INTEGRATED CONTROL OF *CHRYSANTHEMOIDES MONILIFERA* IN NEW SOUTH WALES

Royce H. Holtkamp
NSW Agriculture and Co-operative Research Centre for Weed Management Systems, RMB 944, Tamworth, New South Wales 2340, Australia

Summary *Chrysanthemoides monilifera*, a native of South Africa, was extensively used in Australia during the early 1950s as a sand stabilizing plant and to revegetate coastal areas mined for mineral sands. It is now a serious weed of conservation areas. In invaded vegetation, plant diversity is reduced with a subsequent detrimental effect on native fauna. *C. monilifera* currently mainly infests coastal areas of southern Queensland, New South Wales and Lord Howe Island as well as conservation areas in Victoria, South Australia, Western Australia and Tasmania. A biological control program against *C. monilifera* was commenced in 1989 and six species of insects have been released with additional species under investigation. Of these insects, bitou tip moth, *Comostolopsis germana* has been the most successful. It has now been released at 67 sites in New South Wales and has established at, or is colonizing, many of these. At several of these sites it is having a significant impact on flowering and seed production of *C. monilifera*. Studies on integrated control of *C. monilifera* commenced in 1992. These combine the use of biological control agents together with strategic herbicide applications. Regeneration of coastal areas cleared of *C. monilifera* by local volunteer groups is also important.

INTRODUCTION

Bitou bush and boneseed, two subspecies of *Chrysanthemoides monilifera* (L.) Norlindh, are competitive environmental weeds of South African origin. Despite distinct differences between these subspecies (Weiss 1986) the similarities in pest status and habit often mean that they are lumped together. Bitou bush (*C. monilifera* ssp. *rotundata* (DC.) Norlindh) is restricted to areas of summer rainfall (Parsons and Cuthbertson 1992) and infests coastal areas of southern Queensland, New South Wales and Lord Howe Island. There is also an localized infestation at Menindee Lakes, New South Wales. In New South Wales it is common in areas north of Sydney and occurs south to the Victorian border (Love 1985). Boneseed (*C. monilifera* ssp. *monilifera* (L.) Norlindh) is restricted to areas of winter rainfall (Parsons and Cuthbertson 1992) occurring extensively throughout southern Australia but is also present in coastal areas of New South Wales as far north as Sydney. Boneseed was first recorded as a garden shrub in Sydney in 1852 (Gray 1976). Bitou bush was first recorded in Australia from Stockton near Newcastle in 1908 (Weiss 1986) where it appears to have been an accidental introduction in ships ballast.

THE PROBLEM

During the early 1950s bitou bush was used as a sand stabilizing plant (Mort and Hewitt 1953) and to revegetate coastal areas mined for mineral sands (Barr 1965). The capacity of bitou bush to invade native vegetation had been recognised by the early 1970s and its recommendation for coastal planting was withdrawn. However, by 1976, Gray reported that bitou bush was naturalized along much of the New South Wales coast.

Aerial surveys of the New South Wales coastline were conducted by the NSW National Parks and Wildlife Service in 1981 and 1982. These indicated that *C. monilifera* was distributed along approximately 60% (645 km) of the coast and was the dominant species along 230 km. The range of *C. monilifera* has expanded since these surveys and Love (1985) predicted that it could spread to occupy over 90% of the New South Wales coastline by 2010 and would dominate the native vegetation along two thirds of the coastal fringe.

Chrysanthemoides monilifera is a serious weed of conservation areas (Adair and Scott 1989). In invaded vegetation, plant diversity is reduced and structural alterations occur as native plants are displaced (Dodkin and Gilmore 1985). This displacement has a detrimental effect on native fauna (Dodkin and Gilmore 1985).

Chrysanthemoides monilifera is largely an environmental weed as it is easily controlled by stock grazing and cultivation. It is primarily restricted to non-agricultural areas such as national parks, forests, coastal dune ecosystems and other recreational land. In the past, physical and chemical control have been used to reduce infestations and limit spread of *C. monilifera*.

