Phytophagous organisms associated with the woody shrub *Polygala myrtifolia* (Polygalaceae) and their potential for classical biological control in Australia

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Summary
Coastal ecosystems in southern Australia have been invaded by the South African shrub *Polygala myrtifolia* L. (Polygalaceae), leading to ecological disruptions and loss of biodiversity. Expansion of *P. myrtifolia* populations is expected unless effective containment or suppression activities are implemented. Low herbivory pressure in Australia compared to the species' native range is likely to have contributed to the invasion success of *P. myrtifolia*. Twenty-eight phytophagous organisms are recorded from *P. myrtifolia* in South Africa and six have potential as classical biological control agents, but require formal host specificity and impact evaluation. Further understanding of seed-bank dynamics and recruitment patterns of *P. myrtifolia* in Australia would contribute to the selection of suitable biological control candidates. Seed-destroying agents were not found on *P. myrtifolia* in South Africa, but additional survey effort is warranted as seed-destroying agents could alleviate conflicts of interest between environmental protection and the ornamental garden trade.

Introduction
The South African shrub *Polygala myrtifolia* L. (myrtle-leaf milkwort) occurs naturally in a broad range of vegetation associations distributed across the coastal and near-coastal belt of southern South Africa extending into mountainous areas of KwaZulu-Natal (Drakensberg) and Lesotho and the north-western Western Cape (Bokkeveld Mountains). The species is morphologically highly variable and several infraspecific taxa have been described (Harvey 1860, Bredenkamp 2000). *Polygala myrtifolia* is a popular garden ornamental in South Africa, and is also widely used for horticultural purposes in other temperate climates, particularly Australia, New Zealand, USA and southern Europe (Esler 1988, Cervelli 2001, Meerow and Ayala-Silva 2005). In Australia, the earliest record of *P. myrtifolia* is from nursery catalogues in Adelaide in 1845 (Carter *et al.* 1990). The first presumed wild collections of *P. myrtifolia* in Australia were made in New South Wales at Hastings River between 1856 and 1862 (MEL 2244752), followed by a collection in Victoria between Brighton and Mentone in 1886 (MEL 2120881). *Polygala myrtifolia* is now naturalized across southern Australia with extensive infestations present in Victoria around Melbourne and in South Australia on the Eyre Peninsula. Isolated and expanding populations are widely scattered in coastal New South Wales, eastern Tasmania and south-west Western Australia (Figure 1). Dense infestations of *P. myrtifolia* disrupt ecological processes in native coastal vegetation and threaten biodiversity values. Mechanical and chemical control techniques are utilized to suppress *P. myrtifolia*, but are generally only successful when applied to small areas where regular follow-up treatments can be implemented.

In Australia, few phytophagous arthropods occur on *P. myrtifolia*, and herbivory damage is low to negligible. Low herbivory pressure in Australia may contribute to the success of *P. myrtifolia* as an environmental weed. In contrast, phytophagous species can cause substantial damage to *P. myrtifolia* in South Africa, and several species have potential for classical biological control (Adair and Neser 1996). Although *P. myrtifolia* has not been formally accepted as a target for biological control in Australia, this form of suppression is considered the only effective long-term management option.

In this paper, the phytophagous biota associated with *P. myrtifolia* and their potential for biological control are discussed with an emphasis on potential impact on plant health and possible conflicts of interest with horticultural industries. A comparison of herbivory levels on *P. myrtifolia* in South Africa and Australia is made.

Methods
Survey for phytophagous species
Sampling of phytophagous organisms and pathogens associated with *P. myrtifolia* and other Polygalaceae was undertaken between 1996 and 2003 at 41 sites in South Africa, most of which were in the Western Cape (Figure 2). Most sites were sampled once, usually in the spring–summer period.

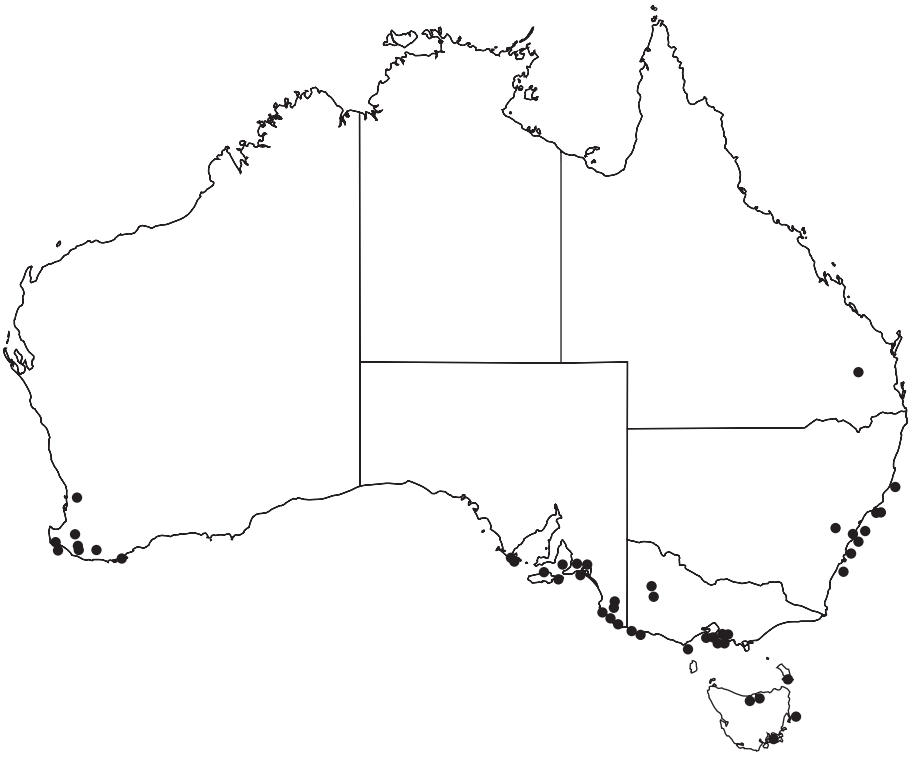

Figure 1. Australian distribution of *Polygala myrtifolia* based on Australia's Virtual Herbarium (2011) records.

