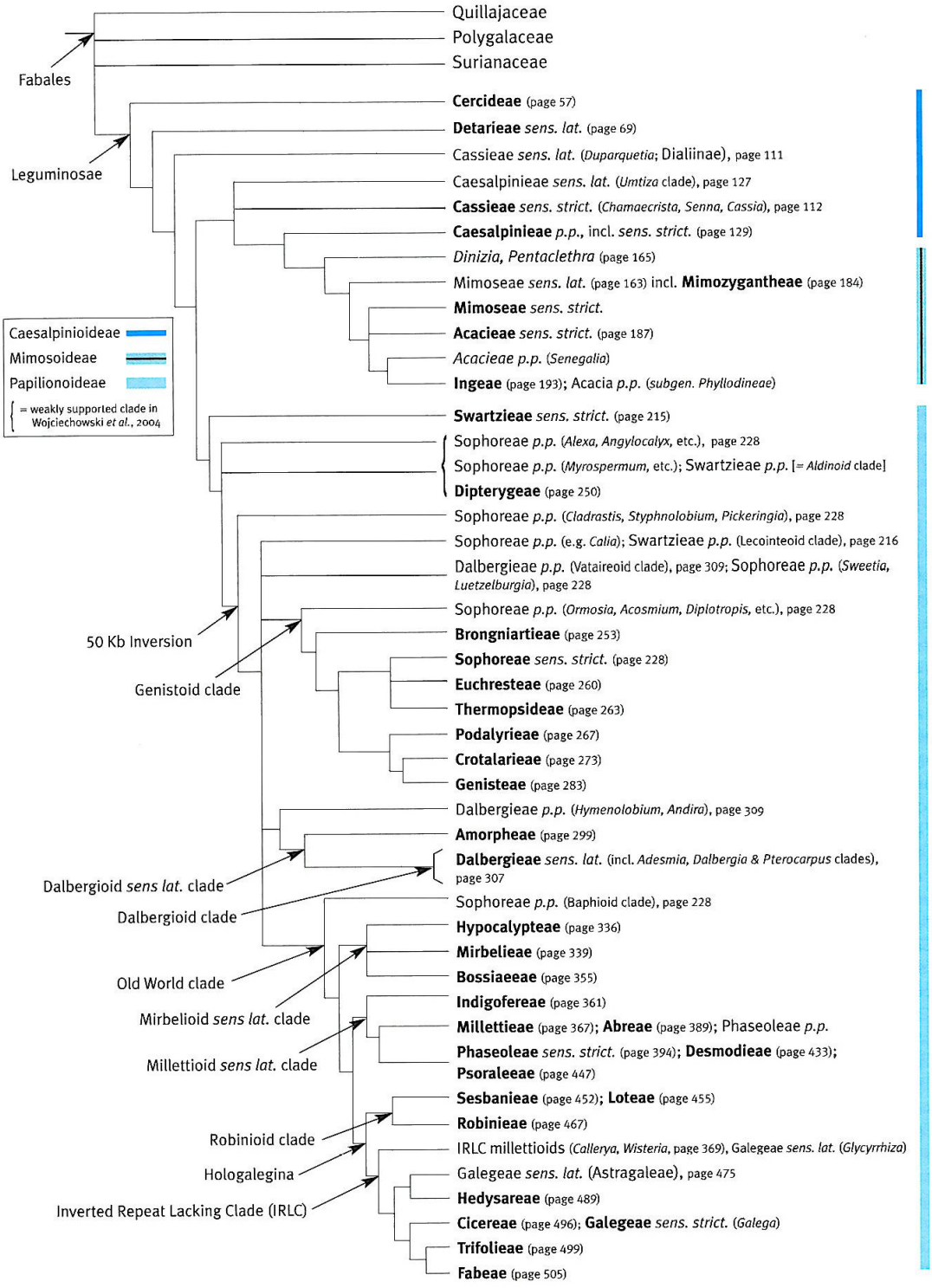

FIG. 1 **Phylogeny of Leguminosae compiled as a supertree, based on analyses by Doyle *et al.* (2000); Crisp *et al.* (2000); Wojciechowski *et al.* (2000; 2004); Pennington *et al.* (2001); Kajita *et al.* (2001); Herendeen *et al.* (2003a); Luckow *et al.* (2003); Wojciechowski (2003). The 36 tribes dealt with in this volume are in bold type. Page references are either to the beginning of the tribe or to the diagram of relationships following the introduction to that tribe**

Figure 4. Phylogeny of the Leguminosae family (reproduced from Lewis *et al.* 2005)

