HORSES AS VECTORS IN THE DISPERSAL OF WEEDS INTO NATIVE VEGETATION

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Summary The spread of environmental weeds into areas of native vegetation is of increasing concern to managers, and considerable attention has been given to controlling or banning of potential weed dispersal agents such as horses from these areas. This paper reports 29 species of weeds which are dispersed via horse manure, and discusses the relationship between weed dispersal, and weed establishment and spread along horse riding tracks in three National Parks in Victoria. Weed diversity decreased with increasing distance from the track, and the strength of this trend appears to be related to track characteristics and patterns of horse use. The weeds recorded are not dispersed exclusively by horses, and alternative vectors are already known for most.

INTRODUCTION

Recreational horse riding is a contentious issue in National Parks and other conservation areas (Cubit 1990), and in spite of the adoption of a Horse Riding Policy (DCNR 1988) many managers of nature reserves continue to have concerns about the impacts of horse riding, particularly in relation to erosion hazard and the potential for the spread of weeds.

While there is a considerable body of evidence showing accelerated erosion resulting from horse traffic (McQuaid-Cook 1978, Gillieson and Davies 1986, Whinam and Comfort 1996), and increasing evidence of vegetation change caused by trampling (Dale and Weaver 1974, Cole 1978, Whinam *et al*. 1994), there has been little information on the extent of weed dispersal by horses. Seeds of a number of species are known to remain viable after passage through the digestive tracts of both cows (Atkeson *et al*. 1934, Burton 1948) and horses (St. John-Sweeting and Morris 1991).

Recently, Hatton (1989) has reported the dispersal and establishment of *Rosa rubiginosa* seeds by horses in NSW, while Whinam *et al*. (1994) identified 10 weed species germinating from horse manure from the Central Plateau of Tasmania. However, the relationship between weed dispersal by horses, and weed establishment, has generally been inferred from the patterns of weed invasion along tracks and trails (Tyser and Worley 1992), and the role of other dispersal vectors such as vehicles (Wace 1975, Lonsdale and Lane 1991) or other vertebrate species (Brunner *et al*. 1976, Hatton 1989, Bass 1990, Loyn and French 1991) has received limited attention.

This project aimed to:

a. identify which weeds were being dispersed in horse manure, and
b. identify which weeds were established along track verges used by horse riders in native vegetation in Victoria.

MATERIALS AND METHODS

Two holding pens and seven tracks were chosen for sampling in three Victorian National Parks which allow recreational horse riding. These were Jerusalem Track, Everard Track and Island Creek Track (Kinglake National Park), Parker Road, Sandy Ridge Track and Station Beach (Otway National Park) and Bennison Plain Track, Wellington Stock Yards and Tamboritha Saddle holding yards (Alpine National Park, Wonnangatta-Moroka Unit).

Manure sampling A total of 197 manure samples of 500 mL each were collected from individual piles of manure along each track. Ninety-six samples were collected from Kinglake National Park in January and February 1995, 62 samples from Otway National Park in May 1995, and 39 samples from Alpine National Park in March 1995. As seeds available for ingestion by horses will vary in relation to season, the range of species identified from these samples is likely to underestimate the species dispersed by horses.

Individual samples were placed in trays in a glasshouse (Deakin University, Rusden Campus) and seeds in the manure allowed to germinate. Species were either identified on emergence or allowed to grow to a point where an definite identification could be made.

Species frequency was calculated as the percentage of the total samples in which it was recorded.

Track–verge weeds To assess the extent and pattern of the existing weed flora along track verges, four 10 × 0.2 m transects were placed at each of five random locations along each track. The four transects were placed parallel to the track at 0.25, 5, 10 and 20 m from the track edge. Presence of all weed species within the transect were recorded. However, some annual species may not have

been visible at the time of sampling, and species presence along track verges may be underestimated.

Species nomenclature follows Ross (1993) and Auld and Medd (1987).

RESULTS

A total of 29 species were recorded from the 197 manure samples collected from the three National Parks (Table 1). Both Otway National Park and Alpine National Park samples produced 11 species each, and Kinglake NP samples produced 25 species. Of these, seven species were recorded from less than 1% of samples.

