IMPACTS OF HUMAN WASTE DISPOSAL IN THE BACK-COUNTRY AREAS OF TASMANIA

By Jamie Kirkpatrick and Kerry Bridle

SUSTAINABLE TOURISM CRC

TECHNICAL REPORTS

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National Library of Australia Cataloguing in Publication Data

Kirkpatrick, J. B. (James Barrie).
Impacts of human waste disposal in the back-country areas of Tasmania.

Bibliography.
ISBN 1 920704 23 X.

1. Ecological assessment (Biology) - Tasmania. 2. Ecotourism - Tasmania - Evaluation. I. Bridle, Kerry Lynn. II. Cooperative Research Centre for Sustainable Tourism. III. Title.

363.709946

Acknowledgements

The Sustainable Tourism Cooperative Research Centre, an Australian Government initiative, funded this research. Thanks to the many field assistants and technical officers with special mention to Denis Charlesworth, Margaret Gill, Paul Smart, Mona Loofs, Nick Fitzgerald, Micah Visoiu and Bonnie Wintle. The Tasmanian Parks and Wildlife Service, the Forestry Commission, the University of Tasmania and Jennie Whinam of the Nature Conservation Branch, facilitated access to the study sites.

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Summary

The presence of human wastes and the products that help dispose of them are unpleasant for tourists in wild country, and present possible health and environmental hazards. Very little research has been undertaken on the impacts of human waste disposal in the wild.

The research objective of the present project was to determine the relative impacts of disposal of human wastes on vegetation and soils in Tasmanian vegetation types that occur in areas used for wild country camping, with particular emphasis on the impact of digging, the impact of nutrient accessions, the persistence of toilet paper, tissues and tampons, and the disturbance of burials by native animals.

The implementation objective was to use the results of the research to develop habitat-specific prescriptions for human waste disposal in wild areas that are consistent with long term maintenance of natural values, while being acceptable to users, and to effectively communicate these prescriptions to users and managers.

The digging of holes 15 cm deep, typical of those used for waste disposal in the Tasmanian wild, had largely negative effects on the growth of a few native plant species. These effects were of little or no conservation significance.

The addition of artificial urine to undug ground and dug ground had largely positive effects on nine distinct types of native vegetation, encouraging the growth of many plant species at many sites, while discouraging the growth of moss at one site.

An experiment that tested whether native animals differentially excavate faeces and toilet paper buried at different burial depths did not result in excavation. However, there was a low incidence of excavation of packets of tampons, toilet paper and tissues buried at 5 cm in the 760 holes used in the study, with even less excavation of packets buried at 15 cm.

It was remarkably difficult to dig a hole to 15 cm, as is suggested by the present minimum impact code of practice, using the plastic trowels often sold for this purpose.

Tampons proved much more resistant to decay than tissues, bleached toilet paper and unbleached toilet paper. These latter three products all disappeared at most sites by 24 months from burial, with unbleached toilet paper breaking down most quickly. At the western alpine site there was little decay of any products after two years. In the coastal eucalypt forest most decay took place in the first six months.

Artificial urine, used because urine is more nutrient-rich, convenient and safe to handle than faeces, accelerated the rate of decay of all products at most sites. Its effect was positively related to total phosphorus, and mitigated by sandy soils.

Depth of burial had no effect on mean decay at individual sites. There is no great benefit in terms of decay in disposing of products under rocks in alpine areas.

Variation in mean decay by sites for all products combined was largely explained by climatic variables (summer mean daily maximum temperatures and annual rainfall) and soil chemical variables related to the acidity of the soil. The order of mean decay by site was largely predicted by a simple index involving these variables. Decay was promoted by summer warmth, decreased by increasing precipitation and decreased by increasing acidity, with precipitation being the most influential variable.

The above results suggest that the minimum impact bushwalking code should be amended to:

1. recommend no disposal of faeces, toilet paper or tissues in treeless vegetation above 800 m in western Tasmania;
2. emphasise that placement of waste under rocks causes more environmental harm than disposal by burial, even in alpine environments;
3. emphasise that strong metal trowels are necessary to excavate holes for defecation in most wild places.

The overall ban on the disposal of tampons in the bush should remain.

Given the high degree of non-compliance with the MIB guidelines for the disposal of human waste that is evident in parts of the Tasmanian bush (von Platen 2002), it is probably time to consider enforceable regulations, rather than non-enforceable guidelines

The project was initiated with a steering committee, and has involved constant propagation of results and their management implications through a web site, papers at various conferences, many of which included stakeholders, and the mass media (including national television and radio, local radio and newspapers). The work will be published in refereed journals and communicated directly to managers and bushwalkers in the form of the present publication and the web site. These results will also be presented to the media through a media release from the University of Tasmania.

This project did not cover the public health aspects of disposal of human wastes in different environments or the degree to which codes of practice actually influence individual human waste disposal behaviour in the wild. These questions are currently being addressed by us in another Sustainable Tourism CRC project, to be completed in 2003.

The index we derived for predicting the speed of decay of human waste disposal products requires testing outside Tasmania, to determine its universality.

Chapter 1

Introduction

The overnight walking experience attracts substantial numbers of tourists to wild country. Approximately 20,000 people spend at least one night out camping in the Western Tasmanian Wilderness World Heritage Area per annum (S. Rundle pers. comm.). While toilet facilities are provided at many popular back-country camping sites, a substantial number of overnight walkers defecate and urinate *au naturel*. The present project was initiated as the result of concerns that the processes of disposing of human wastes outside toilets in the wild might have deleterious effects on environment, human health and human sensibilities. Despite some research interest in the impact of human waste disposal on non-serviced wilderness areas in the 1970s (Leonard & Plumley 1979; Reeves 1979), and more recently (Ells 2000a, 2000b) the importance of the subject has been noted (Cole, Watson, Hall & Spildie 1997; Leung & Marion 2000a, 2000b; Rochefort & Swinney 2000; Cilimburg, Monz & Kehoe 2000), more than researched, since this time. Most recent research on the impacts of wilderness users has concentrated on the physical disturbances caused by trampling and camping (Marion & Cole 1996; Leung & Marion 2000a, 2000b; Sun & Walsh 1998). However, Ells (1999) has shown that faecal matter does not break down quickly within 12 months in the nival zone. Given the lack of research, and increasing use of wild places by overnight walkers (Lachapelle 2000; Sun & Walsh 1998; Poll 2002) there is an obvious need to determine the nature and significance of any effects, and the manner in which they vary in different bushwalking environments.

Minimum impact guidelines for walker behaviour have been disseminated to those who camp in the wild country of Tasmania for more than a decade (O'Loughlin 1988). These guidelines are believed to have been effective in changing the behaviour of back-country users in critical areas, such as the use of fire and the avoidance of water pollution. The guidelines for the disposal of faeces require burial to at least 15 cm depth at least 100 m from lakes or streams. This depth is not attainable over most of the glaciated country of Tasmania (Kirkpatrick & Bridle 1999), and the excavation process, to whatever depth is attainable, requires the severance of a dense mat of roots. Cutting of roots occurs even where excavation takes place in bare ground, as in fjaeldmark treads (Kirkpatrick, pers. obs.). This severance could affect vegetation well away from the disposal hole. Digging is also a form of disturbance that could favour the establishment or spread of particular species (Pyrke 1994). Urine is rich in nutrients, especially nitrogen. Huts in the wilderness generally have a ring of introduced herbs around their doors, probably largely for this reason (Kirkpatrick 1997). Faeces are also nutrient rich, in comparison to soils. The addition of nutrients to native ecosystems has the potential to change their nature (Kirkpatrick & Harris 1999).

The rate of degradation of human faeces, toilet paper, tissues and tampons, once buried, is also likely to vary considerably between vegetation and soil types. For example, low temperatures, acid conditions and anaerobic soils slow the rate of decomposition (Liddle 1997). The rate of decomposition has direct relevance to the duration of the health hazard and the visual impact presented by the deposit.

Native animals do not have the human aversion to eating faeces, and may excavate to obtain a meal, with obvious public health implications, such as the already realized ubiquity of *Giardia* in possum populations, as well as implications for visual amenity. It is therefore important to determine the disposal methods that minimize such excavation.

In North America it has been argued that 'pack it in - pack it out' should pertain to faeces (Meyer 1994; Drake 1995), an option used in Australia only on some commercial operations such as rafting and skiing. It would obviously be socially preferable for walkers to be able to bury their faecal waste in those environments where such burial has no serious impacts.

The research objective of the present project was to determine the relative impacts of disposal of human wastes on vegetation and soils in Tasmanian vegetation types that occur in areas used for wild country camping, with particular emphasis on the impact of digging, the impact of nutrient accessions, the persistence of toilet paper, tissues and tampons, and the disturbance of burials by native animals. The implementation objective was to use the results of the research to develop habitat-specific prescriptions for human waste disposal in wild areas that are consistent with long term maintenance of natural values, while being acceptable to users, and to effectively communicate these prescriptions to users and managers.

In the following sections we report on our research results relating to the impact on vegetation of digging and urine addition, our research results in relation to animal disturbance, our research results in relation to the decay of products used for the disposal of human wastes, and the implications of these results for managers and users. We also report on communication related to the project and further research needs.

Chapter 2

The Impacts of Digging and Urine on Vegetation

Introduction

The aim of the research reported in this section was to determine whether digging for human waste disposal, the nutrients in human urine and their combination affected attributes of the vegetation at each of nine sites representing the major bushwalking environments in Tasmania.