At a survey site, plants from the Polygalaceae were haphazardly chosen and visually searched for the presence of damaging species. Most survey sites were selected where *P. myrtifolia* was the dominant polygalaceous species present. Other species included in the survey were: *P. fruticosa* P.J.Bergius., *P. teretifolia* L.f., *P. pedunculares* Burch. ex DC., *Polygala myrtifolia* var. *pinifolia* (Lam. ex Poir.) Paiva, *P.* sp. (labelled as *P. empetrifolia* Houtt.), *Muraltia heisteria* (L.) DC. and *Nylandtia spinosa* (L.) Dumort.

Where damage symptoms were evident, stems, twigs or roots were dissected for evidence of phytophage activity and suspected causative agents were collected. Sweep netting and beating were also utilized in instances where bushes were dense and difficult to search visually. Buds, flowers, fruits and seeds were collected, if available, and dissected for phytophagous organisms. Adult arthropods were collected, preserved and deposited with the South African National Insect Collection (Plant Protection Research Institute – Agricultural Research Council (PPRI-ARC), Pretoria) for identification. Mycological specimens were deposited with PPRI (Stellenbosch). If immature arthropod specimens were present, these were reared to adults in the laboratory using the same host taxa that they were collected from in the field as a food source. To increase the extent of the survey, all sheets of *Polygala* and *Muraltia* held at the Compton Herbarium, South African National Biodiversity Institute (SANBI), Kirstenbosch were examined for evidence of phytophage symptoms. Host and phytophage data were collected where clear identifications of phytophages could be made.

Comparison of herbivory levels between South Africa and Australia

In 1996, 15 sites in the Western Cape, South Africa and 12 sites in south-eastern Australia, were sampled for herbivory levels by haphazardly collecting 20–25 leaves from the canopy of 2–5 plants of *P. myrtifolia*. Sites in South Africa were sampled in January and February, and Australian sites were sampled mostly in February and March. Leaves were pressed and air-dried. Leaf damage levels were determined by scanning leaves with an ADC Area Meter (Bioscientific Ltd), and calculating leaf area removed from entire individual leaves. Levels of seed herbivory were determined by haphazardly sampling green, but full sized fruits of *P. myrtifolia* and counting the number of seeds in each capsule. Seeds were dissected and searched for signs of herbivory. At least 10 fruits were collected from each of 1–6 plants, where they were available. Inflorescence size and herbivory damage levels were determined by haphazardly sampling racemes from each of 2–4 plants of *P. myrtifolia*. Buds, flowers and fruits were counted to give a measure of inflorescence size, and all floral units were dissected for evidence of herbivory. Shed floral structures were also counted and were recognized by the presence of small bracteoles on the raceme rachis. Data from Australian and South African collections of *P. myrtifolia* were compared using a Students *t*-test assuming unequal variance to determine differences between means. Percentage data was arcsine transformed before analysis.

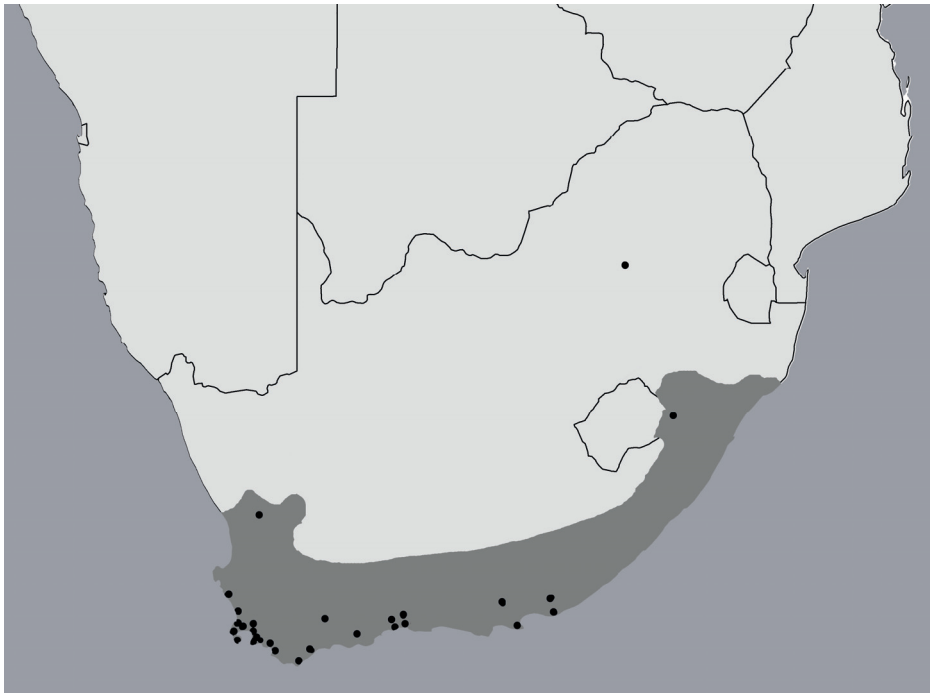

Figure 2. Distribution of *Polygala myrtifolia* in South Africa (shaded) and location of survey points (●) for phytophagous organisms.