Six species, *Holcus lanatus*, *Medicago truncatula*, *Poa annua*, *Stellaria media*, *Trifolium arvense* and *Oxalis* sp. were found in all three National Parks and all except *Oxalis* occurred in more than 10% of the manure samples. Two of these, *Poa annua* and *Trifolium arvense* were found in manure from all nine tracks/holding yards in the three National Parks. *Poa annua* occurred in over 63.5% of the total manure samples, and *Trifolium arvense* occurred in 31.7 % of the total samples.

Table 1. Frequency (%) of occurrence of species recorded from manure samples collected from Kinglake National Park (KLNP), Otway National Park (ONP) and Alpine National Park (ANP).

Species	KLNP (n=96)	ONP (n=62)	ANP (n=39)	% Frequency of total samples (n=197)
				>50% samples
Poa annua		74.9	64.6	35.9 63.5
				50–10% samples
Trifolium arvense	24.9	19.2	51.3	31.7
Trifolium subterraneum	28.2	22.5		20.8
Trifolium repens	21.9		35.9	17.8
Medicago truncatula	16.6	6.4	33.3	16.8
Juncus bufonius	25.0			12.2
Stellaria media	3.1	24.2	10.3	11.2
Holcus lanatus	4.2	14.4	23.1	10.3
				10–1% samples
Medicago polymorpha	10.4	16.0		9.6
Oxalis sp.	1.0	25.8	2.6	9.1
Phalaris paradoxa	2.1		28.2	6.6
Lolium rigidum			25.6	5.1
Medicago minima	10.4			5.0
Lolium perenne	9.4			4.6
Rumex sp.		9.7	2.6	3.6
Cerastium glomeratum	1.0		12.8	3.0
Galium aparine	6.2			3.0
Critesion sp.(syn. *Hordeum*)		8.0		2.5
Trifolium glomeratum		6.4		2.0
Hydrocotyle sp.	3.1			1.5
Melilotus indicus	3.1			1.5
Agrostis capillaris	2.0			1.0
				<1% samples
Avena barbata	1.0			0.5
Avena fatua	1.0			0.5
Briza minor	1.0			0.5
Bromus diandrus	1.0			0.5
Bromus rubens	1.0			0.5
Cenchrus sp. ?	1.0			0.5
Plantago lanceolata	1.0			0.5
Total species	25	11	11	29

A total of 17 weed species were recorded from the track verges and the two holding yards; seven from Kinglake National Park, 14 from Otway National Park and 10 from Alpine National Park (Table 2). Only four species, *Geranium* sp., *Oxalis* sp., *Poa annua* and *Stellaria media* were common to all three Parks, and of these four, only *Geranium* sp. was not also recorded from manure samples. A further six of the species recorded were not found in the manure samples at any of the sampling locations.

At Kinglake National Park 80% of the weeds dispersed in manure were not recorded from the track verges, and at Otway National Park and Alpine National Park 45% of the weeds dispersed were not recorded as established plants along the verges.

Where off-track riding was possible along five of the seven tracks, the number of weed species established along track verges declined with perpendicular distance from the track (Figure 1). On the two tracks where off-track riding was constrained by steep topography (Jerusalem Track and Everard Track, Kinglake National Park) only one species (*Poa annua*), was recorded, and only along the Jerusalem Track was it recorded further than 5 m from the track verge.

DISCUSSION

It is becoming increasingly clear from a number of recent investigations (Hatton 1989, Whinam *et al.* 1994,

Weaver 1995) that horses have the capacity to disperse viable propagules of both woody weeds and a range of herbaceous weeds. A combined total of 33 non-woody species has now been confirmed from horse manure from this study and that of Whinam *et al.* (1994). A number of these, *Bromus* spp., *Holcus lanatus*, *Lolium* spp., *Plantago lanceolata*, *Rumex* sp., and *Trifolium* spp. appear to be common inclusions in horse manure as they were recorded from both the Tasmanian site and the three Victorian sites. In addition, *Poa annua*, *Medicago trunculata*, *Stellaria media* and *Oxalis* sp. were recorded from all tracks within the three Victorian National Parks, suggesting that they too are common inclusions in the manure of horses. It is interesting to note that *Poa* spp. and *Trifolium* spp. have also been frequently reported as prevalent weeds along paths in Britain (Bates 1935) and trailsides used by horses in North America (Dale and Weaver 1974, Cole 1978).