TRADITIONAL CONTROL METHODS

Traditional control methods include physical and chemical control. Physical control is usually carried out by local volunteer groups. These groups mainly organize working parties to remove *C. monilifera* plants by hand pulling although painting cut stumps with glyphosate is also practised. The cut-stump method is preferred by

Table 1. New South Wales releases of biological control agents for *Chrysanthemoides monilifera* July 1996.

	Stage	No.	First released	No. releases	Status
***Comostolopsis germana* (bitou tip moth)**					
Hastings Point	eggs	1000	March 1989	8	established
	larvae	5620			
	adults	368			
Port Macquarie	pupae	2582	December 1989	5	established
	adults	41			
Letitia Spit (Tweed Heads)	larvae	3184	November 1990	6	established
	pupae	1000			
	adults	736			
Ballina	larvae	4360	April 1991	6	established
	pupae	301			
	adults	120			
Port Stephens (Tomaree NP)	larvae	500	April 1991	8	?
	pupae	2125			
Scotts Head	larvae	600	May 1991	3	established
	pupae	1300			
Crowdy Head	larvae	500	August 1991	2	established
	pupae	165			
	adults	30			
Woody Head (Bundjalung NP)	larvae	1000	September 1991	6	established
	pupae	5000			
	adults	65			
Wollongong	eggs	?	September 1991	2	no success
Moruya	eggs	?	October 1991	13	established
	larvae	4640			
	pupae	1057			
Redhead (Awabakal NR)	eggs	?	November 1991	2	no success
Jervis Bay	eggs	?	December 1991	11	established
	larvae	5295			
Crescent Head (Goolawah Res.)	larvae	?	January 1992	3	established
Wilsons Head (Yuraygir NP)	larvae	2045	February 1992	9	established
	pupae	1080			
Coffs Harbour	larvae	1705	February 1992	9	established
	pupae	750			
North Entrance (Wyrrabalong NP)	larvae	1200	February 1992	5	established
	pupae	2037			
	adults	12			
Camden Head (Kattang NR)	larvae	500	March 1992	1	established
Lighthouse Beach	larvae	600	April 1992	2	established
Forster	larvae	1200	June 1992	3	established
Red Cliff	larvae	1200	June 1992	5	established
	pupae	335			
Evans Head	larvae	5000	August 1992	1	established
Broadwater	larvae	5250	September 1992	2	established
Kingscliff	larvae	509	September 1992	1	established
Byron Bay	larvae	5200	September 1992	6	established
Wooyung	larvae	5000	September 1992	3	established
Port Kembla	larvae	500	December 1992	1	established
South West Rocks	larvae	541	December 1992	1	established
Tathra	larvae	1658	December 1992	2	?
Minnie Water	larvae	1345	February 1993	3	established
Culburra	larvae	440	March 1993	1	?
Diamond Head (Crowdy Bay N.P)	larvae	240	April 1993	1	established
La Perouse (Botany Bay NP)	larvae	4100	July 1993	5	established
Hungry Head	larvae	585	September 1993	2	established
Woolgoolga	larvae	400	October 1993	1	established