Methods

Site Environmental Data

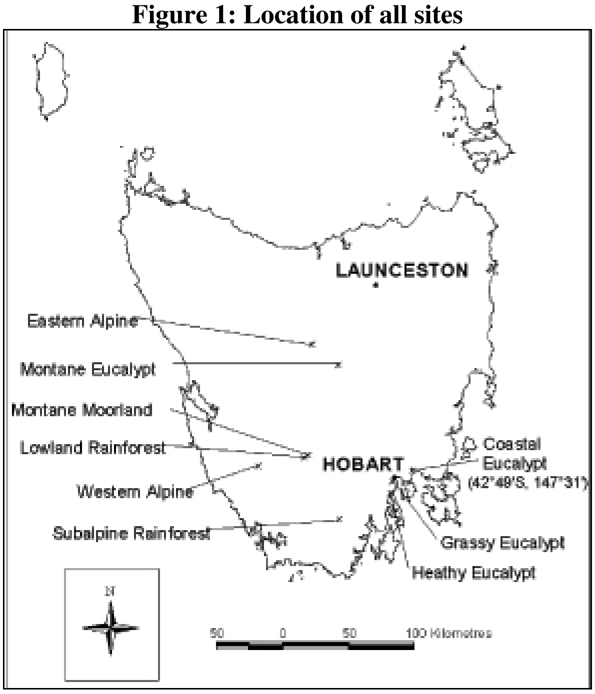
Altitude and surface geology were obtained from maps. Mean annual rainfall, summer rainfall, mean annual temperature and the mean daily maximum summer temperature were estimated. Where possible, climatic data were obtained from stations, or previous data collection, in close proximity to the site. Otherwise precipitation data were obtained from the modelling of Nunez, Kirkpatrick & Nilsson (1996) and temperature data from application of an environmental lapse rate of 0.65°C per 100 m from the nearest station in a similar environment.

Soil depth was determined by probing each of 10 soil sample locations along a transect between the 2 treatment transects. The surface 5 cm of the soil below the litter layer was collected for later analysis. The sample was bulked from five sub-samples. The following attributes of these samples were determined in the laboratory, following the methods described in Rayment and Higginson (1992), except where indicated otherwise below by the absence of a reference number to this volume: pH, 1:5 soil:water suspension (4A1); conductivity, EC of 1:5 soil water suspension (3A1); extractable P, bicarbonate extractable (9B2); total P, nitric/perchloric digest and I.C.P. analysis; %N, semimicro Kjeldahl with steam distillation (7A1); NO_3N, KCl extract (7C2); NH_4N, KCl extract (7C2); extractable K, bicarbonate extractable (18A1); total Ca, nitric/perchloric digest and I.C.P. analysis; Cu, DTPA (12A1); Zn, DTPA (12A1); Mn, DTPA (12A1); Fe, DTPA (12A1); organic carbon, Walkley and Black (6A1). Particle size analysis was undertaken on the soil samples (McDonald et al. 1984).

Site Selection & Characteristics

Alpine areas have proven particularly sensitive to the impacts of trampling (Gibson 1984; Calais & Kirkpatrick 1986; Whinam & Chilcott 1999), and are highly attractive destinations for overnight walkers. Alpine environments in Tasmania vary enormously in their soils and vegetation (Kirkpatrick & Bridle 1998, 1999). For this reason, two alpine sites were used in the project (Figure 1). These exemplified the extremes of the alpine environments in the State.

Figure 1: Location of all sites



The first was the western alpine site at Mount Sprent (western alpine, Figure 2). The climate, soils and vegetation of Mt. Sprent are well-known (Kirkpatrick & Brown 1987; Kirkpatrick, Nunez, Bridle & Chladil 1996; Bridle & Kirkpatrick 1997). It typifies the nutrient-poor, acid (Table 1), high rainfall (Table 2) extreme of alpine vegetation in Tasmania. The plant community is *Donatia novae-zelandiae* bolster heath, with high cover of *D. novae-zelandiae, Oreobolus oligocephalus* and *Dracophyllum milliganii* (
Table 3).

The eastern alpine site (Figure 3), on the Central Plateau (eastern alpine, Figure 1), occurs at the other extreme of alpine vegetation in Tasmania, with relatively nutrient-rich soils (Table 1) and relatively low rainfall (Table 2). The vegetation is alpine heath in which the most abundant taxa are *Grevillea australis, Leucopogon montanus, Pentachondra pumila* and *Poa* spp. (Table 3).

Figure 2: Western Alpine

Figure 3: Eastern Alpine

The montane and subalpine zones of Tasmania are also well-used by overnight walkers. Moorland dominated by buttongrass (*Gymnoschoenus sphaerocephalus*) covers much of these zones in western Tasmania, as well as extensive areas of lowland (Jarman, Kantvilas & Brown 1988). A site (Figure 4) was established at Tim Shea (montane moorland, Figure 1), where the peat soils are acid and nutrient-poor (Table 1) and the rainfall high (Table 2). The vegetation is dominated by buttongrass and shrubs, most notably *Leptospermum nitidum* and *Melaleuca squamea* (Table 3).

Figure 4: Montane Moorland

Subalpine rainforest is also widespread in western Tasmania (Jarman, Brown & Kantvilas 1984). A site (Figure 5) was selected at the Hartz Mountains (subalpine rainforest, Figure 1). The soils formed on sandstone at this site are acid and nutrient-poor (Table 1) and the precipitation is high (Table 2). The vegetation is thamnic rainforest, with a ground stratum dominated by bryophytes (Table 3).

Figure 5: Subalpine Rainforest

The third high mountain site (Figure 6) was placed in eucalypt forest on the Central Plateau (montane eucalypt forest, Figure 1). The soils are relatively nutrient-rich and not extremely acid (Table 1) and the precipitation is moderate (Table 2). The vegetation is *Eucalyptus pauciflora-E. rodwayi* open-forest with an understorey in which *Leucopogon hookeri* and *Poa* spp. are prominent (Table 3).

Figure 6: Montane Eucalypt Forest

A lowland rainforest site (Figure 7) was selected on the Strathgordon Road (lowland rainforest, Figure 1). Soils are nutrient-poor and acid (Table 1) and rainfall is high (Table 2). The site is prone to occasional waterlogging. The callidendrous rainforest that occupies the site has an understorey dominated by bryophytes (Table 3).

Figure 7: Lowland Eucalypt Forest

A heathy forest on sandstone (Figure 8) at Huntingfield (heathy eucalypt forest, Figure 1) was selected to represent the other extreme of dry eucalypt forest. The soils are acid and nutrient-poor (Table 1) and rainfall low (Table 2). The tree canopy is dominated by *Eucalyptus amygdalina*. The understorey is dominated by scleromorphic shrubs and bracken (*Pteridium esculentum*). Bracken, *Bossiaea cinerea* and *Leucopogon collinus* have the greatest covers in this layer (Table 3). The site was burned in 1998.

Figure 8: Heathy Eucalypt Forest

The dry eucalypt forests that occupy most of eastern Tasmania (Duncan & Brown 1984), have understories that vary from heathy to grassy as soils become less acid, more nutrient-rich and clayier. A grassy eucalypt forest (Figure 9) on dolerite in the University of Tasmania Reserve (grassy eucalypt forest, Figure 1) was selected to represent one of these extremes. The soils are only mildly acid and are nutrient rich (Table 1), and rainfall is low (Table 2). *Eucalyptus pulchella* and *E. ovata* dominate the tree layer. The understorey has a dense cover of native tussock grasses, most notably *Themeda triandra* and *Poa rodwayi* (Table 3). This site was burned last in 1995. The coast is one of the most attractive places for bushwalking and coastal sand dunes are one of the easiest places to dig a hole for defecation in the wild.

Figure 9: Grassy Eucalypt Forest

A coastal eucalypt forest on Holocene beach ridges (Figure 10) at Seven Mile Beach (coastal eucalypt forest, Figure 1) was selected. The sandy soils are only mildly acid and moderately nutrient-rich (Table 1) and the precipitation low (Table 3). The forest is dominated by *Eucalyptus viminalis*. The understorey is a mixture of sagg (*Lomandra longifolia*), tussock grasses, shrubs and succulent creepers. The species with the most cover in this layer are the sedge, *Lepidosperma concavum*, sagg and the succulent, *Carpobrotus rossii* (Table 3).

Figure 10: Coastal Eucalypt Forest

Table 1: Results of soil depth, texture and chemical analyses of some elements from bulked soil samples at each site. OC = organic carbon, Cond = conductivity

Site	OC (%)	Tot N (%)	pH (H_20)	pH ($CaCl_2$)	P (ppm)	K (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Tot P (ppm)	Tot Ca (ppm)	Exc N (ppm)	Cond	Mean soil depth (cm)	Soil Texture
Western Alpine	13.0	0.46	4	3.2	11	240	9.6	1.6	130	770	80	7	140	610	40	210	30.2	Loamy Sand
Eastern Alpine	8.7	0.37	5.4	4.4	18	210	2.3	1.7	76	450	100	64	760	410	25	45	25.9	Sandy Loam
Montane Moorland	42.0	1.06	3.5	2.8	10	390	4	0.7	460	640	90	7	160	760	120	300	36.7	Silty Clay
Subalpine Rainforest	19.0	0.40	4.2	3.8	10	250	4.9	2.6	830	1050	250	140	270	890	50	190	29.7	Loam
Montane Eucalypt Forest	7.7	0.31	5.1	4.4	24	290	11	2.5	510	1800	300	130	440	1520	70	135	17.9	Sandy Loam
Lowland Rainforest	13.0	0.44	3.9	3	33	250	3.4	0.5	180	310	140	77	260	330	60	135	46.4	Silty Clay
Heathy Eucalypt Forest	17.0	0.52	3.7	2.7	15	200	20	0.2	84	450	480	14	130	540	30	75	33.6	Loamy Sand
Grassy Eucalypt Forest	3.0	0.16	5.8	5	8	70	13	4	300	1210	480	190	120	1630	20	60	13.6	Sandy Clay
Coastal Eucalypt Forest	2.2	0.16	5.9	5.1	9	80	6.6	0.3	52	1350	180	62	55	1200	40	75	65.2	Sand

Table 2: Environmental attributes and time of first treatment for each of the study areas

Site	Geology	Altitude (m)	Mean Annual Rainfall (mm)	Mean Annual Temperature (°C)	Time of first treatment
Western Alpine	Quartzite	950	3222	10.0	Mar-00
Eastern Alpine	Dolerite	1150	1056	11.6	Feb-00
Montane Moorland	Quartzite	850	1445	12.4	Feb-00
Subalpine Rainforest	Dolerite	755	900	13.1	Feb-00
Montane Eucalypt Forest	Dolerite	945	854	11.1	Feb-00
Lowland Rainforest	Quartzite	450	1215	13.2	Apr-00
Heathy Eucalypt Forest	Sandstone	110	677	16.8	May-00
Grassy Eucalypt Forest	Dolerite	230	619	15.6	May-00
Coastal Eucalypt Forest	Sandstone	5	507	17.4	May-00

Table 3: Mean percentage cover of plant taxa in the ground layer

GEF = grassy eucalypt forest, **CEF** = coastal eucalypt forest, **EA** = eastern alpine, **MEF** = montane eucalypt forest, **HEF** = heathy eucalypt forest, **SRF** = subalpine rainforest, **LRF** = lowland rainforest, **MM** = montane moorland, **WA** = western alpine, * = exotic taxon; a taxon at a higher level does not include the cover of listed taxa at lower levels.