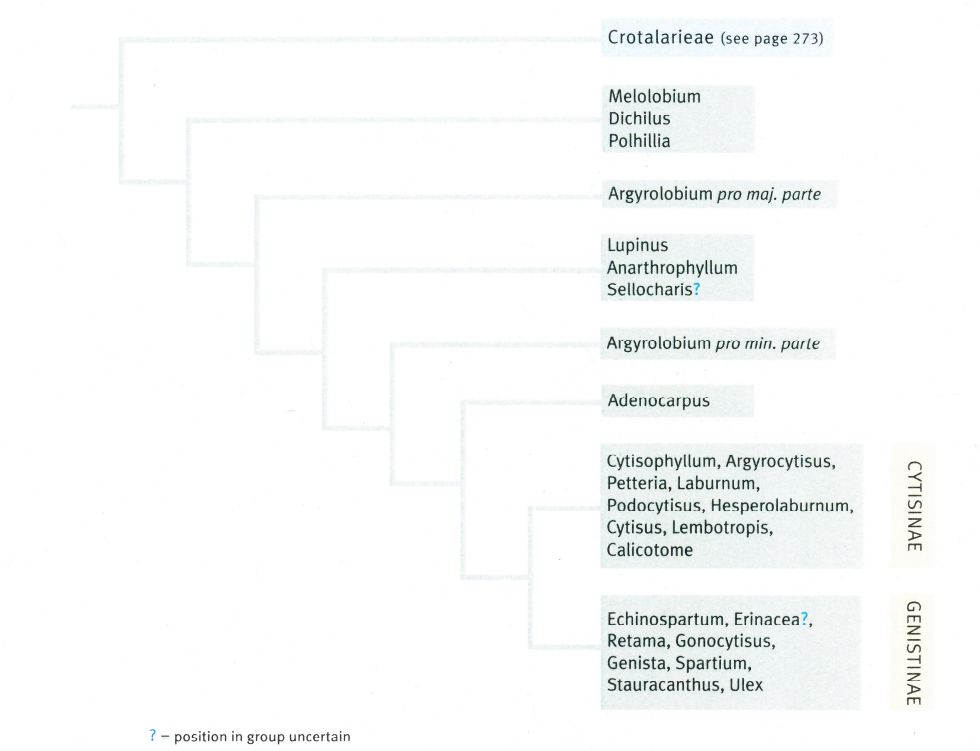

FIG. 38 **Diagram of relationships in tribe Genisteae after Käss & Wink (1997); Pyne (1999); Crisp *et al.* (2000); Cubas *et al.* (2002); Wink & Mohamed (2003); Pardo *et al.* (2004)**

Figure 6. Position of genera within the Genistoid group (reproduced from Lewis *et al.* 2005)

In Australia several exotic weedy genera within the Genisteae are naturalised and invasive (Table 2).

Table 2. List of exotic genera in the Genisteae tribe naturalised in Australia and their regions of origin (Lewis *et al.* 2005).

Subtribes	**Genera**	**Region of origin**
Lupininae	*Lupinus*	Europe, Africa, N and S America
Cytisinae	*Calicotome*	S Europe, N Africa
Cytisinae	*Cytisus*	N Africa, Europe
Genistinae	*Genista*	N Africa, Europe
Genistinae	*Retama*	S Europe, N Africa
Genistinae	*Spartium*	S Europe
Genistinae	*Ulex*	Europe

Following is some information on these exotic genera present in Australia:

Lupinus

The exotic genus *Lupinus* L. originates from the Mediterranean basin in Europe to Turkey, Africa, North and South America and contains about 460 species (Lewis *et al.* 2005), several of them economically important. In 2008 the area sown to lupins for grain in Australia covered 799,000 ha for a total production of 726,000 tonnes (source Australian Bureau of Statistics). Several *Lupinus* species are now naturalised in Australia and regarded as weeds (Table 3).

Lupinus albus L. (broad leaved lupin, white lupin) is naturalised in Victoria, WA and Queensland.

Lupinus angustifolius L. (narrow-leafed lupin, New Zealand blue lupin, bitter lupin, blue lupin) is native to Europe and the Middle East and is an important crop in Australia, often being used as a pulse in crop rotations. It is naturalised on all states except South Australia and the Northern Territory.

Lupinus arboreus Sims (tree lupin) is native to western USA. It is naturalised in Victoria and on the south east coast of Tasmania. It is considered and environmental threat on King Island and a major weed in New Zealand.

Lupinus cosentinii Guss. (sandplain lupin) is native to south-west Europe and the Mediterranean and naturalised in NSW, South Australia, Western Australia and Queensland.

Lupinus luteus L. (yellow lupin) is native to southern Europe and the Mediterranean. It is naturalised in NSW, South Australia and Western Australia.

Lupinus pilosus L. (rough-seeded lupin) is native to the Mediterranean region and is naturalised in NSW and WA.

Lupinus polyphyllus Lindl. (Russel lupin) is native to the north-western America and is a common garden ornamental. It is naturalised in Victoria, NSW and South Australia.

Table 3. Most commonly cultivated and naturalised lupins in Australia (Richardson *et al.* 2007)

		Naturalised in Australian states					
Species	**Cultivated**	**Vic.**	**NSW**	**Tas.**	**SA**	**WA**	**Qld**
Lupinus albus L. (broad leaved lupin)	Yes	✓				✓	✓
L. angustifolius L. (narrow leaved lupin)	Yes	✓	✓	✓		✓	✓
L. arboreus Sims (tree lupin) §		✓		✓			
L. cosentinii Guss. (sandplain lupin)	Yes		✓		✓	✓	✓
L. luteus L. (yellow lupin)	Yes		✓		✓	✓	
L. pilosus L. (rough-seeded lupin) §	Yes		✓			✓	
L. polyphyllus Lindley (Russell lupin) §	Ornamental	✓	✓		✓		

§ considered sleeper weeds (source National list of naturalised invasive and potentially invasive garden plants, http://wwf.org.au/publications/ListInvasivePlants/)

Calicotome

The exotic genus *Calicotome* Link contains three species, one of them *Calicotome spinosa* (L.) Link (spiny broom) is a declared noxious weed in Victoria but does not occur as a weed in the other states (Parsons and Cuthbertson 1992).

Cytisus

C. multiflorus (L'Hér.) Sweet (white Spanish broom) native to Portugal, Spain and France is listed on the Alert List for Environmental Weeds. It is a popular garden plant which is a serious threat to the agriculture and the environment and naturalised in Victoria and South Australia (Richardson *et al.* 2007).