Table 2. Presence (*) of weed species along tracks (t) and frequency (%) of species recorded from manure (m) samples collected from three National Parks. Alternative dispersal vectors (ADF): w = Wace 1975, l = Lonsdale and Lane 1991, f = Loyn and French 1991.

Species	KLNP (m)	KLNP (t)	ONP (m)	ONP (t)	ANP (m)	ANP (t)	ADF
Agrostis capillaris	2.0						w
Avena barbata	1.0						w
Avena fatua	1.0						f
Briza minor	1.0			*			w
Bromus diandrus	1.0						f
Bromus rubens	1.0						f
Cenchrus sp. ?	1.0						
Cerastium glomeratum	1.0				12.8		w
Conyza albida				*			w
Cynodon dactylon		*		*			w
Galium aparine	6.2						w
Geranium sp.		*		***		*	w
Holcus lanatus	4.2		14.4	*	23.1		w
Critesion sp.(syn. *Hordeum*)			8.0				l, f
Hydrocotyle sp.	3.1						w
Juncus acutus				*			w?
Juncus bufonius	25.0						w
Juncus sp.				*		**	w?
Lolium perenne	9.4						w
Lolium rigidum					25.6		w
Medicago arabica				**		***	f?
Medicago minima	10.4						f?
Medicago polymorpha	10.4		16.0				w
Medicago truncatula	16.6		6.4	*	33.3	***	f?
Melilotus indicus	3.1						
Oxalis sp.	1.0	*	25.8	*	2.6	**	w
Phalaris paradoxa	2.1				28.2		w
Plantago lanceolata	1.0	*				*	w
Poa annua	74.9	**	64.6	***	35.9	**	w
Pseudognaphalium sp.				*			w
Rumex sp.			9.7		2.6		w
Stellaria media	3.1	*	24.2	***	10.3	***	w
Trifolium arvense	24.9		19.2		51.3	**	w
Trifolium glomeratum			6.4				w
Trifolium repens	21.9				35.9	*	w
Trifolium subterraneum	28.2	*	22.5	*			w
Total species	25	7	11	14	11	10	

Some species were recorded in only a small percentage of manure samples, suggesting that they either do not maintain high levels of viability during passage through the horse digestive system, or that few seeds are ingested in the first place. However, infrequent occurrence of these species does not necessarily indicate a lower probability of establishment, as species such as *Oxalis* sp. and *P. lanceolata* were recorded from less than 1% of samples from the Kinglake National Park, but were also found to be established along track verges.

Of the taxa recovered in this study, the seeds of *Avena*, *Medicago, Melilotus, Plantago, Rumex* and *Trifolium* are known to maintain viability after passage through the digestive system of horses (Atkeson *et al.* 1934, Harmon and Keim 1953, St. John-Sweeting and Morris 1991), but both Atkenson *et al*. (1934) and Harmon and Keim (1953) reported a substantial decline in seed viability after three to three and a half days digestion. Based on these findings, the Horseriding Code of Practice for horses in the Alpine National Park (Australian Alps National Parks 1994) recommends a quarantine period of three days, but the work of St. John-Sweeting and Morris (1991) demonstrates that horses will pass high levels of viable seed up to four days after ingestion, and for some species such as *Trifolium* and *Medicago,* viable seed can be passed up to 10 days after ingestion.