	GEF	CEF	EA	MEF	HEF	SRF	LRF	MM	WA
Poa rodwayi	27.975	-	-	-	-	-	-	-	-
Themeda triandra	27.051	-	-	-	-	-	-	-	-
Schoenus apogon	6.351	-	-	-	0.055	-	-	-	-
Lepidosperma inops	3.838	-	-	-	-	-	-	-	-
Gonocarpus tetragynus	3.424	-	-	-	-	-	-	-	-
Carex breviculmis	3.226	-	0.213	0.134	-	-	-	-	-
Bossiaea prostrata	2.978	-	-	0.877	-	-	-	-	-
Diplarrena moraea	1.305	-	-	-	-	-	-	-	-
Arthropodium milleflorum	0.878	-	-	0.008	-	-	-	-	-
**Plantago lanceolata*	0.717	-	-	-	-	-	-	-	-
Astroloma humifusum	0.597	0.115	-	-	-	-	-	-	-
**Centaurium erythraea*	0.452	-	-	-	-	-	-	-	-
Lissanthe strigosa	0.428	-	-	0.008	-	-	-	-	-

	GEF	CEF	EA	MEF	HEF	SRF	LRF	MM	WA
Bursaria spinosa	0.225	-	-	-	-	-	-	-	-
Hibbertia hirsuta	0.200	-	-	-	-	-	-	-	-
**Hypochoeris radicata*	0.102	-	-	-	-	-	-	-	-
Eucalyptus ovata	0.083	-	-	-	-	-	-	-	-
Hypericum gramineum	0.047	-	-	-	-	-	-	-	-
Plantago varia	0.033	-	-	0.001	-	-	-	-	-
Senecio spp.	0.025	-	-	-	-	-	-	-	-
Caladenia iridescens	0.025	-	-	-	-	-	-	-	-
Senecio quadridentatus	0.017	0.008	-	-	-	-	-	-	-
Eucalyptus pulchella	0.004	-	-	-	-	-	-	-	-
**Taraxacum officinale*	0.004	-	-	-	-	-	-	-	-
Lepidosperma concavum	-	7.979	-	-	-	-	-	-	-
Carpobrotus rossii	-	3.502	-	-	-	-	-	-	-
Lomandra longifolia	1.392	2.100	-	-	-	-	-	-	-
Poa labillardieri	-	1.835	-	-	-	-	-	-	-
Dianella brevicaulis	0.384	0.935	-	-	-	-	-	-	-
Hibbertia acicularis	-	0.671	-	-	-	-	-	-	-
Pultenaea sp.	-	0.375	-	-	-	-	-	-	-
Pimelea humilis	0.004	0.319	-	-	-	-	-	-	-
Kennedia prostrata	-	0.243	-	-	-	-	-	-	-
Hibbertia prostrata	-	0.231	-	-	-	-	-	-	-
**Pinus radiata*	-	0.104	-	-	-	-	-	-	-
Eucalyptus viminalis	-	0.013	-	-	-	-	-	-	-
Oxalis perennans	0.001	0.008	-	-	-	-	-	-	-
Distichlis distichophylla		0.008	-	-	-	-	-	-	-
Grevillea australis	-	-	8.416	-	-	-	-	-	-
Leucopogon montanus	-	-	8.012	-	-	-	-	-	-
Poa fawcettiae	-	-	4.869	4.083	-	-	-	-	-
Pentachondra pumila	-	-	4.767		-	-	-	-	-
Poa hiemata	-	-	3.958	2.418	-	-	-	-	-
Leptorhynchos squamatus	-	-	3.951	0.013	-	-	-	-	-
Pimelea pygmaea	-	-	2.524	-	-	-	-	-	-
Richea acerosa	-	-	2.115	-	-	-	-	-	-
Coprosma spp.	-	-	2.016	-	-	-	-	-	-
Senecio lautus	-	-	2.054	-	-	-	-	-	-
Epacris gunnii	-	-	1.890	0.007	-	-	-	-	-
Velleia montana	-	-	1.658	-	-	-	-	-	-
Epacris petrophila	-	-	1.439	-	-	-	-	-	-
Cryptandra alpina	-	-	1.005	-	-	-	-	-	-
Luzula spp.	-	-	1.003	0.263	-	-	-	-	-
Bracteantha subundulata	-	-	0.897	-	-	-	-	-	-
**Aira* spp.	-	-	0.576	0.079	-	-	-	-	-
Geranium spp.	-	0.008	0.460	0.006	-	-	-	-	-
Oreomyrrhis ciliata	-	-	0.397	0.093	-	-	-	-	-
Erigeron spp.	-	-	0.395	0.008	-	-	-	-	-
Agrostis spp.	0.081	-	0.362	0.025	-	-	-	-	-
Asperula gunnii		-	0.257	0.175	-	-	-	-	-
Scleranthus biflorus		-	0.236	0.058	-	-	-	-	-
Lycopodium fastigiatum	-	-	0.236	-	-	-	-	-	-
Exocarpos humifusus	-	-	0.178	-	-	-	-	-	-
**Cerastium glomeratum*	-	-	0.136	-	-	-	-	-	-
**Poa annua*	-	-	0.103	-	-	-	-	-	-
Centrolepis monogyna	-	-	0.088	-	-	-	-	-	-
Wahlenbergia spp.	0.012	-	0.067	0.014	-	-	-	-	-
**Acetosella vulgaris*	-	-	0.050		-	-	-	-	-
Microseris lanceolata	-	-	0.045	0.016	-	-	-	-	-
Orites acicularis	-	-	0.035	-	-	-	-	-	-

	GEF	CEF	EA	MEF	HEF	SRF	LRF	MM	WA
**Erophila verna*	-	-	0.031	-	-	-	-	-	-
Craspedia spp.		-	0.022	0.018	-	-	-	-	-
Ranunculus spp.	0.003	-	0.021	-	-	-	0.001	-	-
Uncinia spp.	-	-	0.017	-	-	-	-	-	-
Wahlenbergia saxicola	-	-	0.014	-	-	-	-	-	-
Epilobium spp.	-	-	0.005	-	-	-	-	-	-
Viola spp.	-	-	0.002	-	-	-	-	-	-
Cardamine spp.	-	-	0.001	-	-	-	-	-	-
**Rumex acetosella*	-	-	0.001	-	-	-	-	-	-
Leucopogon hookeri	-	-	-	4.539	-	-	-	-	-
Gonocarpus serpyllifolius	-	-	-	3.155	-	-	-	-	-
Hydrocotyle sibthorpioides	-	-	-	2.457	-	-	-	-	0.050
Cyathodes parvifolia	-	-	-	2.138	-	-	-	-	
Pultenaea juniperina	0.118	-	-	1.423	0.002	-	-	-	-
Ehrharta stipoides	0.223	-	-	0.788	-	-	-	-	-
**Holcus lanatus*	0.038	-	-	0.279	-	-	-	-	-
Acaena novae-zelandiae	-	-	-	0.247	-	-	-	-	-
Leucopogon stuartii	-	-	-	0.233	-	-	-	-	-
Eucalyptus spp.	-	-	-	0.193	-	-	0.001	-	-
Viola betonicifolia	-	-	-	0.138	-	-	-	-	-
Eucalyptus pauciflora	-	-	-	0.108	-	-	-	-	-
Helichrysum scorpioides	-	-	-	0.100	-	-	-	-	-
Plantago glabrata	-	-	-	0.072	-	-	-	-	-
Poranthera microphylla	-	-	-	0.072	-	-	-	-	-
Brachyscome spp.	-	-	0.008	0.056	-	-	-	-	-
Lepidosperma spp.	-	-	-	0.042	-	-	-	-	-
Eucalyptus rodwayi	-	-	-	0.042	-	-	-	-	-
Euchiton spp.	-	-	-	0.029	-	-	-	-	-
Senecio gunnii	-	-	-	0.022	-	-	-	-	-
**Dactylis glomerata*	-	-	-	0.017	-	-	-	-	-
Coprosma nitida	-	-	-	0.013	-	-	-	-	-
Diplarrena latifolia	-	-	-	0.005	-	-	-	-	-
Ozothamnus hookeri	-	-	-	0.001	-	-	-	-	-
Bossiaea cinerea	-	-	-	-	7.903	-	-	-	-
Pteridium esculentum	-	4.704	-	-	6.689	-	-	-	-
Leucopogon collinus	-	-	-	6.106	-	-	0.988	-	-
Amperea xiphoclada	-	-	-	-	3.512	-	-	-	-
Aotus ericoides	-	1.592	-	-	3.256	-	-	-	-
Hypolaena fastigiate	-	-	-	-	2.992	-	-	-	-
Tetratheca labillardier	-	-	-	-	1.299	-	-	-	-
Leucopogon virgatus	-	-	-	-	1.278	-	-	-	-
Baeckea ramosissima	-	-	-	-	1.155	-	-	-	-
Leptospermum scoparium	0.250	-	-	-	1.037	-	-	-	-
Epacris impressa	0.175	-	-	-	0.992	-	-	-	-
Allocasuarina monilifera	-	-	-	-	0.955	-	-	-	-
Cassytha glabella	-	0.050	-	-	0.076	-	-	-	-
Leucopogon ericoides	-	-	-	-	0.067	-	-	-	-
Thelionema caespitosum	-	-	-	-	0.065	-	-	-	-
Styphelia adscendens	-	-	-	-	0.064	-	-	-	-
Pimelea linifolia	-	-	-	-	0.011	-	-	-	-
Thelymitra spp.	-	-	-	-	0.001	-	-	-	-
Archeria eriocarpa	-	-	-	-	-	0.395	-	-	-
Gahnia grandis	-	-	-	-	-	0.280	-	-	-
Trochocarpa disticha	-	-	-	-	-	1.174	0.007	-	-
Anopterus glandulosus	-	-	-	-	-	0.127	0.004	-	-
Bryophyta	0.625	0.018	0.354	29.317	5.370	12.402	66.851	11.668	5.805
Sphagnum spp.	-	-	-	-	-	-	4.958	-	-

