Invertebrate fauna of boneseed, *Chrysanthemoides monilifera* ssp. *monilifera* (L.) T. Norl. (Asteraceae: Calenduleae), an invasive weed in New Zealand

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Abstract

Boneseed, *Chrysanthemoides monilifera* ssp. *monilifera*, is a serious invasive weed in New Zealand, particularly in coastal habitats throughout the North Island, northern parts of the South Island, and in the Port Hills near Christchurch. The invertebrate fauna associated with boneseed in New Zealand was surveyed in 1999-2000 as part of a biological control programme for the weed. Boneseed is attacked by a wide range of native and exotic insects but damage is usually not severe. Potential biological control agents that feed on foliage or seeds are unlikely to meet with significant competition from species already resident in this country. However, the combined effect of generalist predators, such as Argentine ants and spiders, and parasitoids could inhibit the effectiveness of some of the invertebrates that would be potential biological control agents. In New Zealand, most (if not all) herbivore niches on boneseed are under-utilised, and there is considerable scope for the introduction of specialised invertebrates that could reduce the vigour of this invasive weed.

Keywords: Invertebrate fauna, boneseed, *Chrysanthemoides monilifera* ssp. *monilifera*, New Zealand.

Introduction

Chrysanthemoides monilifera (Asteraceae: Calenduleae), a native of South Africa, has been introduced into several countries including Australia, Italy, St Helena, and France (Weiss 1986, Scott 1996). The one subspecies established in New Zealand is *C. monilifera* ssp. *monilifera* (L.) T. Norl., commonly known as boneseed, and occasionally referred to as salt bush. *C. monilifera* ssp. *monilifera* and a second subspecies, *C. monilifera* ssp. *rotundata* (DD.) T. Norl. (bitou bush), are both weeds in Australia.

In New Zealand, boneseed occurs mainly in coastal habitats throughout the North Island, and in Nelson, Marlborough, the Port Hills of Christchurch, and Dunedin's Anderson's Bay in the South Island (Webb *et al.* 1988). It invades plant communities on coastal cliffs and dune-lands, and inland grassland and shrub communities. Dense thickets of boneseed can displace native vegetation. Studies carried out in South Africa and Australia show it to be frost-tolerant, able to grow on a variety of soil types, and tolerant of salinity (Weiss 1986). It grows in both full sun and partial shade.

Although boneseed was first recorded as naturalised in New Zealand in 1870, it is only in recent years that it has become a serious problem weed. It has undergone a lengthy "lag phase" (the period before a species becomes invasive in a new environment) but now appears to have entered a phase of rapid expansion. Biological control is considered appropriate because in many areas affected by boneseed the cost of control is prohibitive, or the use of herbicide is environmentally undesirable. Biological control aims to limit the growth and reproduction of a weed so that it becomes less competitive and is no longer a risk to our environment.

An initial requirement when assessing the feasibility of biological control of a weed is to survey the fauna already associated with the weed in the country of introduction. This allows the selection of exotic control candidates that will damage parts of the plant only lightly damaged in the country of introduction, or may reveal accidentally introduced biological control agents, eliminating them from future study (Michaux 1989). The invertebrate fauna associated with the above-ground parts of boneseed in New Zealand was surveyed in 1999-2000. Invertebrate parasitoids and predators were recorded in order to gain information on factors that may affect any future biological control introductions.

Methods

The invertebrate fauna associated with boneseed was surveyed at 19 sites over a wide geographic range (Fig.1) during the period October 1999 to April 2000. Ten boneseed bushes were selected randomly at each site. A collecting tray, 80 cm square, was placed under a suitable part of each selected boneseed bush, and the foliage above the tray was hit five times with a solid stick. Invertebrates that fell into the collecting tray were collected with an aspirator and the contents were emptied into a container filled with 95% alcohol. Lepidopterous larvae (caterpillars) were collected live and placed, along with boneseed foliage, in a ventilated container in order to rear through to adult stage for identification. Parasitoids emerging from the larvae were also identified.