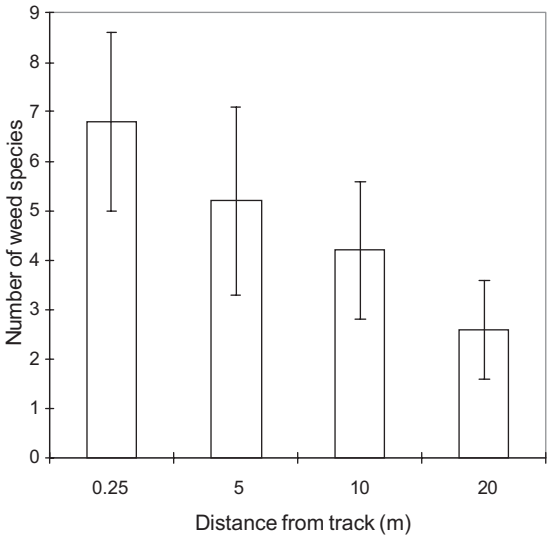

Figure 1. Mean number of weed species with increasing distance from the track verge. Vertical bars indicate 95% confidence intervals.

Although substantial proportions of the species dispersed in horse manure are found growing along the track verges used by horses (KLNP 20%, ONP 45%, ANP 55%), high proportions of species recorded from manure have also not been recorded from track verges. For example, in Kinglake National Park 80% of the weeds recorded from manure were not recorded from track verges, and at Otway National Park and Alpine National Park, 45% of the species found in manure were not recorded from track verges. In spite of the presence of viable propagules along tracks, and increased nutrient levels from manure (Liddle and Chitty 1981), Whinam and Comfort (1996) suggest that the failure of species to establish along track in the Cradle Mountain area of Tasmania may be due to continued churning of the track by horses, while Liddle and Chitty (1981) suggest that lack of water may be the factor inhibiting establishment along tracks in drier environments. Thus track conditions, the level of horse use, and general environmental conditions may all combine to affect the establishment of weed species following initial dispersal.

The discrepancy between the species found established along track verges but not recorded from manure samples may partly reflect the seasonal nature weed seed ingestion, but it is equally probable that species are being introduced by alternative vectors such as vehicles. Whinam *et al.* (1994) report that 66% of the species established on the Central Plateau of Tasmania were not recorded from horse manure, while the proportions of track-verge weeds not found in manure were 25% at Kinglake National Park, 30% at Alpine National Park, and 57% at Otway National Park.

The literature also reports differences in the levels of track and vegetation damage in forest compared with open meadows, heaths or moorlands (Cole 1978, Dale and Weaver 1978, McQuaid-Cook 1978, Whinam *et al*. 1994, Whinam and Comfort 1996), with meadow or grassy vegetation types appearing to suffer less damage due to the ability of horse riders to spread out over the vegetation rather than be forced to follow a single track (McQuaid-Cook 1978). Off-track riding is therefore often encouraged in an attempt to minimized erosion and trampling effects, and the Horse Riding Policy (DCNR 1988) permits off-track riding. However, Figure 1 suggests that the incidence of weeds along tracks is related to decreasing occurrence of weed-bearing manure at increasing distance from the track verge. This in turn is related to frequency of horse use and is determined by the ability of riders to spread out from the track. Of the seven tracks sampled, five had no physical constraints on off-track riding, and the same pattern of weed diversity declining with the perpendicular distance from the track verge was found at each of these tracks. The remaining two tracks had very steep slopes on either side, and in both instances only one species, *Poa annua*, was found established. It is suggested that this trend is the result of physical restriction of horses and their manure to the track itself.

It is clear that horses are a potentially significant vector in the dispersal of a range of weed species, and that the concerns of managers regarding dispersal of weeds by horses are legitimate. However, banning recreational horseriding may not necessarily prevent these species from spreading to nature reserves, as alternative vectors are known to disperse these same weed species. Wace (1975) and Lonsdale and Lane (1991) have established that vehicles carry large numbers of species over long distances, and many bird species are known to ingest and disperse seeds (Loyn and French 1991). Of the 36 species recorded present in either manure or established along track verges (Table 2), only two have not been definitely recorded as being dispersed by a vector other than horses. Thus the role of animal species and management vehicles as weed seed vectors should not be ignored.

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