	GEF	CEF	EA	MEF	HEF	SRF	LRF	MM	WA
Hymenophyllum spp.	-	-	-	-	-	-	0.265	-	-
Cenarrhenes nitida	-	-	-	-	-	-	0.034	-	-
Drymophila cyanocarpa	-	-	-	-	-	-	0.034	-	-
Grammitis billardieri	-	-	-	-	-	-	0.026	-	-
Blechnum wattsii	-	-	-	-	-	0.015	0.018	-	-
Melaleuca squamea	-	-	-	-	-	-	-	19.608	-
Leptospermum nitidum	-	-	-	-	-	-	-	19.371	-
Eurychorda complanata	-	-	-	-	-	-	-	11.796	-
Acion hookeri	-	-	-	-	-	-	-	9.467	-
Sporadanthus tasmanicus	-	-	-	-	-	-	-	8.500	-
Sprengelia incarnata	-	-	-	-	-	-	-	8.413	-
Schoenus lepidosperma	-	-	-	-	-	-	-	6.342	-
Epacris lanuginosa	-	-	-	-	-	-	-	4.780	-
Gymnoschoenus sphaerocephalus	-	-	-	-	-	-	-	2.480	-
Bauera rubioides	-	-	-	-	-	-	-	2.176	-
Hibbertia procumbens	-	-	-	-	0.076	-	-	0.772	-
Actinotus bellidioides	-	-	-	-		-	-	0.722	-
Stylidium graminifolium	0.058	-	-	0.225	0.200	-	-	0.651	-
Lycopodiella lateralis	-	-	-	-	-	-	-	0.415	-
Lepidosperma filiforme	-	-	-	-	-	-	-	0.408	-
Dillwynia glaberrima	-	-	-	-	0.084	-	-	0.317	-
Boronia citriodora	-	-	-	-	-	-	-	0.222	-
Acion monocephalum	-	-	-	-	-	-	-	0.183	-
Boronia parviflora	-	-	-	-	-	-	-	0.152	-
Baeckea leptocaulis	-	-	-	-	-	-	-	0.125	-
Ehrharta tasmanica	-	-	-	-	-	-	-	0.056	-
Baeckea gunniana	-	-	-	-	-	-	-	0.033	-
Banksia marginate	-	-	-	-	-	-	-	0.009	-
Donatia novae-zelandiae	-	-	-	-	-	-	-	-	21.550
Oreobolus oligocephalus	-	-	-	-	-	-	-	-	17.742
Dracophyllum milliganii	-	-	-	-	-	-	-	-	13.712
Sprengelia montana	-	-	-	-	-	-	-	-	7.892
Isophysis tasmanica	-	-	-	-	-	-	-	-	7.818
Empodisma minus	-	-	-	-	-	-	-	1.583	6.892
Ewartia meredithiae	-	-	-	-	-	-	-		5.914
Lichen	-	-	1.753	0.530	0.387	0.982	0.407	3.351	4.272
Epacris navicularis	-	-	-	-	-	-	-	-	3.122
Actinotus suffocata	-	-	-	-	-	-	-	-	2.568
Carpha alpina	-	-	-	-	-	-	-	-	2.003
Mitrasacme montana	-	-	-	-	-	-	-	0.124	1.577
Epacris serpyllifolia	-	-	-	-	-	-	-	-	1.337
Carpha curvata	-	-	-	-	-	-	-	-	1.334
Richea curtisiae	-	-	-	-	-	-	-	-	1.071
Monotoca submutica	-	-	-	-	-	-	-	-	0.976
Drosera arcturi	-	-	-	-	-	-	-	-	0.941
Astelia alpina	-	-	-	-	-	-	-	-	0.805
Xyris marginata	-	-	-	-	-	-	-	0.192	0.429
Forstera bellidifolia	-	-	-	-	-	-	-	-	0.350
Anemone crassifolia	-	-	-	-	-	-	-	-	0.223
Actinotus moorei	-	-	-	-	-	-	-	-	0.195
Celmisia asteliifolia	-	-	0.107					-	0.171
Diplaspis cordifolia	-	-	-	-	-	-	-	-	0.128
Eucalyptus vernicosa	-	-	-	-	-	-	-	-	0.108
Campynema lineare	-	-	-	-	-	-	-	-	0.047
Helichrysum pumilum	-	-	-	-	-	-	-	-	0.041
Ozothamnus rodwayi	-	-	-	-	-	-	-	-	0.033

	GEF	CEF	EA	MEF	HEF	SRF	LRF	MM	WA
Euphrasia hookeri	-	-	-	-	-	-	-	-	0.031
Ehrharta spp.	-	-	-	-	-	-	-	-	0.025
Gentianella spp.	-	-	0.018	-	-	-	-	-	0.024
Euphrasia collina	-	-	-	-	-	-	-	-	0.005

Sampling and Experimental Design

At each site two parallel transects, each approximately 20 m in length were laid out along the contour. Within each transect 20 quadrats (50 x 50 cm) were located in areas that would be attractive as a toilet spot for bushwalkers, that is, the area was free from prickly shrubs, and the soil depth was a minimum of 15 cm. Quadrats were marked by steel roof spikes in each corner and the distance along the transect, and distance and direction of offset from the transect line was recorded. Quadrats were located at least 50 cm from each other in all directions to avoid overlap.

Quadrats were randomly allocated to four treatments: 1) control; 2) 250 ml of artificial urine, formulated according to the recipe of Gotaas (1956), added to the centre of the quadrat at each visit; 3) 10 cm diameter hole dug in centre of the quadrat to 15 cm depth and refilled; 4) hole dug and filled as previously and 250 ml of artificial urine added at each visit. Visits took place at 0, 6 months, 12 months, 18 months and 24 months.

Data Collection

The first data collection took place in summer to autumn 2000. Data collection was repeated at approximately the same time in the year for each site in 2001 and 2002. The first data collection occurred before the excavation of holes and the pouring of artificial urine. The periodic removal and replacement of bags containing toilet paper, tissues and tampons led to re-disturbance of a proportion of the dug quadrats (see 'Breakdown of Products' below) between 2000 and 2001 and 2001 and 2002.

The outline covers of all discernible vascular plant taxa, cryptogam groups, bare soil, litter and rock were measured using a gridded quadrat frame. Bare soil, litter and rock were not counted if beneath vegetation cover. Overlapping cover was used for plant taxa. The maximum height of each taxon was also measured. Vegetation taller than 2m was not included for either cover or height.

Data Analysis

All analyses were undertaken for each of the sites. Global non-metric multidimensional scaling, following the default options in DECODA (Minchin 1990) was used to ordinate the taxon cover data and the taxon height data. The ordination scores provide a measure of overall similarity. Generalized linear modelling was used to test for significant interactions between time and treatment. Only the most abundant taxa, the ordination scores and the cover of bare ground, litter and rock could be analysed in this manner. One way analysis of variance (ANOVA) was used to test for significant changes in values for variables over time. ANOVA was also used to test for significant treatment effects on the difference in cover between 2000 and 2002. In this case, the data for each individual analysis were reduced to those quadrats with a cover value in either or both of 2000 and 2002. In all cases results are regarded as not significant if $P > 0.05$.

Results

The only significant interactive effects between treatment and time were for *Leptorhynchos squamatus* ($F = 2.24$, $P = 0.044$) and *Senecio lautus* ($F = 3.2$, $P = 0.006$) at the Eastern Alpine site (Table 4). The treatments that involved urine additions resulted in accelerated increases in the cover of both species.

Table 4: Percentage covers by time and treatment for Leptorhynchos squamatus and Senecio lautus at the eastern alpine site

Leptorhynchos	Control	Urine	Dig	Dig & urine
2000	3.1	3.0	1.5	1.5
2001	3.7	4.9	1.8	2.6
2002	5.4	12.6	3.3	3.5
Senecio				
2000	0.28	0.97	1.77	0.83
2001	0.39	3.20	0.96	2.00
2002	0.66	6.80	1.66	4.60

Of the taxa by site combinations that exhibited statistically significant changes in cover related to time, 29 increased, 2 decreased and 8 showed no consistent tendency (Table 5). The increasers were concentrated in the eastern alpine (8), heathy eucalypt forest (9) and grassy eucalypt forest (4). The lowland rainforest was the only site where increasers equalled decreasers (1 cf 1). It was also the only site where increasers were outnumbered by species with no consistent tendency (1 cf 2). The two cases of significant decrease were lichen in the western alpine and bryophytes in the lowland rainforest (Table 5).