Samples of berries and seeds were collected into ventilated containers, and any invertebrates emerging from them were identified. A rapid visual inspection, generally less than one minute per plant, was carried out of foliage, growing points, and stems for signs of invertebrates such as gall-formers, leaf miners, stem borers, and scale

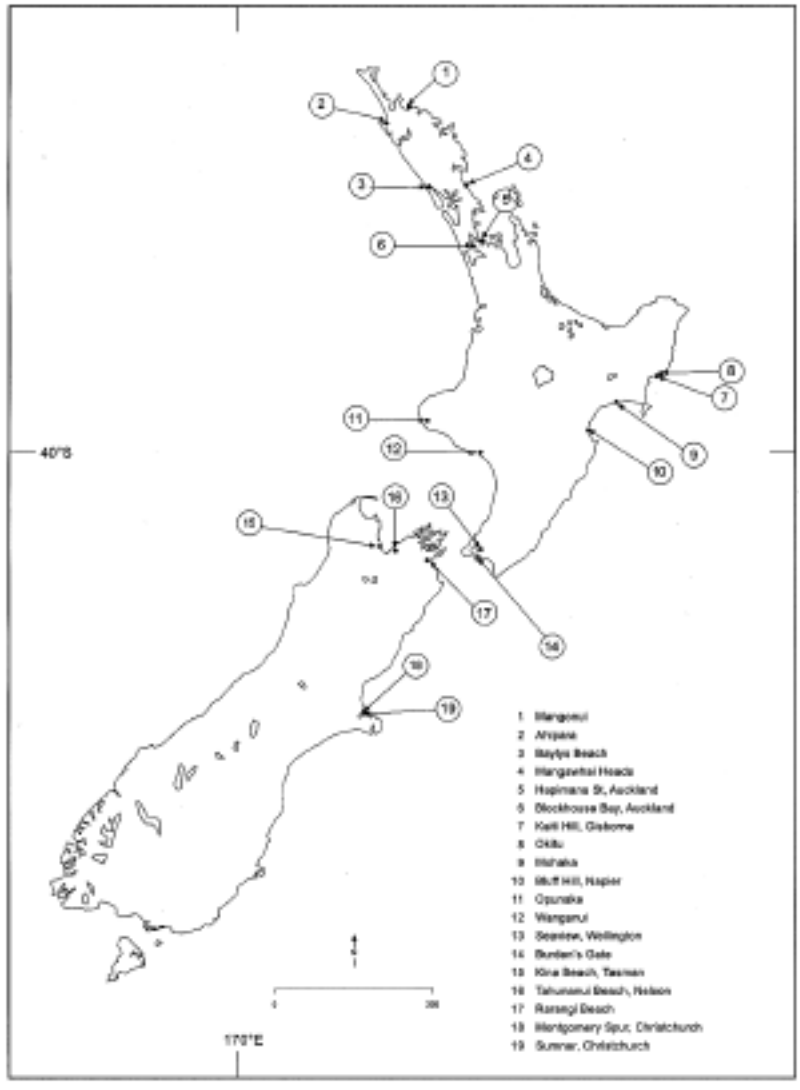

Fig. 1. Boneseed, *Chrysanthemoides monilifera* ssp. *monilifera*, fauna collection sites 1999–2000.

Table 1. Invertebrate species collected from boneseed at 19 New Zealand sites during 1999–2000.
Note: Taxa listed with an asterisk in the 'Origin' column were introduced to New Zealand for biological control purposes

Species	Feeding mode	Frequency	Origin	Collection sites
Species	**Feeding mode**	**Frequency**	**Origin**	**Collection sites**
Arthropoda				
Arachnida				
Acarina				
Anystidae				
Anystis sp.	predatory	common	introduced	1,2,3,9,10
Araneida				
unid. spiders (numerous species)	predatory	common		all sites
Pseudoscorpiones				
unid. pseudoscorpions	predatory	occasional		4
Crustacea				
Isopoda				
unid. slaters	detritivorous	occasional		2,15
Insecta				
Blattodea				
Celatoblatta sp.	detritivorous	occasional	native	2,3,15
Parellipsidium sp.	detritivorous	occasional	native	4,7,8,9,11,12,16
Celerioblattina minor (Johns)	detritivorous	occasional	native	1,2,9,10
Coleoptera				
Anthribidae				
Phymatus phymatodes (Redtenbacher)	fungivorous	occasional	native	7
Pleosporius bullatus (Sharp)	herbivorous	rare	native	4
Brentidae				
Exapion ulicis Forster (found adjacent to gorse bushes)	herbivorous	rare	introduced*	4
Cerambycidae				
Psilocnaeia nana (Bates)	herbivorous	occasional	native	4,5,13,18
Psilocnaeia parvula (White)	herbivorous	occasional	native	15,17