Results

Location of survey sites

Survey sites for phytophagous species were located across the distribution of *P. myrtifolia*, with 32 out of 41 sites present in the Western Cape, the centre of distribution for *P. myrtifolia* (Table 1). Plants of *P. myrtifolia* were found in a range of habitats from coastal strandveld, usually on rocky outcrops close to the high tide mark (Figure 3a), macchia and coastal macchia, renosterveld and mesic succulent thicket. *Polygala myrtifolia* var. *grandiflora* Hook. (see Curtis 1837) occurs naturally in coastal vegetation of southern South Africa, particularly in the Knysna region, and was located at six survey sites.

Phytophagous species

Twenty-eight phytophagous species from six orders were found on *P. myrtifolia* in South Africa (Table 2). Hemiptera was the best represented order with 11 phytophagous species. Sixteen out of 28 species were external feeders and 11 were internal feeders. Leaves and flowers were used as food sources by the greatest number of organisms with eight and seven species, respectively. The only pathogenic fungus found on *P. myrtifolia* was *Uredo polygalae* Kalchbr. which forms pustules on mature leaves.

Herbivory levels

The mean number of flowers produced on racemes, the level of floral abortion, number of seeds produced per capsule, and leaf size were not significantly different between Australian and South African populations of *P. myrtifolia* (Table 3, 4). However, leaf and inflorescences herbivory levels of *P. myrtifolia* populations in South Africa were significantly higher than in Australian populations. Although mean leaf herbivory levels were 0.1% in Australian populations, low herbivory levels (3.3%) were also recorded for South African populations. No seed herbivory was detected in Australian and South African populations of *P. myrtifolia* (Table 3).

Discussion

Australian populations of *P. myrtifolia* are subject to very low levels of leaf, flower and seed damage. Stem and root herbivory was not quantified in this study, although these organs could support as yet undetected pathogens and arthropods. Release from herbivory pressure is likely to be a contributing factor to the success of *P. myrtifolia* as an invader in suitable Australian climates. A total of 28 organisms were found associated with *P. myrtifolia* in South Africa, a modest fauna tally compared to other plants from the region with size and distribution similarities

(113 taxa from *Chrysanthemoides monilifera* (L.) Norl. (Scott and Adair 1990), 400 from *Delairea odorata* Lem. (Grobbelaar *et al*. 2003), 14 from *Senecio madagascariensis* Poir. (Marohasy 1989), and 31 from *Solanum linnaeanum* Hepper & P.-M.L.Jaeger, 49 from *S. panduriforme* Drège ex Dunal and 33 from *S. incanum* L. (Olckers and Hulley 1989, Olckers *et al*. 1995). However, more regular and intense surveys of phytophagous organisms associated with *P. myrtifolia*, particularly in KwaZulu-Natal and the Cedarberg Range north of Cape Town, both areas not well sampled in this study, may increase the total number of organisms known from this plant.

Six organisms found in South Africa potentially reduce growth or reproductive output of *P. myrtifolia*. All require further study on aspects of their biology, host-specificity or taxonomy. In addition, the impact efficacy of these agents needs to be formally assessed by incorporating potential damage attributes into modelled life-history dynamics of *P. myrtifolia.* This approach is outlined by Briese (2006) and McClay and Balciunas (2006). Unfortunately, much of the data required for the construction of an informative life history model for *P. myrtifolia* is either unavailable or poorly detailed. The following organisms are potential biological control agents of *P. myrtifolia* and should receive priority for future evaluation programs:

Diaphorina petteyi Capener (Hemiptera: Psyllidae)

Nymphs and adults feed on the buds and flowers of *P. myrtifolia* causing disfiguration and abortion of fruits (Figure 3b). Early to late bud stages are attacked and many individuals may be found within a single flower bud. In heavily attacked plants, most inflorescences fail to develop and populations of *D. petteyi* are readily recognized by the absence of open flowers or the 'drying off' of inflorescence material. *Diaphorina petteyi* was found at 42% of survey sites across the distribution of *P. myrtifolia* in South Africa indicating a broad acceptance of host genotypes and climatic conditions. Only *P. myrtifolia* was found to be attacked by this insect indicating a high level of specificity. A sibling species, *D. florae*, is recorded from the flower heads of *P. fruticosa* (Capener 1970), which can occur sympatrically with *P. myrtifolia*. *Diaphorina petteyi* is parasitized, often heavily, by a *Pseudotorymus* sp. (Torymidae) and an unidentified braconid in South Africa.