Genista

The exotic genus *Genista* contains seventy-five species (Lewis *et al.* 2005). The most invasive species present in Australia is the evergreen shrub *Genista monspessulana* (L.) L. Johnson (Montpellier or Cape broom), believed to have been introduced during the 19th century. It is now naturalised in all states except the Northern Territory. *G. monspessulana* is capable of forming dense thickets on grazing lands, in native vegetation and on roadsides, which exclude most other vegetation. Dense infestations of Montpellier broom provide harbour for rabbits and foxes and increase fire fuel-loads in native vegetation and agricultural areas. In native vegetation, it excludes desirable indigenous species. It is considered toxic to stock if grazed excessively, but in Australia no cases of poisoning have been reported. Fire stimulates seed germination by breaking the dormancy of soil-stored seed resulting in dense recruitment of seedlings. However a small percentage of seeds are not dormant and are capable of germinating immediately on exposure to suitable temperature and soil moisture conditions. This variation in seed dormancy and germination increases the difficulty of control (DPI Victoria website).

Genista stenopetala Webb & Berthel. (= *Teline stenopetala* Webb & Berthel., = *Genista maderensis* (Webb & Berthel.) (Madeira broom) is cultivated as an ornamental and now naturalised in NSW, Victoria, Tasmania and South Australia (Richardson *et al.* 2007).

Genista linifolia L. (flax-leaved broom) is native to the western Mediterranean. It was originally introduced to Tasmania as a garden plant and has recently been found naturalised in several locations around Hobart. It is widely naturalised on the mainland, where it occurs in New South Wales, Victoria,

South Australia and Western Australia (http://www.cpbr.gov.au/chah/avh/index.html, http://www.tasweeds.org/pdf/Genista%20linifolia.pdf).

Genista tinctoria L. (dyer's broom) is native to Europe and Western Asia. A small infestation of *Genista tinctoria* L. subsp. *depressa* (M.Bieb.) P.E. Gibbs, had been found at Buckleys Falls, near Geelong (Victoria). An hybrid *G. monspessulana* X *Genista* sp. developed by the nursery industry is naturalised at Langwarrin, on the Victorian Mornington peninsula.

Retama
Retama raetam (Forssk.) Webb & Berthel. (white weeping broom) is native to the Mediterranean region, the Middle East and northern Africa. Due to its drought resistance it is a threat to dry regions of South Australia and Western Australia.

Spartium
Spartium junceum L. (Spanish broom) is native to the Mediterranean region. It is a weed of roadsides and bushland in NSW, Victoria, Tasmania and South Australia.

Ulex
Ulex europaeus L. (gorse, furze) is a perennial, woody shrub originating from Europe. It was introduced in Australia during the 19th century and is a weed of national significance (WONS). It now occurs in all the states except the Northern Territory (Richardson and Hill 1998).

1.6 Approval as target for biological control
Scotch broom is not an approved target for biological control as its biological control in Australia was initiated before the introduction of the formal target list. Each biological control agent introduced in Australia was therefore approved on a case by case basis.

1.7 Importance of plant
a. Detrimental Aspects
Scotch broom colonises heathland and wastelands, often on steep slopes, in moderate to high rainfall areas of cool temperate regions, mainly on slightly acidic soils. It tolerates a wide range of soil conditions including low levels of phosphorus but responds readily to added phosphorus. Broom will also invade cleared pasture lands, lowland and grassy woodlands, forest plantations, dry or wet sclerophyll forests, edges of watercourses and riparian habitats, alpine and sub alpine vegetation and will persist in treeless vegetation (Carr *et al.* 1992) but will not grow in heavily shaded or swampy places. Broom grows best on moist, fertile soils in pastures, sub-alpine grasslands, woodlands and open forests and plants establish after vegetation disturbance (Hosking *et al.* 1998). Broom develops infestations under *Eucalyptus* dominated vegetation when tree cover is less than 50 % (Waterhouse 1988) and animal tracks also provide suitable germination sites (Hosking *et al.* 1998).

b. Threat potential
In a study conducted in South Australia it was found that where broom stands occurred, it promoted an increase in bare ground and plant litter and a decrease in herbaceous ground cover. This results in a decline in diversity and the numbers of species present, resulting in changes in the composition and structure of the local vegetation community (Nicholson 1999). By increasing fuel loads, Scotch broom also increase the risk and severity of fires. In NSW and Victoria, Scotch broom harbour foxes considered a threat to the mountain pygmy possum, *Burramys parvus*, a species listed as endangered under the EPBC Act 1999.

c. Legislative status
In Victoria, *C. scoparius* is a declared regionally controlled weed (Land owners have the responsibility to take all reasonable steps to prevent the growth and spread of Regionally Controlled weeds on their land) in the Corangamite, Port Phillip & Westernport Goulburn Broken, North East and West Gippsland Catchment Management Authorities, regionally prohibited (Land owners, including public authorities responsible for Crown land management, must take all reasonable steps to eradicate Regionally Prohibited weeds on their land) in the Wimmera and East Gippsland Catchment Management Authorities and restricted (Plants that pose an unacceptable risk of spreading in this State or to other parts of Australia if they were to be sold or traded in Victoria, and are a serious threat to another State

or Territory of Australia) in the Mallee, North Central and Glenelg-Hopkins Catchment Management Authorities.
In Tasmania the importation, sale and distribution of *C. scoparius* is prohibited.
In NSW Scotch broom is a declared weed Class 4 (the growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority).

1.8 Other methods of control available

The main methods to control *C. scoparius* use herbicides. They are currently over sixty different formulations registered for use on Scotch broom based on the herbicides glyphosate, picloram, triclopyr and 2,4-D (http://apvma.gov.au). The most commonly used herbicides are Grazon (picloram), Garlon 600 (triclopyr) and Roundup biactive (glyphosate). Herbicides are generally applied in spring before flowering. However, access difficulties due to steep terrain leave many infestations untreated.
Other control methods such as burning, slashing or mechanical plant removal are ineffective as they provide a seed bed for seedling establishment (Hosking *et al.* 1998).