Table 5: Significant cover changes through time at each site (ANOVA)

Site and element	2000	2001	2002	F	P
Western Alpine					
Lichen	5.62	4.15	3.04	5.19	0.007
Litter	4.85	7.40	9.55	8.11	0.001
Montane Moorland					
Epacris lanuginosa	3.28	5.31	5.75	3.60	0.031
Dillwynia glaberrima	0.00	0.34	0.61	5.07	0.008
Boronia parviflora	0.06	0.30	0.09	3.45	0.035
Bare	0.35	1.32	0.55	5.51	0.005
Eastern Alpine					
Oreomyrrhis ciliata	0.26	0.26	0.66	4.34	0.015
Leptorhynchos squamatus	2.25	3.24	6.36	8.84	0.000
Senecio lautus	0.98	1.66	3.52	10.08	0.000
Asperula gunnii	0.07	0.18	0.52	6.20	0.003
Luzula spp.	0.55	0.71	1.73	13.9	0.000
Agrostis spp.	0.00	0.43	0.67	6.88	0.002
Aira spp.	0.15	0.38	1.20	3.93	0.022
Exotic grass	0.15	0.38	1.48	4.75	0.011
Lowland Rainforest					
Bryophyta cover	69.5	65.6	57.8	3.26	0.042
Lichen	0.81	0.15	0.25	6.29	0.003
Fungi	0.04	0.58	0.26	8.87	0.000
Litter	22.55	25.83	34.45	6.63	0.002
Subalpine Rainforest					
Lichen	1.04	1.48	1.06	5.01	0.008
Seedlings	0.27	0.37	1.07	6.42	0.002
Montane Eucalypt Forest					
Hydrocotyle sibthorpioides	1.50	1.51	4.35	6.51	0.002
Poa hiemata	1.05	1.62	4.58	14.04	0.000
Heathy Eucalypt Forest					
Epacris impressa	0.32	0.55	2.07	9.69	0.000
Leucopogon collinus	0.68	2.61	14.87	46.52	0.000
Styphelia adscendens	0.01	0.05	0.13	3.93	0.023
Aotus ericoides	1.24	2.26	6.19	11.00	0.000
Bossiaea cinerea	5.90	7.46	10.15	4.24	0.017
Baeckea ramosissima	0.47	0.86	2.10	4.09	0.019
Stylidium graminifolium	0.05	0.12	0.23	4.11	0.019
Hypolaena fastigiata	6.40	1.47	1.90	7.29	0.000
Site and element	2000	2001	2002	F	P
Pteridium esculentum	1.30	4.75	13.85	10.97	0.000
Bryophyta	0.00	8.08	7.90	6.88	0.002
Bare	53.05	22.79	8.25	87.74	0.000
Litter	22.27	55.25	28.12	4.82	0.010
MDS cover 1	-0.43	-0.01	0.46	70.90	0.000
MDS height 1	-0.17	-0.04	0.21	11.02	0.000
MDS height 2	0.16	0.05	-0.22	13.72	0.000
MDS height 3	-0.13	-0.06	0.19	11.11	0.000
Grassy Eucalypt Forest					
Astroloma humifusum	0.20	0.66	0.93	6.17	0.003
Epacris impressa	0.00	0.04	0.49	9.02	0.000
Gonocarpus tetragynus	1.11	4.06	5.09	8.63	0.000
Carex breviculmis	2.43	2.62	4.62	8.84	0.000
Schoenus apogon	5.25	4.85	8.95	8.28	0.000
Bryophyta	0.02	1.85	0.00	20.47	0.000
Bare	0.10	0.75	0.00	3.17	0.046
MDS height 1	-0.08	-0.04	0.12	4.99	0.008
MDS height 2	-0.17	-0.05	0.22	22.11	0.000

Site and element	2000	2001	2002	F	P
MDS height 3	0.09	0.05	-0.13	7.00	0.001
Coastal Eucalypt Forest					
Carpobrotus rossii	1.0	2.3	7.2	5.32	0.006
Lepidosperma concavum	6.3	6.6	11.0	5.13	0.007
Pteridum esculentum	1.9	0.4	11.8	20.12	0.000
Bare	0.0	1.8	0.6	4.68	0.011
Litter	84	81	59	39.97	0.000
Seedlings	0.1	0.5	0.0	4.87	0.031
MDS cover 2	0.16	0.22	-0.39	23.50	0.000
MDS height 2	-0.05	0.16	-0.10	4.87	0.010
MDS height 3	0.07	0.07	-0.01	3.78	0.026

Using all attributes included in the analyses, the control treatment had significantly higher values than one or more of the other treatments in 8 cases, and significantly less in 10 cases (Table 6). The urine treatment had significantly higher values than one or more of the other treatments in 14 cases and significantly less in 7 cases (Table 6). The dig treatment showed the reverse pattern with 3 and 14 respectively, while the dig and urine treatment had 8 in each class (Table 6). This differentiation by treatment is significant (Chi-square = 9.2, d.f. = 3, P < 0.01), with the urine treatment having more positive outcomes than expected and the dig treatment having more negative outcomes than expected.

There were no significant treatment effects in either of the rainforest sites. Both alpine sites showed some effects. In the western alpine *Monotoca submutica* was positively affected by the dig and urine treatment whereas bryophytes were negatively affected by the treatments involving urine. In the eastern alpine 6 non-woody taxa were favoured by urine additions, and the scores on the second axis of the cover ordination were significantly different between the urine treatment and the rest (Table 6).

At the montane moorland site, the dominant shrub, *Melaleuca squamea,* was favoured by the combination of digging and urine, the shrub, *Epacris lanuginosa,* was favoured by urine without digging, and the restiad, *Eurychorda complanata*, was favoured by both the urine treatments (Table 6). Bare ground was significantly greater in the digging treatment than in the urine or control treatments, litter cover decreased in quadrats where urine was added and the scores on the second axis of the cover ordination differentiated between the urine treatment and the rest (Table 6).

The eucalypt forest sites did not individually exhibit as many significant treatment effects as the montane moorland and eastern alpine sites. At the montane eucalypt site urine additions promoted native grass cover (Table 6). In the grassy eucalypt forest urine also promoted native grass cover, while it decreased litter cover (Table 6). The cover ordination scores also indicated a strong effect of urine additions (Table 6). At the heathy eucalypt site urine also decreased litter cover, and on cover ordination axis 2 the scores were significantly different between the control and the urine treatment (Table 6). At the coastal eucalypt forest urine increased the cover of the rhizomatous sedge, *Lepidosperma concavum* (Table 6).

Table 6: Significant effects of treatment on changes in vegetation cover by site from 2000-2002

Site and element	Control	Urine	Dig	Dig & urine	F	P
Western Alpine						
Monotoca submutica	-0.1a	0.7ab	-0.3ab	2.2b	3.87	0.045
Bryophyta	1.0a	-2.2b	-0.6ab	-2.6b	2.95	0.046
Eastern Alpine						
Leptorhynchos squamatus	3.3a	9.2b	2.4a	2.6a	5.55	0.004
Senecio lautus	0.5a	6.3b	-0.2a	5.3b	9.12	0.000
Asperula gunnii	0.6a	2.4b	0.0a	0.9ab	4.54	0.015
Luzula spp.	1.2ab	2.7a	0.7b	0.6b	3.96	0.017
Poa hiemata	0.2a	10.4b	-0.3a	0.4a	4.53	0.014
Native grass	-3.9a	4.4b	0.0ab	4.2b	3.09	0.041
MDS cover 2	0.03b	-0.25a	0.05b	0.01b	5.62	0.003
Montane Moorland						
Melaleuca squamea	-1.2ab	-0.1ab	-1.9a	5.8b	3.11	0.038
Epacris lanuginosa	0.0a	8.1b	2.4a	2.0a	5.19	0.005
Eurychorda complanata	1.7a	12.0b	1.9a	11.5b	3.45	0.029
Bare	-0.3a	-0.4a	1.3b	0.2ab	3.89	0.017
Litter	2.4a	-4.9b	3.4a	-4.6b	3.64	0.022
MDS cover 2	0.00a	0.16b	0.04ab	0.12ab	2.97	0.045
Montane Eucalypt Forest						

Site and element	Control	Urine	Dig	Dig & urine	F	P
Native grass	-0.1a	5.7b	-0.7a	3.9ab	4.67	0.007
Grassy Eucalypt Forest						
Native grass	-11.7ab	4.5b	-20.7a	-2.1b	5.48	0.003
Litter	-0.7a	-13.2b	4.0a	-7.5b	5.32	0.004
MDS cover 1	0.12ab	-0.01a	0.28b	0.00a	3.56	0.024
MDS cover 2	0.02ab	0.16a	-0.02b	0.11ab	3.33	0.030
Heathy Eucalypt Forest						
Litter	24.2a	-3.0b	10.4ab	-8.2b	9.87	0.000
MDS cover 2	0.03a	-0.42b	-0.16ab	-0.29ab	3.42	0.028
Coastal Eucalypt Forest						
Lepidosperma concavum	1.0a	9.3b	3.5a	6.6ab	4.81	0.007

Note that there were no significant treatment effects at either of the rainforest sites.

Discussion

Relatively few taxa, even among those with sufficient data for statistical analysis, exhibited significant impacts from digging, urine application or their combination. Significant effects on the vegetation as a whole were only evident at the eastern alpine, montane moorland, grassy eucalypt and heathy eucalypt sites, which between them accounted for 17 of the 21 significant treatment effects. It is tempting to attribute this pattern to the successional status of the vegetation at these four sites, in comparison to the rest. The eastern alpine site is in process of recovery from a regime of burning and grazing by sheep, the latter of which only ceased in the early 1990s (Bridle, Kirkpatrick, Cullen & Shepherd 2001). The montane moorland, grassy eucalypt forest and heathy eucalypt forest were all burned in the 1990s. In comparison, the rainforest sites were last burned many centuries ago, the western alpine site was likely to have been burned in the 1890s (Marsden-Smedley 1999) and both the montane eucalypt forest and the coastal eucalypt forest exhibit no signs of burning in the last few decades. However, there is no relationship between the number of significant changes through time and the number of significant treatment effects on changes in values between 2000 and 2002, indicating that vegetation dynamism was not related to treatment impact.