Species	Feeding mode	Frequency	Origin	Collection sites
Xyloteles griseus (F.)	herbivorous	occasional	native	4,5,13,16
Xyloteles humeratus Bates	herbivorous	occasional	native	2
Chrysomelidae				
Eucolaspis brunnea (F.)	herbivorous	occasional	native	5,13
Coccinellidae				
Adalia bipunctata (L.)	predatory	occasional	introduced*	1,7,8,12,13,16
Coccinella undecimpunctata L.	predatory	rare	introduced*	7,17
Coelophora inaequalis (F.)	predatory	rare	introduced	1,4,6
Cryptolaemus montrouzieri Mulsant	predatory	occasional	introduced*	1,3,5,6,8,11,12,16
Diomus notescens (Blackburn)	predatory	rare	introduced	3
Halmus chalybeus (Boisduval)	predatory	common	introduced*	1,2,8,9,10,12,16
Rodolia cardinalis Mulsant	predatory	rare	introduced	14
Rhyzobius fagus (Broun)	predatory	rare	introduced	11
Rhyzobius forstieri (Mulsant)	predatory	rare	introduced*	9
Scymnus loewi (Mulsant)	predatory	occasional	introduced	9
Curculionidae				
Asynonychus cervinus (Boheman)	herbivorous	common	introduced	1,2,6,9,10,12,16,17
Graphognathus leucoloma (Boheman)	herbivorous	occasional	introduced	7,10,17
Irenimus aequalis (Broun)	herbivorous	rare	native	19
Phlyctinus callosus Boheman	herbivorous	common	introduced	1,5,8,9,10,11,12,14, 16,17,18
Sericotrogus subaenescens Wollaston	larvae and adults in dead wood	occasional	native	2,4,12
Sitona discoideus Gyllenhal	herbivorous	rare	introduced	3
Elatridae				
Conoderus exsul (Sharp)	herbivorous	occasional	introduced	1,2,5,8,10
Conoderus posticus (Eschscholtz)	herbivorous	occasional	introduced	2

Species	Feeding mode	Frequency	Origin	Collection sites
Languriidae				
Loberus nitens (Sharp)	herbivorous	common	native	4,7,11,12,15,16
Latridiidae				
Melanophthalma sp.	fungivorous	common		9,11,12,16,18,19
Mordellidae				
Zeamordella monacha Broun	herbivorous	rare	native	5
Mycetophagidae				
Litargus balteatus LeConte	fungivorous	rare	introduced	2
Scirtidae (formerly Helodidae)				
unid. species	adults - pollen larvae - detritus	rare		2
Staphylinidae				
unid. species	predatory	rare		9
Dermaptera				
Forficula auricularia L.	omnivorous	occasional	introduced	4,5,7,8,10,12,15,16
Diptera				
Tachinidae				
Trigonospila brevifacies (Hardy)	parasitoid	rare	introduced*	4,13
Therevidae				
unid. species	larvae predacious	rare		16,17
Tipulidae				
Leptotarsus sp.	adults nectar feeders	rare		1,2,16,19
Hemiptera				
Anthocoridae				
Cardiastethus poweri White	sap feeder	occasional	native	1
Aphididae				
Aphis gossypii Glover	sap feeder	occasional	introduced	1,3
Aulacorthum solaniae (Kaltenbach)	sap feeder	occasional	introduced	12
Brachycaudus helichrysi (Kaltenbach)	sap feeder	occasional	introduced	15
Macrosiphon euphorbiae (Thomas)	sap feeder	occasional	introduced	12

Species	Feeding mode	Frequency	Origin	Collection sites
Cercopidae				
Philaenus spumarius (L.)	sap feeder	occasional	introduced	13,14,15,16,17,18,19
Cicadellidae				
Paracephaleus sp.	sap feeder	rare		19
Cicadidae				
Rhodopsalta cruentata (F.)	sap feeder	rare	native	16,18
cicada egg batches		occasional		2,4,5
Coccidae				
Parasaissetia nigra (Nietner)	sap feeder	common	introduced	1,3,5,6,10,16
Saissetia oleae (Olivier)	sap feeder	occasional	introduced	1,2,3,6
Delphacidae				
Ugyops sp.	sap feeder	occasional	native	2
Flatidae				
Anzora unicolor (Walker)	sap feeder	common	introduced	4,7,9,10,13,14,15,16
Siphanta acuta (Walker)	sap feeder	abundant	introduced	all sites except site 15
Lygaeidae				
Rhypodes sp.	plant/seed sucker	occasional	native	7,9,11,12,16
Miridae				
Diomocoris russatus Eyles	sap feeder	rare	native	16
Sidnia kinbergi (Stål)	plant/seed sucker	occasional	introduced	7
Chinamiris nigrifrons Eyles and Carvalho	sap feeder	rare	native	11
Membracidae				
Acanthucus trispinifer (Fairmaire)	sap feeder	occasional	introduced	5
Pentatomidae				
Cuspicona simplex Walker	sap feeder	rare	introduced	2,11
Dictyotus caenosus (Westwood)	sap feeder	rare	introduced	9
Glaucias amyoti (Dallas)	sap feeder	rare	native	16
Monteithiella humeralis (Walker)	sap feeder	occasional	introduced	11,13,16