2 Information on the agent, *Gonioctena olivacea* Forster

2.1 Scientific name:

Order:	Coleoptera
Family:	Chrysomelidae
Tribe:	Chrysomelinae
Genus:	*Gonioctena* Chevrolat
Subgenus:	*Spartophila* Stephens
Species:	*olivacea* Forster 1771

Synonyms: *Chrysomela flavicans* Fabricius, 1787
Chrysomela litura Fabricius, 1775
Phytodecta weisei Reitter, 1896
Chrysomela olivacea Forster, 1771

The genera *Gonioctena* Chevrolat 1837 and *Gonioctena* Redtenbacher 1845 are synonyms, only the former has priority and therefore is valid.

2.2 Brief biology of the agent

The following summarise results of studies conducted in England (Dempster *et al.* 1959) (Richards *et al.* 1961; Waloff and Richards 1958) and information provided by Paynter Q., Gourlay H. and Hill R., Landcare Research, New Zealand (personal communication). In the UK, adult beetles hibernate in the soil or litter layer under broom bushes and emerge in spring from April onwards (Waloff and Richards 1958). Adult emergence peaks in May, and tails off in June. Since adult emergence is protracted, oviposition also spans over a wide period, from the middle of May to the middle of August, and all developmental stages can be found simultaneously. Adult beetles feed on broom leaves and mate immediately after emergence. Female beetles lay eggs mainly on the upper surfaces of the leaves and eggs take about 18 days to hatch. Each of the four larval instars also feed on broom leaves. Fully-fed fourth instar larvae pupate in the soil, giving rise to a new generation of adults that emerge in late summer-early autumn, between August and October. From the middle of June until the end of August adults of the first generation gradually descend back into the soil where they die, or hibernate for a second season. New adults feed on the plants for only one or two weeks before entering the soil with large fat-bodies to hibernate, being still sexually immature. The same adults may appear during three successive years, reproducing in the second and third years. The average number of eggs laid by females during one year ranged between 250 and 320 (Waloff and Richards 1958) with an average of 540 eggs over two seasons for a sample of 10 females.

3. Native range and, if determinable, probable centre of origin

The distribution of *Gonioctena olivacea* includes most of Europe, with unconfirmed records from Algeria (Bedel 1889-1901). *G. olivacea* occurs commonly throughout the UK, Sweden, Finland, Denmark, the Netherlands, Spain, Gibraltar, Portugal, France, Germany, Switzerland, Austria, Italy, Sicily, Poland, Czechoslovakia, Hungary, and Greece, but is absent from the USSR (Waloff and Richards 1958). In Europe *G. olivacea* is widespread and common on *C. scoparius*. The probable centre or origin of the species is Western Europe.

4. Related species and a summary of their host range

The genus *Gonioctena* is associated with a number of plant families and the evolution pathway of the genus and subgenera is now well defined (Mardulyn *et al.* 1997). Phylogenetic analyses of DNA and allozyme data suggest that the Fabaceae was the ancestral host-plant family of the genus and that eight hosts shifts have occurred between hosts belonging to distantly related and chemically dissimilar plant families (Mardulyn *et al.* 1997). The genus *Gonioctena* Chevrolat is widely distributed in the Paleartic region and contains seventy species (Baselga and Novoa 2004; Mardulyn *et al.* 1997) classified into nine monophyletic subgenera associated with host-plants belonging to six families (Mardulyn *et al.* 1997) (Table 4).

Table 4. *Gonioctena* subgenera with number of species, distribution range and host-plants associations (reproduced from Mardulyn *et al.* 1997)

Subgenera	Number of species	Distribution (number of species)	Host plants families and genera
Gonioctena	32	Asia (Siberia, China, Korea, Japan) (21), Europe (7), N America (4)	mainly Salicaceae (*Salix*, *Populus*), Betulaceae (*Alnus*, *Carpinus*), Fagaceae (*Fagus*), Rosaceae (*Prunus*, *Sorbus*)
Asiphytodesta	9	Asia	Fabaceae (*Pueraria*)
Brachyphytodecta	12	Asia	Fabaceae (*Robinia*, *Wisteria*, *Lespedeza*)
Spartoxena	7	N. Africa (5), SW Europe (Spain, Portugal, France, Italy) (2)	Fabaceae (*Lygos*, *Genista*, *Spartium*, *Adenocarpus*, *Calicotome*, *Sarothamnus*, *Cytisanthus*)
Goniomena	4	N and M Europe	Betulaceae (*Alnus*, *Corylus*), Rosaceae (*Sorbus, Prunus*), Salicaceae (*Salix*)
Sinomela	3	Asia (China, Japan)	Ulmaceae (*Celtis*)
Spartophila	1	Europe, N Africa	Fabaceae (*Sarothamnus* (= *Cytisus*), *Genista*)
Spartomena	1	SE Europe	Fabaceae (*Medicago*)
Platyphytodecta	1	Asia (China)	unknown
Total	70		

In the Paleartic region, the known host-plants of *Gonioctena* are species in the families Salicaceae, Betulaceae, Rosaceae, Fagaceae, Ulmaceae and Fabaceae (Takizawa 2007). In Southern Western Europe, besides *G. olivacea*, two other European species, *G.* (*Spartoxena*) *variabilis* (Olivier) and *G.* (*Spartoxena*) *leprieuri* (Pic) also feed on plants in the tribe Genisteae (Fabaceae). Recorded host-plants of *G. leprieuri* are *Genista cinarescens* Lange (Garcia-Ocejo *et al.* 1993), *G. florida* L. and *G. obtusiramea* Gay *ex* Spach (Baselga and Novoa 2000). For other *Gonioctena* species such as *G. viminalis* (L.) and *G. decemnotata* (Marsham) the reported hosts are *Salix* spp. and *Populus* spp. (Salicaceae) while for *G. pallida* (L.) hosts are *Prunus* spp., *Malus* spp. and *Sorbus aucuparia* L. (Rosaceae) (Database of Insects and their Host-Plants, http://www.brc.ac.uk/dbif/homepage.aspx).