The generally positive effect of urine additions on the cover of taxa is consistent with the roles of P and N in plant growth. It is notable that the only taxon to respond negatively to urine additions was the Bryophyta at the western alpine site. The addition of nutrients to native vegetation has been long recognized to have negative outcomes in terms of exotic invasion and reduction of native species richness (e.g. Specht 1963; Connor & Wilson 1968). However, our experiment does not indicate any effect of urine addition on exotic invasion at the sites where exotics occurred, and the local impact of urine addition in the quadrats in which it occurred would mitigate against reductions in species richness. Digging had a predominantly depressive effect on native plant taxa that is revealed both directly through the effects of urine without digging, and in the depressive effect of digging on the positive effects of urine addition (Table 6). The only positive effect of digging on a plant taxon was for *Melaleuca squamea*, and then only when combined with urine addition. Previous work in lowland Tasmania has indicated that physical disturbance, in the absence of nutrient additions, favours rare or threatened species and increases species richness (Pyrke 1994; Kirkpatrick & Gilfedder 1995, 1998; Gilfedder & Kirkpatrick 1998). These tendencies have not been manifest in the present study.

Chapter 3

Animal Disturbance

Introduction

This section presents and discusses our results pertinent to the disturbance of buried material by animals. The aim of the research was to determine whether burial at different depths affected the propensity to excavate faecal material.

Methods

A rainforest in the Vale of Belvoir was selected to undertake a faecal burial experiment. The Vale of Belvoir supports large populations of carnivorous native animals, including devils (*Sarcophilus harrisii*), spotted-tailed quolls (*Dasyurus maculatus*) and eastern quolls (*Dasyurus viverrinus*). There were many signs of carnivorous animals in and adjacent to the site. For two weeks in August 2000 human faeces were deposited in the area by two people, buried alternatively at 5 cm and 15 cm depth. The area was examined daily for animal disturbance of these deposits during this time and for one day one year later (August 2001).

Results and Discussion

None of the faecal deposits were disturbed. This result was surprising given that bags containing only toilet paper, tissues and tampons were excavated or frost-heaved from 34 out of 760 holes where they were buried, largely at 5cm at other sites. It is thought that domestic pets were largely responsible for digging at the heathy eucalypt site (15 bags excavated), while native animals are likely to have accounted for digging at the two rainforest sites (8 bags excavated), with frost heave accounting for losses at the alpine sites (1 bag at western alpine, 8 bags at eastern alpine, Table 7). Thirty bags buried at 5 cm were excavated compared to only 4 bags at 15 cm. One possible flaw in the experimental design was the vegetarian diet of the two persons involved, although one would expect that vegetarian faeces might be more attractive to animals than urine-soaked tissues, tampons and toilet paper. Faecal excavations by native animals have been observed in southwest Tasmania. It is possible that digging mainly occurs in more nutrient poor environments, rather than the relatively rich site of the Vale, despite its numerous and varied animal populations.

Table 7: Number of bags retrieved and excavated at each site

Site	6 m aw	6 m ss	12 m	24 m	All	Lost	Excavated	
							5 cm	15 cm
Coastal Eucalypt Forest	20	20	20	20	80	0	0	0
Eastern Alpine	30 (inc. rock)	0	30 (inc. rock)	20	80	0	8	0
Subalpine Rainforest	20	19	20	19	78	2	5	0
Heathy Eucalypt Forest	20	20	20	20	80	0	12	3
Lowland Rainforest	20	20	17	18	75	5 (2 lost under tree)	2	1
Subalpine Eucalypt Forest	19	0	20	19	58	2	2	0
Western Alpine	30 (inc. rock)	30 (inc. rock)	30 (inc. rock)	19	109	1	1	0
Montane Moorland	20	20	20	20	80	0	0	0
Grassy Eucalypt Forest	20	20	20	20	80	0	0	0
Total	199	149	197	175	720	10	30	4

aw = autumn-winter, ss = spring-summer, m = month.

Chapter 4

Breakdown of Products

Introduction

A Minimal Impact Bushwalking Strategy was adopted by the Tasmanian Parks and Wildlife Service in an attempt to encourage bushwalkers to dispose of their waste in an environmentally safe manner (O'Loughlin 1988). These guidelines advise campers to bury human waste in a hole approximately 15 cm deep and 100 m away from any water source, and to carry out used tampons. Personal observations suggest that paper products used in the disposal of human waste persist much longer on the surface than faeces. This is almost the sum total of our knowledge.

The relative rates of decay of different paper products are not known. The impact on decay rates of different environments is not known. The impact of nutrients, derived from urine and/or faeces, on paper product breakdown is not known. The impact of burial at different depths on decay rates is not known. This section attempts to redress these knowledge deficiencies.

Methods

Field Methods

The same sites were used as in the vegetation study (Figure 1, Tables 1 to 3). The holes in the dig and dig and urine treatments were used, giving a total of 20 per site. Plastic mesh bags filled with known weights of bleached and unbleached toilet paper, facial tissues and tampons (Figure 11) were sealed and then buried, two per hole, at 5 and 15 cm depth. It was difficult to maintain an even weight across all products in all bags. Each product weighed approximately 2 g, with tampons being the heaviest (2.7 g) and unbleached toilet paper being the lightest (1.7 g). Tissues had a mean weight of 2.5 g and bleached toilet paper weighed 2.1 g on average.

Figure 11: Unburied bag and contents

All bags were wetted by application at 5 cm depth during the first burial period, half with 250 ml of artificial urine, and half with 60 ml of distilled water. At later times, urine was applied to the surface of those quadrats that were not dug up. Where bags were dug up and replaced, water or urine was added at 5 cm. Half of the bags in each treatment were dug up and replaced after 6 months. At 12 months the replacement bags were removed and replaced. These replacement bags were then retrieved after 12 months. The bags that had not been removed after the first six months were removed 24 months after their placement. Ten bags were placed under rocks on the surface of the soil at the two alpine sites. At the eastern alpine site these bags were removed and replaced after 6 months and the replacement bags were removed after a further 12 months. At the western alpine site the rock bags were retrieved and replaced at 12 months, then were retrieved and replaced after another six months (due to snowfall).

On revisiting the sites, some of the bags were found to have been dug up by native animals or domestic pets, or had been frost-heaved out of the ground in the alpine environments. Disturbance of these bags was noted before they were reburied. Few bags were lost (Table 7). Other bags became buried under a fallen tree that could not be moved. The spring-summer batch of 6 month old bags at two sites (montane eucalypt forest and eastern alpine) could not be used in the analyses as the bags were in the ground for less than 6 months due to time constraints on field sampling in August 2001 (Table 7). Thus, bags buried in the soil were collected at 6 m (autumn-winter), 12 m and 24 m for all sites. In addition, bags buried in the soils were collected over the 6 m of spring and summer for all but the eastern alpine and montane eucalypt forest sites, and bags placed under rocks were collected at 6 m and 12 m from the western alpine site and the eastern alpine site.

Laboratory Methods

On removal the bags were dried (at 55°C for a minimum of 5 days) and then weighed. A sample of 10 of each of the unburied products was weighed, dried, then weighed again to determine the moisture content of unused samples. After drying and weighing used bags, some bags were found to be heavier after burial than before, due to the presence of plant roots and soil attached to them. Therefore it was necessary to adopt a scalar estimate of decay: 1 = no decay, 2 = up to ¼ decayed, 3 = ½ decayed, 4 = ¾ decayed, 5 = all decayed.

Statistical Analysis

The decay scores for the four products were averaged to give a mean decay score for each hole. Generalized linear modelling was used to determine the single and interactive effects of site, time, treatment and depth of burial using the 6 m (autumn-winter), 12 m and 24 m buried bag data, and the single and interactive effects of site, time and treatment for the two sets of 6 m buried bag data. The distribution of the residuals was examined to ensure normality. One way analysis of variance was used to determine the significance of variation in mean decay rates between site, time, depth and treatment classes.

The Wilcoxon Sign rank test was used to compare the relative decay of pairs of products, using the full data set. The Kruskal-Wallis test was used to determine the significance of differences between the medians of decay classes for individual products by site. Pairwise multiple comparisons employed Dunn's method.

The continuous environmental variables in Table 1 and Table 2 were used as independent variables in multiple regressions for decay for product-time-treatment combinations for the sites as a whole. Only regressions that approximated normality in the residuals were used. The procedure was to examine scatter graphs of all relationships with a dependent variable, searching for the strongest meaningful relationship. If that relationship was not linear, transformations, and quadratic and polynomial fits were attempted, searching for the most explanatory significant model. Using residuals, this process was iterated until no more variables with significant slopes could be fitted into the equation. Where more than one variable was included in the model, the multiple regression procedure in Minitab (Minitab Inc. 2000) was used for the final model.

Results

Mean Decay for All Products Combined

There was a significant site x time x treatment interaction in the generalized linear model for mean decay rates which included 6, 12 and 24 months (Table 8). At six months over autumn and winter mean decay of products was well-advanced at the coastal eucalypt forest and the grassy eucalypt forest, but negligible in the lowland rainforest, the heathy eucalypt forest, the montane moorland and the western alpine sites (Table 9). By 24m decay was almost complete (approximately 75% decayed) at all sites except the montane moorland and the western alpine (Table 9). At all sites, except lowland rainforest, there was a significant positive impact of urine addition on decay (Table 10). The impact of urine addition on decay was most marked at six months over autumn-winter (Table 11).