Aceria myrtifoliae Meyer & Ueckermann (Acari: Eriophyiidae)

Immatures and adults feed in terminal and axillary buds causing rosette-like structures of fleshy, crinkly, leaves (Meyer and Ueckermann 1996) (Figure 3c). Both floral and vegetative buds are attacked resulting

Table 1. Field sites in South Africa surveyed for phytophagous organisms associated with *Polygala myrtifolia.*

Site #	Site name	Location	Host
1	Gordons Bay, Western Cape	34°12'S, 18°49'E	Pm
2	Betty's Bay, Western Cape	34°22'S, 18°53'E	Pm
3	Palmiet River, Western Cape	34°19'S, 18°58'E	Pm
4	East Fort, Cape Peninsula, Western Cape	34°03'S, 18°21'E	Pm
5	Millers Point, Cape Peninsula, Western Cape	34°15'S, 18°28'E	Pm
6	Hermanus, Western Cape	34°25'S, 19°09'E	Pm
7	Franskraal, Western Cape	34°36'S, 19°23'E	Pm
8	Cape Agulhas, Western Cape	34°49'S, 20°01'E	Pm
9	Goukamma Nature Reserve, Western Cape	34°04'S, 22°56'E	Pmg
10	Phantom Pass, Western Cape	34°00'S, 22°59'E	Pm, Pf
12	Van Stadens Pass, Eastern Cape	33°54'S, 25°11'E	Pm
13	Boesmansriviermond, Eastern Cape	33°41'S, 26°40'E	Pm
14	Kariega Nature Reserve, Eastern Cape	33°21'S, 25°44'E	Pm
15	Fairy Knowe, Western Cape	33°58'S, 22°35'E	Pmg
16	Gourits River, Western Cape	34°14'S, 21°47'E	Pm
17	Barrydale, Western Cape	33°53'S, 20°43'E	Pm, Pmp
18	Kogel Bay, Western Cape	34°13'S, 18°50'E	Pm
19	Klippers Bay, Western Cape	34°13'S, 18°50'E	Pm
20	Rhodes Memorial, Rondebosch, Western Cape	33°57'E, 18°27'E	Pm
21	Postberg Nature Reserve, Langebaan, Western Cape	33°07'S, 18°01'S	Pm
22	Silvermine Nature Reserve, Cape Peninsula, Western Cape	34°05'S, 18°25'E	Pm, Mh
23	Kirstenbosch Botanic Gardens, Cape Town, Western Cape	33°59'S, 18°25'E	Pm
24	Cape of Good Hope Nature Reserve, Western Cape	34°21'S, 18°29'E	Pm
25	Sedgefield, Western Cape	34°01'S, 22°49'E	Pmg
26	Stellenbosch, Western Cape	33°55'S, 18°51'E	Pm, Pv
27	De Hoop Nature Reserve, Western Cape	34°28'S, 20°25'E	Pm, Ppd
28	De Hoop Nature Reserve, Potberg, Western Cape	34°28'S, 20°24'E	Pm
29	Giant's Castle Pass, Drakensburg Mountains, KwaZulu Natal	29°16'S, 29°31'E	Pm
30	Pretoria National Botanical Institute, Pretoria, Gauteng	25°44'S, 28°16'E	Pmg
31	Struisbaai, Western Cape	34°48'S, 20°03'E	Pm
32	Red Hill, Silvermine Nature Reserve, Western Cape	34°06'S, 18°24'E	Pm
33	Kleinmond, Western Cape	34°20'S, 19°00'E	Pm
34	Rooi Els, Western Cape	34°17'S, 18°49'E	Pm
35	Grahamstown, Eastern Cape	33°15'S, 26°35'E	Pm
36	Grahamstown, Eastern Cape	33°19'S, 26°31'E	Pm
37	Yzerfontein, Western Cape	33°20'S, 18°09'E	Pm
38	Lake Brenton, Western Cape	34°03'S, 23°01'E	Pmg
39	Port Elizabeth, Eastern Cape	34°00'S, 25°41'E	Pmg
40	Homtini Pass, Western Cape	33°56'S, 22°54'E	Pf
41	Papkuilsfontein, Western Cape	31°26'S, 19°08'E	Pm, Ns

Pm = *Polygala myrtifolia* var. *myrtifolia*, Pmg = *P. myrtifolia* var. *grandiflora*, Pmp = *P. myrtifolia* var. *pinifolia*, Ppd = *P. peduncularis*, Pf = *P. fruticosa*, Pv = *P. virgata*, Mh = *Muraltia heisteria*, Ns = *Nylandtia spinosa.*

Figure 3. Biological control of *Polygala myrtifolia*. a) Low stature plants on pebble beach at Betty's Bay, Western Cape Province. b) *Diaphorina petteyi* damage to flowers and buds. c) Shoot galls formed by *Aceria myrtifoliae*. d) ?*Coryphodema* sp. larva in split basal stem of *P. myrtifolia*. e) *Duffyoemida barkeri* from *P. fruticosa*. f) Shoot-tip galls formed by *Dasineura* sp. g) Leaf lesions of *Uredo polygalae* from *P. myrtifolia* at Betty's Bay.

Table 2. Phytophagous species collected on *Polygala myrtifolia* in South Africa.