Species	Feeding mode	Frequency	Origin	Collection sites
Nizara viridula (L.)	sap feeder	common	introduced	1,2,3,4,8,9,12,13,14,16
Oechalia shellenbergi (Guérin)	predatory	occasional	native	3,9
unid. pentatomid egg-batches		occasional		2,11,14
Ricaniidae				
Scolypopa australis (Walker)	sap feeder	abundant	introduced	1,2,4,5,6,7,9,10,12,13, 14,15,16,17
Scolypopa australis (Walker) egg-batches		common		4,9,10,12,15
Rhyparochromidae				
Metagerra obscura White	plant/seed sucker	occasional	native	16
Pachybrachius nigriceps (Dallas)	plant/seed sucker	occasional		9
Hymenoptera				
Aphelinidae				
Coccophagus sp.	parasitoid (reared from *Parasaissetia nigra*)	occasional		6
Aphidiidae				
Lysiphlebus testaceipes (Cresson)	parasitoid (reared from *Aphis gossypii*)	occasional	introduced	1
Apidae				
Bombus sp.	pollen and nectar feeder	rare	introduced	9
Braconidae				
unid. Microgastrinae	lepidopteran parasitoids	rare		18
Dryinidae				
unid. species	hemipteran ectoparasitoids	rare		8
Formicidae				
Monomorium antarcticum (F. Smith)	omnivorous	occasional	native	
Doleromyrma darwiniana (Forel)	omnivorous	occasional	introduced	18
Iridomyrmex anceps (Roger)	omnivorous	rare	introduced	9

Species	Feeding mode	Frequency	Origin	Collection sites
Linepithema humile (Mayr)	omnivorous	occasional	introduced	1,3,6
Ochetellus glaber (Mayr)	omnivorous	occasional	introduced	2,5,8,9,10
Paratrechina vaga (Forel)	omnivorous	occasional	introduced	1,5,16
Technomyrmex albipes (Smith)	omnivorous	occasional	introduced	4,5,7,9
Tetramorium bicarinatum (Nylander)	omnivorous	occasional	introduced	1
Ichneumonidae				
Anacis sp.	lepidopteran parasitoid	rare		8
Vespidae				
Polistes chinensis F.	omnivorous	rare	introduced	3
Vespula germanica (F.)	omnivorous	rare	introduced	2
Lepidoptera (collected as larvae and reared to adult for identification)				
Geometridae				
Chloroclystis inductata Walker	herbivorous	rare	native	19
Declana leptomera Walker	herbivorous	rare	native	19
Phrissogonus laticostatus Walker	herbivorous	rare	introduced	5
unid. geometrid larvae	herbivorous	occasional		14,17
Noctuidae				
Feredayia graminosa (Walker)	herbivorous	rare	native	16
Graphania sp.	herbivorous	rare	native	19
Oecophoridae				
unid. oecophorid larvae	herbivorous	rare		16
Psychidae				
Liothula omnivora (Fereday)	herbivorous	rare	native	7
undescribed species A	herbivorous	rare	introduced	1
undescribed species B	herbivorous	rare	introduced	12
Tortricidae				
'Cnephasia' jactatana Walker	herbivorous	occasional	native	4,5,16