Table 8: Generalised linear model for mean decay (for all products combined)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	8	397.919	385.5636	48.1954	117.32	0
Time	2	264.8782	271.5806	135.7903	330.55	0
Depth	1	0.6037	1.0417	1.0417	2.54	0.112
Treat	1	131.7514	131.7242	131.7242	320.65	0
Time*Depth	2	2.2718	2.1241	1.0621	2.59	0.077
Time*Treat	2	1.0061	0.9525	0.4762	1.16	0.315
Depth*Treat	1	0.0472	0.043	0.043	0.1	0.747
Site*Time	16	59.7229	59.1552	3.6972	9	0
Site*Depth	8	8.796	10.0606	1.2576	3.06	0.002
Site*Treat	8	51.3052	51.8737	6.4842	15.78	0
Time*Depth*Treat	2	0.2866	0.1829	0.0914	0.22	0.801
Site*Time*Depth	16	7.7724	8.6592	0.5412	1.32	0.182
Site*Depth*Treat	8	2.1793	2.6083	0.326	0.79	0.608
Site*Time*Treat	16	52.6324	53.3149	3.3322	8.11	0
Site*Time*Depth*Treat	16	7.5907	7.5907	0.4744	1.15	0.302
Error	423	173.7688	173.7688	0.4108		
Total	**530**	**1162.532**				

Table 9: Mean decay (for all products combined) by site and time, showing significant differences between sites

Site	Number of months		
	6	12	24
Coastal Eucalypt Forest	3.7500a	4.1500a	4.7250a
Grassy Eucalypt Forest	3.3750ab	4.2625a	4.6875a
Montane Eucalypt Forest	2.7237b	4.2500a	4.6447a
Lowland Rainforest	1.5125c	3.4853a	4.5972a
Subalpine Rainforest	2.5125b	3.7000a	4.4342a
Heathy Eucalypt Forest	1.6875c	2.1750b	4.1000a
Eastern Alpine	2.4000b	2.6000b	3.7375ab
Montane Moorland	1.5125c	2.7000ab	3.2875b
Western Alpine	1.0000c	1.1750c	1.8816c
All	2.2723	3.161	4.01

Sites that do not share a letter are significantly different.

Table 10: Mean decay scores (for all products combined) by site and treatment, showing F and P for analyses of variance

Site	Dig	Dig and urine	F	P
Eastern Alpine	1.825	4	83	0
Montane Moorland	1.65	3.35	28	0
Subalpine Rainforest	2.8879	4.1583	20	0
Montane Eucalypt Forest	3.3125	4.4083	15	0
Grassy Eucalypt Forest	3.775	4.4417	10	0.002
Coastal Eucalypt Forest	3.975	4.4417	9	0.005
Heathy Eucalypt Forest	2.175	3.1333	9	0.004
Western Alpine	1.0667	1.6293	6	0.014
Lowland Rainforest	3.1696	3.0926	0	0.848
All	2.6387	3.6419	69	0

Table 11: Mean decay scores (for all products combined) by treatment and time

Time	Dig	Dig and urine	F	P
6 months	1.7219	2.8167	38	0
12 months	2.6477	3.6685	27	0
24 months	3.5568	4.4684	29	0
All times	2.6387	3.6419	69	0

Depth of burial was only significant in interaction with site, this relating to variability between sites in the ratio of decay at the two depths. At the eastern alpine site, the heathy eucalypt forest and the subalpine rainforest, decay was faster at 15 cm, whereas, at the other sites it was faster at 5 cm (Table 12). At the eastern alpine site at 12 months, buried urine-soaked bags broke down faster (3.85) than bags on the surface, placed under rocks (2.86), which in turn broke down faster than buried bags without urine (1.35) (ANOVA F =30.36, P = 0.000). At the western alpine site there was no breakdown at all at 6 months at any depth, but by 12 months there was some decay (1.25) at 5 cm, negligible decay under rocks (1.02) and no decay at 15 cm (ANOVA, F = 4.07, P = 0.036).

Table 12: Mean decay scores (for all products combined) by site and depth

Site	Depth (cm)		Ratio	F	P
	5	15	15/5		
Subalpine Rainforest	3.319	3.7417	1.13	2	0.197
Eastern Alpine	2.8333	2.9917	1.06	0	0.672
Heathy Eucalypt Forest	2.5833	2.725	1.05	0	0.684
Montane Eucalypt Forest	3.9107	3.85	0.98	0	0.85
Grassy Eucalypt Forest	4.1667	4.05	0.97	0	0.608
Coastal Eucalypt Forest	4.2917	4.125	0.96	1	0.326
Lowland Rainforest	3.2596	3.0172	0.92	0	0.546
Montane Moorland	2.6417	2.3583	0.89	1	0.469
Western Alpine	1.5517	1.1417	0.74	3	0.078

There was a significant site x time x treatment interaction in the generalized linear model for the two six month samples (Table 13). All sites included in the analysis showed significant variation between treatment/time combinations, except the lowland rainforest and western alpine. In all cases where there was significant variation, the urine treatment in the autumn-winter period produced the most decay, although in the case of the grassy eucalypt forest this decay was statistically identical with both the spring-summer treatments (Table 14).

Table 13: Generalised linear model for mean decay (for all products combined) for the two sets of six month sites, excluding the rock treatment

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	6	258.565	258.799	43.133	115.93	0
Time	1	8.824	9.062	9.062	24.36	0
Treat	1	17.463	17.667	17.667	47.48	0
Site*Time	6	22.283	22.208	3.701	9.95	0
Site*Treat	6	9.174	8.958	1.493	4.01	0.001
Time*Treat	1	3.706	3.764	3.764	10.12	0.002
Site*Time*Treat	6	5.275	5.275	0.879	2.36	0.031
Error	251	93.387	93.387	0.372		
Total	**278**	**418.677**				

Table 14: Mean decay scores (for all products combined) for the two sets of six months samples by treatment and site

Site	ss/d	ss/d+u	aw/d	aw/d+u	P
Coastal Eucalypt Forest	2.5250a	3.2250b	3.4000b	4.1000c	0
Grassy Eucalypt Forest	3.8250a	4.0000a	2.6750b	4.0750a	0
Subalpine Rainforest	1.0278a	1.4000a	1.6250a	3.4000b	0
Heathy Eucalypt Forest	1.0500a	1.5500ab	1.3500ab	2.0250b	0.03
Montane Moorland	1.0000a	1.0000a	1.3250ab	1.7000b	0.008
Western Alpine	1.025	1.025	1	1	0.578
Lowland Rainforest	1.425	1.575	1.4	1.625	0.786
All	**1.7065a**	**1.9679a**	**1.8250a**	**2.5607b**	**0**

P values are derived from oneway ANOVA. aw = autumn-winter, ss = spring-summer, d = dig, u = urine

Decay of Individual Products

There was a significant difference in decay between the four products. Tissues decayed more readily than tampons (Wilcoxon Signed Rank test W= -84168.000, P = <0.001), but decayed more slowly than bleached (W= 9938.000, P = <0.001) or unbleached (W= 19966.000, P = <0.001) toilet paper. Bleached and unbleached toilet paper decayed more readily than tampons (W= 111078.000, P = <0.001, W= 126684.000, P = <0.001), and unbleached toilet paper decayed more readily than bleached toilet paper (W= 4717.000, P = <0.001) (Figure 12). Sites had largely the same order in median decay values for the four products (Table 15).

Figure 12: Mean decay of all products for each site after 24 months burial

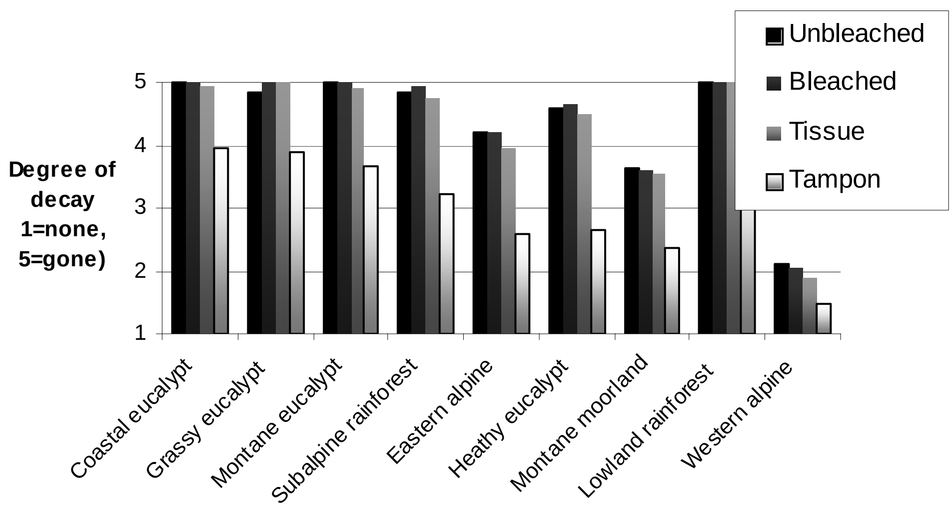


Table 15: Significant differences in the median of decay of each individual product by site

Site		Tissue			Tampon			Bleached			Unbleached		
		H=185.823 P<0.001			H=192.589 P<0.001			H=205.462 P<0.001			H=206.025 P<0.001		
	N	median	25 %	75 %	median	25 %	75 %	median	25 %	75 %	median	25 %	75 %
Coastal Eucalypt	80	4ab	3.5	5	3a	2	4	4ab	4	5	4ab	4	5
Grassy Eucalypt	80	5a	4	5	3a	2	4	5a	4	5	5a	4	5
Montane Eucalypt	78	4abc	2	5	3ab	1	4	4abc	2	5	4.5abc	2	5
Subalpine Rainforest	78	3bcd	1	5	2bc	1	3	4bcd	1	5	4bcd	2	5
Lowland Rainforest	75	2cd	1	5	1c	1	3	3cde	1	5	3cde	2	5
Eastern Alpine	80	2cd	1	4	1c	1	3	3cde	1	4.5	3cde	1	5
Heathy Eucalypt	80	2d	1	4	1cd	1	2	2de	1	4	2de	1	4
Montane Moorland	80	1d	1	4	1cd	1	2	1e	1	4	2e	1	4
Western Alpine	79	1e	1	1	1d	1	1	1f	1	1	1f	1	1

Kruskal-Wallis H test. Sites with median values for each product with the same letters are not significantly different. Pairwise Multiple Comparison Procedures (Dunn's Method, P<0.05) was used to determine differences between sites. Data analysis does not include the rock treatment from the Eastern and Western Alpine sites.