Order/family	Species	Sites	Host[A]	Abundance[B]	Organs attacked	Impact[C]	References/accession #s
Lepidoptera							
Cossidae	*?Coryphodema.* sp.	1, 2, 4, 6, 7, 9, 14, 15, 16, 18, 22, 35, 37	**Pm**, Pmg	A	stems, roots	D/K	UCT594, 611; AcSN1879
Tortricidae	*Tortrix capensana* (Walker)	25	**Pmg**	R	shoot tips	N	AcUCT559
	Tortrix sp.	2, 7, 8, 9, 12, 13, 15, 16, 31, 32, 34, 36, 37, 38	**Pm**, Pmg	S	shoot tips, flowers	S	
Psychidae	Unidentified taxon	14	Pm	R	leaves	N	
Coleoptera							
Curculionidae	*Diaphna* sp. nr *D. odiosa* (Botheman)	6, 38	**Pm**	R	roots, crown	K	AcSN1838
Cerambycidae	*Duffyoemida barkeri* Martins	1, 2, 6, 13, 15, 16, 17, 18, 22, 35, 38, 40	**Pm**, Pmg Pf, Pp, ?Mh	C	stems	D	AcSN1823
Bupestridae	Unidentified taxon	40	Pf	R	roots	?S	
Hemiptera							
Aphidae	Unidentified taxon	7, 31,	Pm	R	stems	S	
Psyllidae	*Diaphorina petteyi* Capener	2, 6, 9, 14, 15, 16, 17, 20, 21, 22, 23, 26, 27, 36, 37, 38, 41	**Pm, Pmg**, Pmp	A	buds, flowers, fruits	D	Capener 1970
Coccidae	*Pulvinaria* sp.	1, 6, ?37	**Pm**, Pmp, Ppd,	S	stems	N	
Pseudococcidae	Unidentified taxon	4, 12, 31, 34	Pm	S	buds, flowers	N	
Aleyrodidae	Unidentified taxon	10, 40,	Pm, Pf, Pmp	R	leaves	N	
Cicadellidae	*Bonaspeia cedari* Davies	2, 7, 8, 16, 31	**Pm**	S	leaves	N	UCT579-584
Miridae	Unidentified taxon	7	Pm	R	seeds	?S	UCT567-578
Pentatomidae	*?Dryadocoris* sp.	7	**Pm**	R	leaves, flowers, fruits	N	UCT585-592
	Nezara viridula (L.)	7	**Pm**	R	stems	S	
	Unidentified taxon	7	**Pm**	R	stems	N	UCT593
Scutelleridae	Unidentified taxon	14	**Pm**	R	leaves	N	
Diptera							
Agromyzidae	Unidentified taxon	1, 5, 6, 9, 10, 12, 13, 14, 15, 16, 17, 22, 27, 28, 36, 37, 40	**Pm**[4], **Pmg**, Pt[2], Pmp, Pf, Ppd[2],	C	stems	S	AcUCT595, 605
	Unidentified taxon	5, 7, 9, 12, 13, 14, 15, 18, 20, 21, 22, 34, 38	**Pm, Pmg**, Ppd	C	leaves	N	AcUCT596, 601, 604, 605
Cecidomyiidae	*Lasioptera* sp.	3, 18, 22	**Pm**	R	small stems	N	AcUCT524,
	Clinodiplosis sp. *Dasineura* sp.	2, 4, 5, 12, 13, 14, 16, 17, 22, 27, 28, 32, 34, 36, 37	**Pmg**, Pmp[3], Pt[2], Psp, Ppd	C	shoot apices	D	AcUCT525, RJA3081
	Contarinia sp.	2, 6	**Pmg**	R	buds	S	RJA3049
Thysanoptera	Unidentified taxon	1, 5, 6, 7, 9, 41	**Pm**, Pmg	S	flowers, fruits	S	
Acari							
Eriophyiidae	*Aceria myrtifoliae* Meyer & Ueckermann	12, 13, 14, 25, 26, 29, 30, 34, 36, 37, 40	**Pm, Pmg**[5]	S	shoot tips, buds	D	Meyer and Ueckermann (1996)
Tetranychidae	*Tetranychus urticae* (Koch)	40	Pf	R	leaves, seedlings	S	
Uredinales	*Uredo polygalae* Kalchbr.	2, 9, 33, 38	**Pm, Pmg**, Pf, [1, 2]	S	leaves	S	

[A] Pm *Polygala myrtifolia* var. *myrtifolia*, Pmg *Polygala myrtifolia* var. *grandiflora*, Pf *Polygala fruticosa*, Pt *Polygala teretifolia*, Psp *Polygala* sp. (labelled as *P. empetrifolia*), Ppd *Polygala peduncularis*, Pmp *Polygala myrtifolia* var. *pinifolia*, Mh *Muraltia heisteria*, Ns *Nylandtia spinosa.* Hosts listed in bold are those where specimens were collected and submitted for identification. 1. *Polygala fruticosa* in Compton Herbarium Sheet 3573, 3567. 2. Record based on herbariun specimens showing symptoms of attack the same as seem in field specimens. 3. An unidentified Cecidomyiidae that galls flowers of *P. myrtifolia* var. *pinifolia* may be also be present on this host. 4 *Ophiomyia* sp. with similar gall symptoms was reared from *M. heisteria* (AcUCT526). 5 Gall-forming *Aceria* from *P. fruticosa, P. virgata* and *N. spinosa* can be distinguished morphologically from *A. myrtifoliae.* [B] A = abundant (often in high numbers), C = common (at most sites but in small numbers), S = sporadic (at a small number of sites, but sometimes in abundance), R = rare (few sites with few individuals seen). [C] K = capable of killing host, D = debilitates host but recovery usually occurs, S = slight impact, N = negligible impact.

Table 3. Herbivory levels from *Polygala myrtifolia* collected from South Africa and southern Australia.