Species	Feeding mode	Frequency	Origin	Collection sites
Ctenopseustis obliquana (Walker)	herbivorous	occasional	native	4,11,13
Epiphyas postvittana (Walker)	herbivorous	occasional	introduced	5,11,13,16,18,19
unid. tortricid larvae	herbivorous	occasional		2,9,12,17
Mantodea				
Miomantis caffra Saussure	predatory	occasional	introduced	1,5,7,13,16
Orthodera novaezealandiae (Colenso)	predatory	occasional	native	2,3,4,10,12,15
Neuroptera				
Micromus tasmaniae (Walker)	predatory	common	introduced	4,5,7,9,11,12,15,16,17
Orthoptera				
Anostostomatidae				
Hemideina thoracica White	omnivorous	rare	native	5
Gryllidae				
Bobilla sp.	herbivorous	rare	native	2
Tettigoniidae				
Caedicia simplex (Walker)	herbivorous	occasional	native	4,12,13,14,15
Conocephalus sp.	herbivorous	occasional	introduced	3
Phasmatodea				
Clitarchus hookeri (White)	herbivorous	rare	native	4
Psocoptera				
unid. species	detritivorous and fungivorous	common		1,2,3,5,18,19
Mollusca				
Gastropoda				
Cantareus aspersus (Müller)	herbivorous	occasional	introduced	14,16
unid. snails	herbivorous	occasional		4

insects, which are often missed by beat sampling. Sections of the stem were cut through to see if there were any invertebrates inside. Invertebrates found during the visual inspections were collected live, along with the boneseed material they were on, for identification. A visual estimate was made of the amount of foliage that appeared to have been consumed by herbivores (percent foliage consumed) and the likely cause of the damage was noted (e.g. adult weevils, leafroller caterpillars, etc.).

The species collected were identified, and then ranked on a scale of frequency according to the total number of individuals collected, and the number of sites at which they were present. They were allocated to four frequency classes according to the definitions below:

rare: fewer than 5 individuals collected
occasional: 5-29 individuals collected, **or** present at fewer than five sites
common: 30+ individuals collected **and** present at five or more sites
abundant: 200+ individuals collected **and** present at 10 or more sites.

Results

A list of invertebrates associated with boneseed in this survey is presented in Table 1. None are specialist on boneseed.

Herbivores

A total of 62 herbivorous invertebrate species were identified from specimens collected from boneseed during this survey. Two of those species (*Scolypopa australis* and *Siphanta acuta*) were classed as "abundant", six were "common", 30 were "occasional", and 24 were "rare".

Foliage feeders

The most obvious feeding damage observed on boneseed was caused by the adults of the garden weevil, *Phlyctinus callosus* (a native of South Africa), and, to a lesser extent, Fuller's rose weevil, *Asynonychus cervinus*. Garden weevils produced roughly circular, often windowed, feeding holes in the foliage. Fuller's rose weevil adults produced more ragged feeding damage, mostly to leaf margins. Larvae of both these weevil species feed on plant roots but were not searched for in this survey. Adult weevil feeding damage was sometimes severe, with estimates of up to 25% of the foliage of some boneseed plants consumed. Generally, however, the damage was much less severe, and it was common for about 2-5% of the foliage to have been consumed. Fifteen other species of herbivorous beetles were identified during the survey, but due to their relatively low numbers, and often small size, their combined effect was minimal.

Several species of leafroller caterpillars (Tortricidae) commonly tied boneseed leaves together with white, silken webs. However, they appeared to produce only minor damage.

Sap feeders

The passionvine hopper (*Scolypopa australis*), the green planthopper (*Siphanta acuta*), and to a lesser extent the grey planthopper (*Anzora unicolor*), were generally common and sometimes very numerous. The passionvine hopper was not present at the Canterbury sites, as the Nelson/Marlborough area is the southern limit of its range. The green vegetable bug, *Nezara viridula*, was also common. Scale insects (Coccidae) were particularly common at the three sites where Argentine ants were present. Other sap feeders included aphids (Aphididae) and spittle bugs (Cercopidae).

Wood borers

Adult long-horn beetles (Cerambycidae), belonging to four species, were commonly found on boneseed plants. Long-horn beetle larvae are wood borers, and their tunnels were occasionally found in boneseed branches. However, there was no evidence that they were causing any substantial damage to boneseed.

Seed feeders

A number of seeds (which have a very hard outer coat) were found with holes in them. These holes appear to have been made by chewing from the outside, as opposed to invertebrates living and feeding within the seeds. Intact seeds, which were collected and stored, showed no evidence of herbivores emerging from inside the seed.

Discussion

This study has shown that boneseed is utilised by a wide range of native and exotic invertebrates in New Zealand. However, no specialised boneseed feeding invertebrates were found during this survey, and there was no evidence that any of the invertebrate biological control agents introduced to Australia have become established in New Zealand by accident.