TABLE 3. Host-plant associations known for the genus *Gonioctena*, inferred from the literature (see Table 1) and from our observations. If an insect species did not feed in the laboratory on a plant genus that was mentioned in the literature, that plant genus is not shown in this table. Such discordances were observed only for plant genera mentioned in general reviews. Some plant genera cited in Table 1 are not shown here because, although they were assigned in the literature to a particular *Gonioctena* subgenus, no details were given on which insect species they are associated with.

Species	Subgenus	Host plants
G. americana	*Gonioctena*	*Populus*
G. arctica	*Gonioctena*	*Salix*
G. flavicornis	*Gonioctena*	*Salix*
G. hiranoi	*Gonioctena*	*Alnus, Fagus*
G. holdausi	*Gonioctena*	*Salix*[a]
G. honchuensis chujoi	*Gonioctena*	*Salix*
G. japonica	*Gonioctena*	*Alnus*
G. kaufmanni	*Gonioctena*	*Salix*
G. linnaeana	*Gonioctena*	*Salix*[a]
G. moritomoi	*Gonioctena*	*Prunus, Sorbus*
G. nivosa	*Gonioctena*	*Salix*
G. notmani	*Gonioctena*	*Salix*
G. occidentalis	*Gonioctena*	*Salix*
G. rufipes	*Gonioctena*	*Salix, Populus*[a]
G. sibirica	*Gonioctena*	*Salix*
G. sorbina	*Gonioctena*	*Salix*
G. springlovae	*Gonioctena*	*Salix*
G. takahashii	*Gonioctena*	*Fagus*
G. viminalis	*Gonioctena*	*Salix, Populus*[a]
G. tredecimmaculata	*Asiphytodecta*	*Pueraria*
G. rubripennis	*Brachyphytodecta*	*Wisteria*
G. secsaouia	*Spartoxena*	*Adenocarpus, Calycotome*
G. sexnotatus	*Spartoxena*	*Genista, Lygos*
G. variabilis	*Spartoxena*	*Spartium, Sarothamnus, Lygos*[a]
G. gobanzi	*Spartoxena*	*Genista, Cytisanthus*
G. intermedia	*Goniomena*	*Prunus*[a]
G. interposita	*Goniomena*	*Alnus*[a]
G. pallida	*Goniomena*	*Corylus, Salix*[a]
G. quinquepunctata	*Goniomena*	*Sorbus*[a]
G. nigroplagiata	*Sinomela*	*Celtis*
G. olivacea	*Spartophila*	*Sarothamnus, Genista*[a]
G. fornicata	*Spartomena*	*Medicago*[a]

[a] Plant diet was tested in the laboratory.

Figure 7. Known host-plant associations for the genus *Gonioctena* (reproduced from Mardulyn *et al.* 1997)

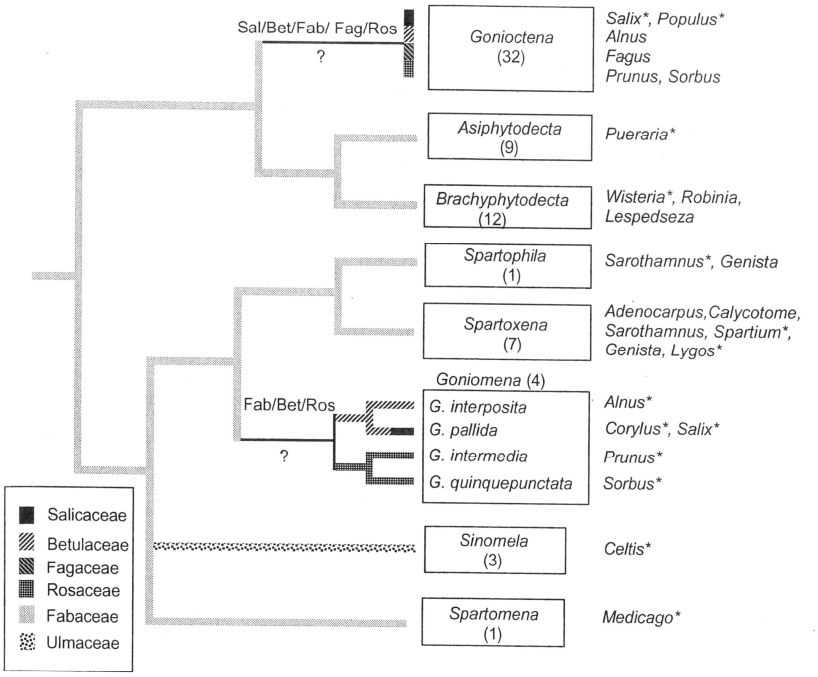

FIGURE 6. Most-parsimonious reconstruction of ancestral host-plant associations in the genus *Gonioctena* based on the phylogenetic relationships shown in Figure 5. The known plant genera associated with each *Gonioctena* subgenus are displayed and the number of species included in each subgenus is given in parentheses. An asterisk indicates that a species feeding on this plant genus was included in our phylogenetic study.