Site	State/ Province[1]	No. flowers/ raceme[2]	n[3]	Inflorescence herbivory[4]	Floral shedding[5]	No. seeds/ capsule[6]	n[7]	Seed herbivory[8]	Leaf herbivory[9]	Leaf area[10]
Australia										
Merimbula	NSW	7.1 ± 1.2	4 (43)	0.5 (217)	28.1 ± 9.3	1.7 ± 0.03	4 (145)	0	0	176.2 (5)
Coolart	VIC	9.6 ± 0.2	4 (40)	0.4 (250)	34.1 ± 13.1	1.6 ± 0.3	4 (111)	0	0.13	222.1 (4)
Mornington	VIC	10.2 ± 1.6	4 (40)	0 (258)	34.1 ± 10.2	1.5 ± 0.3	4 (43)	0	0.27	153.8 (4)
Victor Harbour	SA	9.5 ± 1.5	4 (41)	0.3 (308)	23.0 ± 6.6	1.5 ± 0.1	3 (60)	0	n/a	n/a
Point Nepean	VIC	11.2 ± 1.3	4 (35)	0 (202)	42.1 ± 9.4	1.8 ± 0.3	3 (42)	0	0	176.7 (4)
Quakers Hut	NSW	9.9 ± 0.5	4 (39)	1.0 (204)	46.2 ± 12.5	1.5 ± 0.5	3 (44)	0	0.69	98.5 (4)
Rye	VIC	10.7 ± 1.6	3 (28)	0 (262)	21.9 ± 7.4	1.6 ± 0.2	3 (72)	0	0	143.4 (3)
Dalrymple	NSW	6.2 ± 2.4	2 (28)	0 (178)	n/a	1.7 ± 0.06	2 (24)	0	0.3	226.3 (3)
Swan Lake	VIC	7.3 ± 1.6	3 (32)	6.7 (179)	22.2 ± 3.8	n/a	n/a	n/a	0	179.8 (3)
Sandy Beach	TAS	11.5 ± 3.8	4 (40)	0 (413)	34.7 ± 12.7	1.7 ± 0.1	4 (63)	0	0	123.5 (4)
Casula	NSW	4.3 ± 0.8	3 (35)	0 (151)	25.1 ± 11.1	1.7 ± 0.2	3 (57)	0	0	138.7 (3)
John Forest	WA	11.7 ± 2.8	2 (25)	0.4 (263)	10.2 ± 3.5	1.9	1 (23)	0	0	161.8 (2)
South Africa										
Goukamma	WC	5.9 ± 1.7	3 (8)	11.6 (69)	n/a	1.6 ± 0.5	1 (28)	0	5.1	235.3 (3)
Cape Agulhas	WC	3.4 ± 0.4	2 (17)	0 (59)	31.2 ± 13.6	1.7 ± 0.5	2 (6)	0	0.7	125.3 (3)
Franskraal	WC	10.0 ± 0.5	3 (15)	1.1 (90)	33.1 ± 14.8	1.8 ± 0.2	3 (25)	0	1.7	157.5 (3)
Gouritz River	WC	9.4 ± 3.7	6 (23)	40.8 (144)	38.0 ± 24.9	1.1 ± 0.4	1 (29)	0	6.7	55.3 (3)
Fairy Knowe	WC	7.1 ± 2.8	2 (14)	45.5 (77)	71.7 ± 8.6	n/a	n/a	n/a	4.8	314.8 (3)
Kariega	EC	3.7 ± 0.4	3 (31)	42.3 (78)	28.7 ± 4.2	n/a	n/a	n/a	3.5	83.6 (4)
Rhodes Memorial	WC	8.4 ± 2.1	3 (16)	18.2 (99)	29.2 ± 10.2	1.59 ± 0.5	1 (27)	0	n/a	n/a
Hermanus	WC	8.8 ± 1.8	4 (24)	9.8 (132)	39.0 ± 8.5	1.7 ± 0.02	2 (23)	0	3.3	137.4 (3)
Millers Point	WC	9.1 ± 2.2	1 (9)	15.4 (52)	n/a	1.5 ± 0.2	2 (23)	0	1.1	149.9 (2)
Sandy Point	WC	n/a	n/a	n/a	n/a	1.4 ± 0.4	3 (29)	0	2.1	120.7 (3)

[1] VIC = Victoria, NSW = New South Wales, SA = South Australia, WA = Western Australia, TAS = Tasmania, WC = Western Cape, EC = Eastern Cape
[2] Mean maximum number of floral units per raceme ± standard deviation. Includes abortion scars.
[3] Number of plants sampled (total number of racemes per site)
[4] Mean percentage herbivory in buds, flowers and fruits (seeds excluded) (total number of floral organs sampled)
[5] Mean percentage of floral units shed per raceme ± standard deviation
[6] Mean number of seeds per capsule ± standard deviation.
[7] Number of plants sampled for capsules (total number of capsules sampled)
[8] Mean percentage of seed herbivory
[9] Mean percentage of leaf area destroyed by herbivory
[10] Mean leaf area (mm^2) (number of plants sampled)
n/a data not available

Table 4. Comparison of herbivory levels between Australian and South African populations of *Polygala myrtifolia*. Data are means from sites sampled in each country ± standard deviation. NS = means not significantly different. Superscripts follow Table 3.