Stockton	larvae	1500	November 1993	2	?
Angourie (Green Point)	larvae	200	November 1993	1	site sprayed
	larvae	260	August 1993 (new site)	1	established
Grassy Head	larvae	700	December 1993	1	?
Brooms Head	larvae	250	December 1993	1	no success
Sandon River (Yuraygir NP)	larvae	1170	December 1993	3	established
Caves Beach	larvae	800	February 1994	1	colonizing
Blacksmiths Beach	larvae	500	February 1994	1	established
Redhead Beach	larvae	1000	February 1994	2	colonizing
Catherine Hill Bay	larvae	800	February 1994	1	colonizing
Moonee Beach	larvae	2000	February 1994	4	established
Avalon	larvae	800	February 1994	2	established
Hawks Nest (Myall Lakes NP)	larvae	2300	March 1994	3	established
Iluka Bluff (Bundjalung NP)	larvae	480	March 1994	2	established
Tallow Beach (Bouddi NP)	larvae	1200	March 1994	2	established
Shoalhaven Heads (Seven Mile Beach NP)	larvae	650	March 1994	1	no success
Maitland Bay (Bouddi NP)	larvae	500	July 1994	1	established
Wollongong	larvae	1000	August 1994	2	? (Korongulla wetland)
Hat Head (Hat Head NP)	larvae	1543	October 1994	2	established
Mylestom (Tuckers Rocks)	larvae	805	October 1994	3	established
Black Rocks (Bundjalung NP)	larvae	280	November 1994	1	established
Yamba	larvae	2000	November 1994	4	established
Newcastle Golf Club (Fern Bay)	larvae	800	January 1995	1	?
Manning Point	larvae	750	February 1995	1	?
Pacific Palms	larvae	500	March 1995	1	established
Norah Head	larvae	500	May 1995	1	?
Port Stephens	larvae	500	June 1995	1	?
Sawtell (Bongle Bongle NP)	larvae	450	August 1995	1	?
Byron Bay	larvae	600	August 1995	2	?
Pottsville	larvae	685	September 1995	2	colonizing
Cabarita Beach	larvae	805	September 1995	2	colonizing
Moruya (Pedro Point)	larvae	1000	December 1995	1	established
Dudley Beach (Glenrock SRA)	larvae	500	March 1996	1	?
Kooragang Island (BHP)	larvae	500	March 1996	1	?
Belmont North	larvae	800	April 1996	1	?
***Chrysolina* sp. 1 (black boneseed leaf beetle)**					
Tathra	eggs	4200	October 1990	3	no success
	adults	225			
Moruya	eggs	8000	October 1990	3	no success
Jervis Bay	eggs	1200	October 1990	5	no success
	adults	1211			
Port Macquarie	eggs	1000	October 1991	2	no success
Camden Head (Kattang NR)	eggs	28	April 1993	1	no success
	larvae	13			
	adults	47			
***Chrysolina* sp. 2 (painted boneseed leaf beetle)**					
Ulladulla	larvae	3600	February 1995	2	?
Geebung and Cheese Tree Picnic Areas (Crowdy Bay NP)	larvae	4000	January 1996	1	?
Yacaaba Head (Myall Lakes NP)	larvae	2950	March 1996	1	?
La Perouse (Botany Bay NP)	larvae	8073	April 1996	2	?
Port Stephens (Tomaree NP)	larvae	6495	May 1996	1	?
Banksia Green (Myall Lakes NP)	larvae	6000	May 1996	1	?
***Cassida* sp. (bitou tortoise beetle)**					
La Perouse (Botany Bay NP)	adults	500	December 1995	1	colonizing
Mungo Brush (Myall Lakes NP)	adults	200	January 1996	1	colonizing
***Mesoclanis polana* (bitou seed fly)**					
Dunbogan (Crowdy Bay NP)	adults	57	July 1996	1	?

many workers because it results in minimal soil disturbance. These forms of control are particularly effective in small areas of high conservation significance. Larger scale control using these methods is not practical because it is too labour intensive. The possibility of removing *C. monilifera* in areas infested for many years is compounded by large soil seed banks. Weiss and Milton (1984) recorded a soil seed bank of 2030 seeds per m^2 near Moruya on the south coast of New South Wales and Holtkamp (unpublished data) has recorded a soil seed bank of up to 1968 viable seeds per m^2 as well as almost 4000 damaged seeds per m^2 at Port Macquarie.

Chrysanthemoides monilifera can be controlled using herbicides. However, various problems such as access to sites and the possibility of non-target damage arise. The most effective method of application is by air, either by plane or helicopter, but this is extremely costly. Cooney *et al.* (1982) evaluated the herbicide glyphosate (Roundup®) on *C. monilifera* infestations and found that it was effective on the target plant and caused little damage to native species in the same area. However, only five native species were tested in these trials. Unfortunately, as the large *C. monilifera* plants died, there was prolific germination of seeds. This necessitated retreatment of infested areas. Re-spraying needs to be carried out regularly until the large soil seed bank is exhausted or the surrounding native vegetation outcompetes the emerging *C. monilifera* seedlings. Retreatment on this scale is extremely costly.