Figure 8. Phylogeny of *Gonioctena* subgenera and their host plant specialisation (reproduced from Mardulyn *et al.* 1997)

5. Proposed source(s) of agent

It is proposed to import *G. olivacea* from New Zealand where it has recently been released by Landcare Research to control Scotch broom.

6. Mode of action against target organism and extent of action

Female *G. olivacea* oviposit on broom leaves and adults and the four instar larvae feed on broom leaves. Young larval instars are reported to feed preferably on the tips of young broom shoots while other instars are found on the older foliage. Female fecundity is dependent on the weight of mature females and on the length of time they spend on the broom bushes, while the daily oviposition rate is influenced by temperature and the age of the females (Waloff and Richards 1958).

7. Potential for control of target

Both adults and larvae *G. olivacea* feed on broom foliage with early larval instars feeding on the twigs tips. Adult females may live up to three years and lay eggs over two years. It is therefore expected that once released, beetle populations would expand significantly. Feeding damage would reduce broom vigour and reproductive capacity. *G. olivacea* adults are reported to be able to fly but this behaviour has rarely been observed. Should adults disperse by flying, colonisation of remote broom infestations could occur.

8. Non-target organisms at risk from agent

Cytisus scoparius (broom) is widely recognised as the main host plant of *G. olivacea.* However they are literature records of *G. olivacea* collected from *Cytisus purgans (*L.) Boiss*., C. multiflorus* (L'Hér.) Sweet (white broom), *C. striatus* (Hill) Rothm. (Portuguese broom), *Genista cinerea* (Vill.) DC*., G. florida* L. and *Lupinus arboreus* Sims (tree lupin). Waloff and Richards were unable to rear *G. olivacea* on *Ulex europaeus* L.*, Trifolium repens* L.*,* or *Laburnum* sp. (Waloff and Richards 1958). These authors report that *Genista tinctoria* L. is the main host plant in Denmark (Hansen 1927), but made no mention

of this host in UK. They also report that Kaltenbach gives *Spartium scoparium, Genista tinctoria, Cytisus laburnum* and *Prunus* as host plants in Germany (Kaltenbach 1874). These records may be misidentifications of *G. leprieuri*. In a field study aimed at measuring the natural host range of beetles feeding on broom in SW Europe, *G. olivacea* was shown to clearly favour *Cytisus* spp. over *Genista* spp. and *Spartium junceum* L. (Spanish broom) (Syrett and Emberson 1997).

9. Possible interactions with existing biological control programs

Four arthropods have been released in Australia to control *C. scoparius*. The broom twig mining moth *Leucoptera spartifoliella* (Hübner) (Lepidoptera: Lyonetiidae) was released from the 1990's onwards at 48 sites in NSW and over 100 sites in Victoria and has established at most of the release sites. In Tasmania where it has also been released during the 2000's and its establishment has not been confirmed yet. On the mainland, parasitisation of *L. spartifoliella* larvae by *Megadicylus* sp. (Hymenoptera: Pteromalidae) and an unidentified ichneumonid wasp (Sheppard *et al.* 2006) may contribute to limit this agent's efficacy.

The broom psyllid *Arytainilla spartiophila* Förster (Hemiptera: Psyllidae) was released at 10 sites in NSW and 6 sites in Victoria. Establishment in Victoria had been confirmed at only one site. Establishment after release in Tasmania has not been confirmed yet. The damage levels from this agent are not yet reported as being significant (Sheppard *et al.* 2006).

The broom seed-feeding *Bruchidius villosus* (Fabricius) (Coleoptera: Bruchidae) was released at five sites in NSW and ten sites in Victoria. Except for one site in NSW, no monitoring has been conducted.

The broom gall mite *Aceria genistae* (Nal.) (Acarina: Eriophyoidea), was released in 2008 in Victoria and South Australia and in 2009 in Tasmania (Sagliocco 2009). Establishment of this agent has yet to be confirmed but on-going release programs in these states are underway.

Each of the four arthropods released for the biological control of *C. scoparius* feed on different parts of the plants and no direct competition between agents is likely to occur. However, it is expected that cumulative herbivory pressure should reduce broom vigour, flowering and seed production.

10. Details of results of host-specificity testing undertaken overseas

G. olivacea has been extensively tested overseas by different research organisations prior its release in New Zealand for the biological control of *C. scoparius*. Tests were conducted in England by CABI, in New Zealand by Landcare Research New Zealand Ltd, in France by CABI and in the USA. Host specificity tests were designed according to criteria established by Zwölfer and Harris (Zwolfer and Harris 1971) and Wapshere (Wapshere 1974) (Hill 2007). Overall 103 plant species were tested: 61 species from the Fabaceae including 20 species from the Genisteae, and 42 species from 34 other families.

Different host specificity tests methodologies were used (Hill 2007):

- Tests conducted in the UK with *G. olivacea* from the UK: choice and no-choice tests in field cages to assess oviposition preference, field tests for host preference, laboratory choice and no-choice adult feeding tests in Petri dishes, laboratory no-choice adult feeding and oviposition tests in Petri dishes.
- Tests conducted in New Zealand with *G. olivacea* from the UK: laboratory no-choice adult feeding and oviposition tests in Petri dishes, no-choice larval feeding tests.
- Tests conducted in France with *G. olivacea* from France: no-choice adults and larvae feeding tests, tests in field cage for oviposition, orientation and development tests.

A summary of results of tests conducted with some adult feeding damage is presented below (Table 5).