	No. flowers/ raceme[2]	Inflorescence herbivory[4]	Floral dehiscence [5]	No. seeds/ capsule[6]	Seed herbivory[8]	Leaf herbivory[9]	Leaf area[10]
Australia	9.1 ± 2.3	0.7 ± 1.9	29.2 ± 10.3	1.7 ± 0.1	0	0.1 ± 0.2	164.1 ± 36.8
South Africa	7.3 ± 2.4	20.5 ± 17.8	38.7 ± 15.1	1.6 ± 0.2	0	3.3 ± 1.9	154.0 ± 74.1
P	NS, P = 0.1	P = 0.004	NS, P = 0.3	NS, P = 0.6	–	P = 0.0005	NS, P = 0.7

in stunted growth and a substantial reduction in flower and fruit production. *Aceria myrtifoliae* was found on *P. myrtifolia* in the Western Cape, growing in garden situations, while natural occurrences were found at 11 sites across a broad climatic range. *Polygala myrtifolia* var. *grandiflora* was severely galled by *A. myrtifoliae* in Gauteng in garden situations. *Polygala virgata* Thunb. is galled by *A. virgatae* (Meyer and Ueckermann 1996) in South Africa. Evidence of eriophyiid damage to shoot tips was found on a herbarium specimen of *P. leptophylla* Burch. (Compton Herbarium Sheet Number 115452) from Vioolsdrift in the Northern Cape, but whether this was caused by *A. myrtifoliae* remains to be determined. In exploratory tests, Australian accessions of *P. myrtifolia* var. *myrtifolia* collected from Anglesea (Victoria) were susceptible to *A. myrtifoliae*, with galls forming in shoot and floral apices within several weeks from inoculation. Biotypes of *A. myrtifoliae* galls collected from Stellenbosch from the Western Cape form of *P. myrtifolia* failed to give rise to gall symptoms on *P. myrtifolia* var. *grandiflora*. *Aceria* from shoot galls on the Australian native Polygalaceae species *Comesperma volubile* Labill. and *P. japonica* Houtt. and the South African species *N. spinosa* and *M. heisteria* are distinguishable from *A. myrtifoliae* using morphological features, but require more detailed examination including biological and molecular characteristics to determine if all belong to a single variable species, or to a complex of sibling species (Craemer 2001).

?Coryphodema sp. (Lepidoptera: Cossidae)

The larvae of *?Coryphodema* are conspicuously red-coloured and feed on woody tissue in the roots, crown, trunk and branches of *P. myrtifolia* (Figure 3d). Large tunnels are created by larvae and infected plants may contain many individuals at various stages of development, indicating a mutivoltine breeding cycle. Infected plants show signs of stem die-back and heavily infected plants may completely die. No evidence of pupation was found within feeding sites suggesting that larvae move out of the plant and perhaps construct cocoons in the soil. Larvae are highly mobile when removed from *P. myrtifolia*. Adults were obtained by transferring larvae to Petri dishes containing blocks of a meridic medium (Harley and Willson 1968), where larvae continued development, often for several months, before forming flimsy silk cocoons in which pupation occurred. Adults emerged within 2–3 weeks of pupation at room temperature. *?Coryphodema* is widely distributed on *P. myrtifolia* in southern South Africa and was collected from 13 sites and only from *P. myrtifolia*. *Coryphodema tristis* Drury (Apple Trunk Borer) is a polyphagous pest in South Africa (Annecke and Moran 1982) and further specimens of *?Coryphodema* sp. are required to clarify the identity of this insect.

Duffyoemida barkeri Martins (Coleoptera: Cerambycidae)

Larvae bore through the woody tissue of stems and branches of *P. myrtifolia* causing die-back of branches and in severe cases branch death (Figure 3e). Feeding tunnels are long and packed with frass. Pupation occurs within the stem and there is no cocoon produced. All adults were collected during summer, but the presence of larvae in various stages of development within a single plant suggest that emergence may occur over a longer period of time. *D. barkeri* is widely distributed *on P. myrtifolia* in South Africa and was found at 12 sites (29% of total), all in near-coastal situations and mostly in the Western Cape. Cerambycid feeding damage similar to that caused by *D. barkeri* on *P. myrtifolia* was found on *P. fruticosa*, *P. myrtifolia* var. *pinifolia* and *M. heisteria*, but specimens were not obtained for identification.

Dasineura sp. – shoot tip galler (Diptera: Cecidomyiidae)

Several Cecidomyiidae species were collected from *P. myrtifolia* in South Africa, but the most abundant and most damaging species was a gall-forming *Dasineura* sp., which induces stunted stem growth and in some cases death of the stem meristems (Figure 3f). Galls consist of crowded, rosette-like structures of overlapping leaves which are reduced in size and bunched together to forming a bulbous swelling around 20 mm diameter. Larvae feed in a smooth cup-like cavity in the centre of the gall around the shoot meristem and are gregarious. Active galls are present on *P. myrtifolia* during spring and summer. Shoot growth can resume from the gall after the completion of feeding by cecidomyiid larvae. Galls were widespread on *P. myrtifolia* and were found from the far western Cape to Boesmansriviermond in the Eastern Cape. Shoot-tip galls with identical morphology were found in the field on *P. myrtifolia* var. *pinifolia* and *P. peduncularis* and on herbarium specimens of *P. teretifolia* and *P.* sp. (labelled as *P. empetrifolia* Houtt., a name of uncertain application). While Cecidomyiidae are generally highly specific to a single host species or closely related taxa (Gagné 1989), it is unclear whether one or a number of species are responsible for shoot-galls on *Polygala* in South Africa. Galls were utilized by a Pseudococcidae and early instar stages of *Tortrix* sp. which would have contributed to herbivory pressure to the host plant. In addition, *Clinodiplosis* sp. (Cecidomyiidae) was reared from *Dasineura* galls and is assumed to be a predatory inquiline, not a primary gall former.