Toth *et al.* (1993) have considerably refined the original work on aerial application of glyphosate using helicopters and have discovered a 'window of opportunity' during the winter period immediately following peak flowering of *C. monilifera.* At this time *C. monilifera* was most susceptible and seven native species tested were least susceptible. Toth *et al.* (1995) have since increased to 66 the number of native species tested. Further herbicide treatments are required approximately every two years until the soil seed bank is exhausted. It is important that none of the regenerating plants be allowed to flower and set seed.

Aerial application of glyphosate has now become widely accepted and several hundred hectares of NSW National Parks and Wildlife Service land was treated during 1995 (J. Toth personal communication).

BIOLOGICAL CONTROL

A biological control program against *C. monilifera* was approved by Standing Committee On Agriculture in 1987. Surveys in South Africa indicated that there are more than 100 species of phytophagous insects associated with the *Chrysanthemoides* species complex (Scott and Adair 1990). To date, seven species of insects have been imported from South Africa into Australia for host specificity testing. Host specificity testing for *Chrysanthemoides* insects is being conducted at Keith Turnbull Research Institute, Victoria. Insects imported are bitou tip moth (*Comostolopsis germana* Prout); five species of leaf feeding beetle: black boneseed beetle (*Chrysolina* sp. 1), blotched boneseed beetle (*Chrysolina picturata* (Clark)), painted boneseed beetle (*Chrysolina* sp. 2), *Ageniosa electoralis* (Vogel) and bitou tortoise beetle (*Cassida* sp.); and bitou seed fly (*Mesoclanis polana* Munro). A leaf feeding moth (*Tortrix* sp.) is currently undergoing quarantine host specificity testing in Australia. Six species have been released, *C. germana*, *Chrysolina* sp. 1, *C. picturata*, *Chrysolina* sp. 2, *Cassida* sp. and *M. polana*. *A. electoralis* was able to develop on a number of plant species and has been rejected as a possible biological control agent. Additional insects and a rust fungus are now under investigation in South Africa.

Of the six insects currently released in Australia (Table 1), *C. germana* has been the most successful. This species only develops on *Chrysanthemoides* spp. (Adair and Scott 1989). It has now been released at 68 sites in New South Wales and has established at, or is colonizing, many of these. At several of these sites it is having a significant impact on flowering and seed production of bitou bush. One example of the success of *C. germana* is at Port Macquarie where it has spread about 5 km since the initial release in 1990. At this site, numbers in excess of 400 larvae per m^2 have been found and are significantly reducing flowering and seed production of bitou bush. *Chrysolina* sp. 1 has been released at five sites in New South Wales. Its current status is unclear but it does not appear to have established at any site. The larvae of this beetle appear to be particularly prone to predation by ants and spiders (R. Adair personal communication) and this may limit their potential as biological control agents. *C. picturata* will not be released in New South Wales as it is specific to boneseed and prefers winter rainfall areas found in Victoria and South Australia. *Chrysolina* sp. 2 has been released at six sites in New South Wales but it is too early to determine whether it has established. *Cassida* sp. has been released at two sites in New South Wales during late 1995/early 1996. This insect is persisting and reproducing at these two sites but it is too early to say whether it has established. *M. polana* was released for the first time in Australia in July 1996 at a site in Crowdy Bay National Park near Dunbogan, New South Wales. No data are available yet on this release.

INTEGRATED CONTROL

Toth *et al*. (1995) are currently investigating the feasibility of integrated control of *C. monilifera* at several sites on the New South Wales coast including Jervis Bay

National Park and Myall Lakes National Park. The technique involves the aerial application of glyphosate to control mature plants, combined with the release of biological control agents to control seedling regeneration.