Table 5. Summary of tests results with species onto which some adult *G. olivacea* feeding occurred (Hill 2007)

Fabaceae Tribes	Species tested	Exotic to Australia/Native	No-choice tests	Choice tests
Genistinae	*Genista monspessulana*	E	Yes	*
Genistinae	*Genista tinctoria*	E	*	Yes
Genistinae	*Spartium junceum*	E	Yes	Yes
Genistinae	*Laburnum anagyroides*	E	Minor	*
Genistinae	*Laburnum* x *vossii*	E	*	Yes
Genistinae	*Ulex europaeus*	E	Minor	No
Cytisinae	*Cytisus palmensis* †	E	Yes	Yes
Lupininae	*Lupinus arboreus*	E	Yes	Yes
Lupininae	*Lupinus polyphyllus*	E	*	Yes
Lupininae	*Lupinus* 'Russell hybrid'	E	*	Yes
Sophoreae	*Sophora microphylla*	E	Minor	Yes
Loteae	*Lotus corniculatus*	E	Minor	*
Trifolieae	*Medicago sativa*	E	Minor	*
Acacieae	*Acacia dealbata*	N	Minor	*
Caesalpinieae	*Gleditsia triacanthos*	E	*	Yes

*= test not conducted
†= *Cytisus palmensis* is also referred to as *Chamaecytisus palmensis, = C. proliferus*

Overall tests results were summarised as follows (Hill 2007):

1. No-choice adults feeding tests:
   - Feeding levels on species outside of the tribe Genisteae were 20-60% of that on broom controls
   - Outside of the tribe Genisteae, there was some feeding on *Sophora microphylla*, *Medicago* sativa, *Acacia mearnsii* and *A. dealbata*
2. No-choice and choice oviposition tests:
   - No eggs were laid on plants outside of the Genistae
   - Eggs were laid on *C. palmensis* and *Lupinus arboreus*
   - In the absence of broom, eggs were laid on *C. palmensis*
   - When tested together, broom was preferred over *C. palmensis*

Additional oviposition tests were conducted to identify host selection through oviposition. In choice oviposition tests conducted in field cage in the UK with 500 *G. olivacea* adults on 78 plants of 24 test species in the family Fabaceae, eggs were laid only on *C. scoparius* (22.8 eggs per plant), *Genista tinctoria* (4.8 eggs per plant) and *Lupinus* sp. (0.3 egg per plant).
In choice oviposition tests conducted in New Zealand with 30 adults housed in small cages for 24 hours eggs were laid only on *C. scoparius* and *C. palmensis*.

3. Proposed Test List

The following proposed test list was established based on the latest information available on the Leguminosae tribes' relationships (Lewis *et al.* 2005). None of the Australian endemic tribes and genera were previously tested and therefore representative species from each native tribe are included in this test list. Species were selected for their ecological or morphological similarities with *C. scoparius.* Host-specificity tests will be conducted using adults and larvae on whole tests plants with *C. scoparius* subsp. *scoparius* as controls. No-choice tests will be conducted first and if feeding occurs, additional choice tests will be conducted to confirm host preference.

Leguminosae, subfamily Papilionoideae

Tribe Genisteae

Cytisus scoparius subsp. *scoparius* (L.) Link (controls)
Chamaecytisus proliferus (L.f.) Link

Tribe Lupininae

Lupinus albus L. cvs. Rosetta, Luxor, Kiev
Lupinus angustifolius L. cvs. Mandelup, Jindalee
Lupinus pilosus L. cv. Atlanticus

Tribe Brongniartieae

Templetonia retusa (Vent.) R.Br.

Tribe Mirbelieae

Aotus ericoides (Vent.) Don
Daviesia ulicifolia Andrews
Dillwynia phylicoides A.Cunn.
Eutaxia microphylla (R.Br.) C.H.Wright & Dewar (rare in Tasmania)
Gompholobium huegelii Benth.
Mirbelia oxylobioides F.Muell.
Oxylobium ellipticum (Labill.) R. Br.
Phyllota diffusa (Hook. f.) F. Muell.
Podolobium ilicifolium (Andrews) Crisp & P.H.Weston
Pultenaea daphnoides J.C.Wendl.
Viminaria juncea (Schrad.) Hoffmanns

Tribe Caesalpinieae

Gleditsia triacanthos L.

Tribe Bossiaeeae

Goodia lotifolia Salisb.
Bossiaea prostrata R.Br.
Platylobium formosum Sm.

Tribe Indigofereae

Indigofera australis Willd.

Tribe Phaseoleae, subtribe Kennediinae

Hardenbergia violacea (Schneev.) Stearn
Kennedia prostrata R.Br.

Tribe Phaseoleae, subtribe Glycininae

Glycine clandestina J.C.Wendl.

Tribe Desmodieae

Desmodium gunnii Benth. ex Hook.f.

Tribe Psoraleeae

Cullen microcephalum (Rchb. ex Kunze) J.W.Grimes

Proposed Test List (continued)

Tribe Loteae
Lotus australis Andrews

Tribe Galegeae
Swainsona galegifolia (Andrews) R.Br.

Tribe Trifolieae
Medicago sativa L.

Leguminosae, subfamily Mimosoideae
Tribe Acacieae
Acacia dealbata Link

References

Baselga A, Novoa F (2000) Los Chrysomelidae de la Sierra de Ancares, Noroeste de Espana (Coleoptera). *Nouvelle Revue d'Entomologie* **17**, 165-180.

Baselga A, Novoa F (2004) Larvae of the *Gonioctena* subgenus *Spartoxena*: description of mature larvae of *G. leprieuri* and *G. aegrota* (Coleoptera: Chrysomelidae: Chrysomelinae). *The Canadian Entomologist* **136**, 313-321.