Uredo polygalae Kalchbr. (Uredinales)

Infection by *U. polygalae* leads to the formation of patchy to general chlorosis and dark necrotic patches on foliage of *P. myrtifolia* (Figure 3g). Urediniospores develop on the upper or lower surface of leaves. Severely infected foliage appears to fall prematurely from the plant, but due to limited levels of attack in South Africa, high levels of defoliation were never noted. In South Africa, a secondary fungus has been recorded from the pustules of *U. polygalae* (M. Morris personal communication, 1996), which may limit the impact of *U. polygalae* on its host. *U. polygalae* was found at four sites in South Africa and only on *P. myrtifolia* (including *P. myrtifolia* var. *grandiflora*). Herbarium sheets of *P. fruticosa* from Kirstenbosch (Compton Herbarium 3573 and 3567) and Montagu were found with symptoms resembling *U. polygalae* infection, but further diagnostic effort is required to confirm whether these are *U. polygalae*. The sexual teleomorph stage of *U. polygalae* was not found on *P. myrtifolia* in South Africa. Either this stage may have been lost from the reproductive cycle of *U. polygalae*, or may occur on an alternative host species. Resolving this aspect of the biology of *U. polygalae* is an important step before this fungus can be considered as a potential biological control agent for *P. myrtifolia*.

In South Africa, *P. myrtifolia* is one of the most polymorphic members of the genus, and has several distinct forms that are connected by series of intergrades which make separation into well defined taxa difficult (Harvey 1860, Levyns 1955). Currently only *P. myrtifolia* var. *myrtifolia* and *P. myrtifolia* var. *pinifolia* are formally taxonomically recognized (Paiva 1998).

Application of molecular-based techniques is required to resolve the taxonomy of *P. myrtifolia*. In Australian horticulture there are several forms of *P. myrtifolia*, at least two of which are relatively distinctive. The most common form closely matches the morphological characters of *P. myrtifolia* found in coastal and hilly situations on the Cape Peninsula, and is characterized by obovate, elliptic to broad-elliptic leaves (10–40 mm long) that are obtuse to shallowly emarginate, and with lateral wing-like sepals (12–18 mm) that are mauve on the inner surface and green on the outer surface. The second form is similar to *P. m.* var. *grandiflora* and *P. myrtifolia* 'Grandiflora', but both *P. m.* var. *grandiflora* and *P. myrtifolia* 'Grandiflora' are distinguished by longer and wider leaves that are darker green and with more acute apices; longer and wider wings which are rich purple on both the inner and outer surfaces. The taxonomy and nomenclature of *P. myrtifolia* var. *grandiflora* and *P. myrtifolia* 'Grandiflora' is complex and requires clarification, and both may be utilized in the Australian horticulture industry

(Hibbert 2004). Other *Polygala* species (*P. fruticosa*, *P. chamaebuxus* L. and hybrids (*P.* × 'Dalmaisiana') are also used in Australian horticulture. Planned biological control of *P. myrtifolia* needs to take into account possible conflicts of interest with those that derive benefits from this plant. In South Africa, *P. myrtifolia* is reported as an ethnomedicinal plant having inhibition activity against the human respiratory bacteria *Mycobacterium tuberculosis* (Lall and Meyer 1999). While naturalized *P. myrtifolia* currently has negligible commercial and ecological value in Australia, non-target impacts to closely related taxa, require careful assessment. Horticultural forms of *Polygala myrtifolia* are at most risk from potential biological control agents. Although *P. myrtifolia* and cultivars are permitted in Australian horticulture, a review of the potential threat posed by *P. myrtifolia* and other invasive plants is under consideration in some jurisdictions (Weiss *et al*. 2004). As the large-flowered horticultural forms of *P. myrtifolia* produce viable seeds and seedlings in Australia, and are not sterile, as commonly believed, there is a risk that these forms will become naturalized, and may have already done so in southern Victoria (Molenaar 1996). Australian native *Polygala* are likely to be at little risk from stenophagous organisms selected from *P. myrtifolia*, as most have vastly different life strategies (annual and herbaceous versus perennial and woody), have allopatric distributions due to large differences in eco-climatic limits, and differ considerably in morphological features such as leaf and flower size.

In the absence of capability to effectively contain *P. myrtifolia* infestations in Australia, classical biological control has been recommended (Scott and Delfosse 1992, Adair and Neser 1996), although the species is not yet formally accepted as a target. Others have ranked *P. myrtifolia* as a low priority for classical biological control (Paynter *et al*. 2009) as the species had relatively low importance at a national scale. However, impacts at a regional scale are significant and escalating, and the low Weeds of National Significance score used in the national assessment (Paynter *et al*. 2009) should not preclude *P. myrtifolia* for consideration as a target for biological control.

The distribution of *P. m*. var. *myrtifolia* in southern Australia is scattered, with expanding populations, particularly in coastal areas. The application of classical biological control has the potential to reduce the rate of spread into new areas, as well as reducing the ecological impact in established infestations. Early intervention by application of biological control before *P. m*. var. *myrtifolia* reaches its full distribution in Australia would therefore be a highly cost-effective management option. Utilization of inundative biocontrol approaches with existing organisms, such as *Cylindrocladium pauciramosum* C.L.Schoch & Crous (teleomorph *Calonectria pauciramosa* C.L.Schoch & Crous), a generalist pathogen known to infect *P. myrtifolia* in Europe (Polizzi and Crous 1999, Perez-Sierra *et al*. 2006), and also present in Australia (Cunnington 2003), is worthy of consideration.

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