The role of fire in an integrated control program for *C. monilifera* is still to be investigated but observations of burnt areas suggest that fire stimulates germination of *C. monilifera* seeds. These young seedlings support extremely large and active populations of *C. germana.*

DISCUSSION

Biological control of *C. monilifera*, if successful, will reduce this weed to a minor component of invaded vegetation. However, it must be remembered that biological control will not eradicate *C. monilifera*. Integrated control combining biological control, strategic herbicide application and possibly fire appears to be the most viable long term solution. Any integrated program will have to ensure that sufficient biological control agents remain following other forms of treatment to ensure re-establishment of biological control agent populations. Continuing physical and herbicidal control by volunteer groups in areas of high conservation significance is also important. The regeneration of coastal areas cleared of *C. monilifera* by local volunteer groups also forms an important component of this program. It is essential that revegetation of disturbed habitat occurs quickly to prevent the niche previously occupied by *C. monilifera* being occupied by *C. monilifera* seedlings or by another weed species.

ACKNOWLEDGMENTS

Research on biological control of *C. monilifera* is partly funded by the Australian and New Zealand Environment and Conservation Council (ANZECC) and administered by the ANZECC Task Force for Weeds of Conservation Concern. Research on integrated control of *C. monilifera* is partly funded by the New South Wales Government through its Environmental Trusts grants. I would also like to thank John Hosking for helpful comments on the manuscript.

REFERENCES

Adair, R.J. and Scott, J.K. (1989). The life-history and host specificity of *Comostolopsis germana* Prout (Lepidoptera: Geometridae), a biological control agent of *Chrysanthemoides monilifera* (Compositae). *Bulletin of Entomological Research* 79, 649-57.

Barr, D.A. (1965). Restoration of coastal sand dunes after beach mining. *Journal of Soil Conservation NSW* 21, 199-209.

Cooney, P.A., Gibbs, D.G. and Golinski, K.D. (1982). Evaluation of the herbicide "Roundup" for control of bitou bush (*Chrysanthemoides monilifera*). *Journal of Soil Conservation NSW*, 38, 6-12.

Dodkin, M.J. and Gilmore, A.M. (1985). Species and ecosystems at risk—a preliminary review. Bitou Bush and Boneseed. Proceedings of a conference on *Chrysanthemoides monilifera*. National Parks and Wildlife Service and Department of Agriculture NSW, pp. 33-52.

Gray, M. (1976). Miscellaneous notes on Australian plants. 2. *Chrysanthemoides* (Compositae). *Contr. Herb. Australiense* 16, 1-5.

Love, L.A. (1985). Distribution of bitou bush along the NSW coast. Bitou Bush and Boneseed. Proceedings of a conference on *Chrysanthemoides monilifera.* National Parks and Wildlife Service and Department of Agriculture NSW, pp. 53-64.

Mort, G.W. and Hewitt, B.R. (1953). Vegetation survey of marine sand drifts of NSW. Part III. Some remarks on useful stabilizing species. *Journal of Soil Conservation NSW* 9, 59-69.

Parsons, W.T. and Cuthbertson, E.G. (1992). 'Noxious Weeds of Australia'. (Inkata Press, Melbourne).

Scott, J.K. and Adair, R.J. (1990). The commencement of biological control of bitou bush and boneseed (*Chrysanthemoides monilifera*). Proceedings of the 9th. Australian Weeds Conference, Adelaide, South Australia, pp. 126-9.

Toth, J., Milham, P. and Nazer, C. (1993). Aerially applied herbicides selectively control bitou bush growing in communities of indigenous plants on sand dunes. Proceedings of the 10th Australian and 14th Asian Pacific Weeds Conference. Brisbane, Australia, Volume 2, pp. 67-71.

Toth, J, Milham, P.J. and Holtkamp, R.H. (1995). Integrated control of bitou bush. Terminating report on R and R Grant No. 114 1992–94. NSW Environmental Trusts.

Weiss, P.W. and Milton, S.J. (1984). *Chrysanthemoides monilifera* and *Acacia longifolia* in Australia and South Africa. Proceedings of the 4th International Conference on Mediterranean Ecosystems. Perth, Western Australia, pp. 159-160.

Weiss, P.W. (1986). The Biology of Australian Weeds 14. *Chrysanthemoides monilifera* (L.) T. Norl. *Journal of the Australian Institute Agricultural Science* 52, 127-34.