Bedel L (1889-1901) 'Faune des Coleopteres du bassin de la Seine.' (Paris).

Carr GW, Yugovic JV, Robinson KE (1992) Environmental weed invasions in Victoria : conservation and management implications. Department of Conservation and Environment, Melbourne.

Cristofolini G, Troìa A (2006) A reassessment of the sections of the genus *Cytisus* Desf. (Cytiseae, Leguminosae). *Taxon* **55**, 733-746.

Dempster JP, Richards OW, Waloff N (1959) Carabidae as predators on the pupal stage of the Chrysomelid beetle, *Phytodecta olivacea* (Forster). *Oikos* **10**, 65-70.

Garcia-Ocejo A, Gurrea P, Petitpierre E (1993) Chrysomelidae (Coleoptera) de la sierra de Gredos (Sistema Central): datos faunisticos, ecologicos y fenologicos. *Miscellania Zoologica* **16**, 81-92.

Hansen V (1927) 'Danmarks Fauna.' (Copenhagen).

Hill R (2007) Release from containment of *Aceria genistae*, *Agonopterix assimilella* and *Gonioctena olivacea*, three biological control agents for broom, Application to the Environmental Risk Management Authority (ERMA) New Zealand, Appendix E. The host plant range of *Gonioctena olivacea* as revealed by tests conducted in Europe and New Zealand. Christchurch, New Zealand.

Hosking JR, Smith JMB, Sheppard AW (1998) *Cytisus scoparius* (L.) Link ssp. *scoparius*. In 'The biology of Australian weeds, Volume 2'. (Eds FD Panetta, RH Groves, RCH Shepherd) pp. 77-88. (R. G and F. J. Richardson: Melbourne).

Kaltenbach JH (1874) 'Die Pflanzenfeinde aus der Klasse der Insekten.' (Stuttgart).

Klitgaard BB, Bruneau A (2003) Advances in Legume Systematics 10, Higher Level Systematics. (Royal Botanic Gardens: Kew).

Lewis G, Schrire B, Mackinder B, Lock M (Eds) (2005) 'Legumes of the world.' (The Royal Botanic Gardens Kew).

Malo JE (2004) Potential ballistic dispersal of *Cytisus scoparius* (Fabaceae) seeds. *Australian Journal of Botany* **52**, 653-658.

Mardulyn P, Milinkovitch MC, Pasteels M (1997) Phylogenetic analyses of DNA and allozyme data suggest that *Gonioctena* leaf beetles (Coleoptera: Chyrsomelidae) experienced convergent evolution in their history of host-plant family shifts. *Systematic Biology* **46**, 722-747.

Nicholson J (1999) The Impact of Broom (Cytisus scoparius) on Native Vegetation in the Adelaide Hills. Honour Thesis, Flinders University.

Parsons WT, Cuthbertson EG (1992) 'Noxious Weeds of Australia.' (Inkata Press: Melbourne).

Polhill RM (1981) Papilionoideae. In 'Advances in Legume systematics '. (Ed. PHR R. M. Polhill) pp. 191-208. (Royal Botanic Gardens: Kew).

Richards OW, Waloff FRS, Waloff N (1961) A study of a natural population of *Phytodecta olivacea* (Forster) (Coleoptera: Chrysomelidae). *Philosophical Transactions of the Royal Society of London (B)* **244**, 205-257.

Richardson FJ, Richardson RG, Shepherd RCH (2007) 'Weeds of the South-East, an identification guide for Australia.' (R. G. & F. G. Richardson: Meredith).

Richardson RG, Hill RL (1998) *Ulex europaeus* L. In 'The biology of Australian weeds, Volume 2'. (Ed. FD Panetta, Groves, R. H and Shepherd R. C. H.) pp. 269-290.

Rowell RJ (1991) 'Ornamental flowering shrubs in Australia.' (New South Wales University Press, Kensington).

Sagliocco J-L (2009) Defeating the Weeds Menace, Project VPI10: Importation and Release of a New Biological Control Agent for Scotch Broom, Additional Report to Milestone 5. Department of Primary Industries, Frankston.

Sheppard AW, Hosking JR, Sagliocco J-L, Thomann T, Downey PO, Kwong RM (2006) Biological control of brooms in Australia: an update. In '15th Australian Weeds Conference, Managing Weeds in a changing climate'. Adelaide Convention Centre, 24-28 September 2006, Adelaide South Australia. (Ed. C Preston, Watts, J. H., Crossman, N. D.) pp. 573-576. (Weed Management Society of South Australia).

Syrett P, Emberson RM (1997) The natural host range of beetle species feeding on broom, *Cytisus scoparius* (L.) Link (Fabaceae) in Southwest Europe. *Biocontrol Science and Technology* **7**, 309-326.

Takizawa H (2007) A revision of the genus *Gonioctena* Chevrolat in Japan (Coleoptera; Chrysomelidae). *Insecta Matsumurana* **63**, 35-53.

Waloff N, Richards OW (1958) The biology of the Chrysomelid beetle, *Phytodecta olivacea* (Forster) (Coleoptera: Chrysomelidae). *Transactions of the Royal Society, London* **110**, 99-116.

Wapshere AJ (1974) A strategy for evaluating the safety of organisms for biological weed control. *Annals of Applied Biology* **77**, 201-211.

Waterhouse BM (1988) Broom (*Cytisus scoparius*) at Barrington Tops, New South Wales. *Australian Geographical Studies* **26**, 239-248.

Zwolfer H, Harris P (1971) Host specificity determination of insects for biological control of weeds. *Annual Review of Entomology* **16**, 159-178.