The garden weevil, *Phlyctinus callosus*, and Fuller's rose weevil, *Asynonychus cervinus*, (both introduced species with a wide host range) occasionally produced very obvious damage, with up to 25% of the foliage of some plants being consumed. However, damage was usually much less severe (2-5%), and specialised foliage-feeding biological control agents are unlikely to meet with significant competition from herbivorous species already resident in New Zealand. Although seeds were occasionally found with holes chewed in them, they are a largely unexploited resource, and there would be little competition for a specialised seed feeder such as the seed-feeding fly (*Mesoclanis magnipalpis*) that has been introduced to Australia for biological control of boneseed.

The combined effect of generalist predators, such as spiders, predatory shield bugs, earwigs, ants, wasps, and praying mantids could inhibit the effectiveness of some potential invertebrate biological control agents. Judging by experiences in Australia, predation could be particularly significant for the three species of chrysomelid beetles released there as biological control agents for boneseed (*Chrysolina picturata*, *Chrysolina* sp. A, and *Chrysolina* sp. B) if they were introduced to New Zealand. Although large numbers of beetles were released (Weiss *et al.* 1998), establishment in Australia is not yet confirmed for any of the three species, and it is believed that predatory ants and spiders have had a significant adverse effect on them (Raelene Kwong, pers. comm.).

During our survey, it was noted that at the three sites where large numbers of Argentine ants were present, scale insects were particularly common. Argentine ants are known to "farm" sap-feeders, such as scale insects, by providing protection from predators and parasitoids, in order to gain access to their carbohydrate-rich secretions (honeydew) (Gullan 1997). They also improve sanitation by reducing fouling caused by the sugary excreta and the sooty moulds that grow on it. Argentine ants can reach very high densities in New Zealand, and they are able to out-compete most other ant species (Harris 2002). As well as feeding on carbohydrate, such as honeydew, Argentine ants feed on protein, which could take the form of a wide range of invertebrates. It was noted that where there were very large numbers of Argentine ants, the numbers and diversity of other invertebrates (apart from scale insects) was reduced. This could be significant in terms of biological control introductions, if Argentine ants become more widespread in New Zealand.

Parasitoids were reared from a variety of caterpillar species collected from boneseed. These parasitoids could possibly affect the boneseed leafroller (*Tortrix* s.l. sp. "chrysanthemoides") and the tip moth (*Comostolopsis germana*) if these biological control agents are introduced into New Zealand. However, the tip moth has established in parts of Australia, despite being attacked by at least two species of parasitoids there (Holtkamp & Maguire 1993).

In New Zealand most (if not all) herbivore niches on boneseed are under-utilised and there is considerable scope for the introduction of specialised invertebrates, which could markedly reduce the vigour of boneseed.

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References

Gullan PJ. 1997. Relationship with ants. In: *Soft Scale Insects - their Biology Natural Enemies and Control* (eds. Y. Ben-Dov and C.J. Hodgson) Pp. 351-373. World Crop Pests Series, Elsevier Press, Amsterdam.

Harris RJ. 2002. Potential impact of the Argentine ant (*Linepithema humile*) in New Zealand and options for its control. *Science for Conservation* 196. 36 p.

Holtkamp R, Maguire AJ. 1993. NSW biological control program. *In*: Proceedings of a National Workshop on *Chrysanthemoides monilifera*, 28-30 April 1993, Tamworth, Australia (ed R. Holtkamp) Pp. 24-25. New South Wales Department of Agriculture.

Michaux B. 1989. Associated fauna at one site of Cirsium vulgare (Savi.) Ten., (Compositae: Cynareae). *New Zealand Entomologist 12:* 13-17.

Scott JK. 1996. Population ecology of *Chrysanthemoides monilifera* in South Africa: implications for its control in Australia. *Journal of Applied Ecology 33:* 496-508.

Webb CJ, Sykes WR, Garnock-Jones PJ. 1988. *Flora of New Zealand. Volume IV. Naturalised Pteridophytes, Gymnosperms, Dicotyledons.* Department of Scientific and Industrial Research, Christchurch. 1365 pp.

Weiss PW. 1986. The biology of Australian weeds 14 *Chrysanthemoides monilifera* (L.) T. Norl. *Journal of the Australian Institute of Agricultural Science 52:* 127-134.

Weiss PW, Adair RJ, Edwards PB. 1998. *Chrysanthemoides monilifera* (L.) T. Norl. In: *The Biology of Australian Weeds Volume 2* (eds. F. D. Panetta, R. H. Groves and R. C. H . Shepherd). Pp. 49-61. R. G. & F. J. Richardson, Melbourne.