Only two sites (lowland rainforest and western alpine), recorded no significant difference in the decay of any of the four products between treatments (Table 16). Three sites (subalpine rainforest, heathy eucalypt forest and montane moorland) recorded significant differences in decay for all four products between treatment types. Products that had been subjected to the addition of urine, were more decayed than those that had not.

Table 16: The influence of treatment on the median values of decay for each product at each site

Site	Tissue	Tampon	Bleached	Unbleached
Eastern Alpine				
Dig -median	1a	1a	1a	1b
25%	1	1	1	1
75%	2	1	3	3
Dig and Urine - median	4b	3b	4b	5a
25%	3	2	4	4
75%	5	4	5	5
Rock - median	2.5a	1a	2a	2.5b
25%	1	1	1	2
75%	4	2	4	4
Grassy Eucalypt				
Dig -median	4a	3a	5a	4a
25%	3.5	2	4	4
75%	5	3	5	5
Dig and Urine - median	5a	4b	5a	5b
25%	4	3	5	5
75%	5	4	5	5
Subalpine Rainforest				
Dig -median	2.5a	1a	2.5a	2.5a
25%	1	1	1	1
75%	4	2	4	4.5
Dig and Urine - median	4b	3b	5b	5b
25%	1.5	1	2	2.5
75%	5	4	5	5
Heathy Eucalypt				
Dig -median	1a	1a	1a	1a
25%	1	1	1	1
75%	2.5	2	3	3.5
Site	Tissue	Tampon	Bleached	Unbleached

Site	Tissue	Tampon	Bleached	Unbleached
Heathy Eucalypt (cont.)				
Dig and Urine - median	3b	2b	3b	3b
25%	1	1	1.5	2
75%	4	3	5	4
Lowland Rainforest				
Dig -median	2a	1a	3a	3a
25%	1	1	1.5	2
75%	5	2	5	5
Dig and Urine - median	2a	1a	3a	3a
25%	1	1	1	1.75
75%	5	3	5	5
Coastal Eucalypt				
Dig -median	4a	3a	4a	4a
25%	3	2	3	3.5
75%	5	4	5	5
Dig and Urine - median	4b	4b	5b	5a
25%	4	3	4	4
75%	5	4	5	5
Montane Eucalypt				
Dig -median	4a	3a	4a	4a
25%	1	1	2	2
75%	5	3	5	5
Dig and Urine - median	5b	4b	5b	5b
25%	4	3	5	5
75%	5	4	5	5
Western Alpine				
Dig -median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	1	1
Dig and Urine - median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	1	1.75
Rock - median	1a	1a	1a	1a
25%	1	1	1	1
Site	Tissue	Tampon	Bleached	Unbleached
Western Alpine (cont.)				
75%	1	1	1	1
Montane Moorland				
Dig -median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	2	2
Dig and Urine - median	2.5b	1.5b	2.5b	2.5b
25%	1	1	1	1
75%	5	3	5	5

Mann-Whitney U test, median values with different letters are significantly different (within sites), P<0.001. Dig = no nutrients added, Dig and Urine = nutrients added, 25% = 25% percentile, 75% = 75% percentile.

Only one site (western alpine) recorded no significant difference in breakdown of any of the four products over time (Table 17). Four sites (subalpine rainforest, heathy eucalypt forest, lowland rainforest and montane eucalypt forest) showed a significant difference in decay between the two extreme time periods (6 months and 24 months) in all four products. Six sites recorded no significant difference in breakdown of any of the four products between the 6 month and the 12 month period. Four sites recorded no significant difference in breakdown of any of the four products between the 12 month period and the 24 month period (subalpine rainforest, montane moorland, coastal eucalypt forest and western alpine).

Table 17: The influence of time on the median values of decay for each product at each site

Site	Tissue	Tampon	Bleached	Unbleached
Eastern Alpine				
6 m ss-median	2a	1a	2a	2ab
25%	1	1	1	1. 5
75%	4	3	4	5
12 m-median	2.5a	1.5a	1a	3b
25%	1	1	1	1
75%	4	1	4.5	4
24 m-median	4.5b	3a	5b	5a
25%	2.5	1.5	3. 5	3
75%	5	4	5	5
Grassy Eucalypt				
6 m ss-median	4b	2bc	4b	5a
25%	3	1	3	3. 5
75%	4	4	4	5
6 m aw-median	5a	2c	5a	5a
25%	4	1	4	4
75%	5	3	5	5
12 m-median	5a	3b	5a	5a
25%	4	3	5	4
75%	5	3.5	5	5
24 m-median	5a	4a	5a	5a
25%	5	4	5	5
75%	5	4	5	5
Subalpine Rainforest				
6 m ss-median	2bc	1bc	2c	2b
25%	1	1	2	2
75%	4	2	4	4.5
6 m aw-median	1b	1b	1b	1c
25%	1	1	1	1
Site	Tissue	Tampon	Bleached	Unbleached
Subalpine Rainforest (cont.)				
75%	1	1	1	2
12 m-median	4ac	2ac	4ac	5ab
25%	3	2	3	4
75%	5	4	5	5
24 m-median	5a	4a	5a	5a
25%	5	2.25	5	5
75%	5	4	5	5
Heathy Eucalypt				
6 m ss-median	1b	1b	1.5b	2b
25%	1	1	1	1
75%	2	1.5	3	2
6 m aw-median	1b	1b	1b	1b
25%	1	1	1	1
75%	1	1	1.5	1
12 m-median	2b	1b	2a	2.5b
25%	1	1	1	1
75%	3	2	3.5	3.5a
24 m-median	5a	2a	5a	5
25%	4	2	4.5	4
75%	5	3	5	5
Lowland Rainforest				
6 m ss-median	1b	1c	2b	2b
25%	1	1	1	2
75%	1	1	2	2
6 m aw-median	1b	1bc	1b	1b

Site	Tissue	Tampon	Bleached	Unbleached
25%	1	1	1	1
75%	2	1	2	3
12 m-median	4a	2b	4a	5a
25%	2.75	1	3	4
75%	5	3	5	5
24 m-median	5a	4a	5a	5a
25%	5	3	5	5
75%	5	4	5	5
Site	Tissue	Tampon	Bleached	Unbleached
Coastal Eucalypt				
6 m ss-median	4bc	3a	4bc	4bc
25%	4	2. 5	4	4
75%	4	4	4	5
6 m aw-median	3c	2b	4b	4b
25%	2	1	3	3
75%	4	2	4	4
12 m-median	4ab	3a	5ac	5ac
25%	4	3	4	4
75%	5	4	5	5
24 m-median	5a	4a	5a	5a
25%	5	4	5	5
75%	5	4	5	5
Montane Eucalypt				
6 m ss-median	2a	2a	3a	4a
25%	1	1	1.25	2
75%	4	3	4.75	5
12 m-median	4b	4b	5ab	5ab
25%	4	3	4	4
75%	5	4	5	5
24 m-median	5c	4b	5b	5b
25%	5	3	5	5
75%	5	4	5	5
Western Alpine				
6 m ss-median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	1	1
6 m aw-median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	1	1
12 m-median	1a	1a	1a	1a
25%	1	1	1	1
75%	1	1	1	1.5
24 m-median	1a	1a	1a	1a
Site	Tissue	Tampon	Bleached	Unbleached
Western Alpine (cont.)				
25%	1	1	1	1
75%	2	1	2.75	3
Montane Moorland				
6 m ss-median	1bc	1bc	1.5bc	2ab
25%	1	1	1	1
75%	2	1	2	2
6 m aw-median	1b	1b	1b	1b
25%	1	1	1	1
75%	1	1	1	1
12 m-median	3.5ac	2ac	3.5ac	3.5a
25%	1	1	1	1
75%	4	3	4.5a	4

Site	Tissue	Tampon	Bleached	Unbleached
24 m-median	4.5a	2a	5	5a
25%	1.5	1	1.5	1.5
75%	5	4	5	5

Kruskal-Wallis H test, median values with different letters are significantly different (within sites), P<0.001. 25% = 25% percentile, 75% = 75% percentile, m = month, ss = spring-summer, aw = autumn-winter

Models of Decay

The models for mean decay were dominated by annual precipitation, with decay declining as precipitation increased. The exception was with the urine treatment at six months in which decay was strongly related to the mean maximum daily temperature during summer (Table 18). The models for tampon decay were varied. Precipitation was negatively related to decay at 24 months with urine. The mean maximum daily temperature during summer explained decay at six months without urine. Total Ca, N and pH explained decay in the other classes, with the relationships all being positive (Table 18). The other three products had very similar models for time/treatment classes. At six months without urine, K had negative relationships. At 6 months with urine, pH had a positive relationship with decay in all models. At 12 months without urine, Mn had a positive relationship with decay. At 12 months with urine, precipitation had a negative relationship with decay in all models. By 24 months most tissues and toilet paper samples had completely decayed, invalidating the assumptions of regression models.

Table 18: Elements, directionality, explanation and significance of regression models for mean decay of all products combined, buried materials and the average for buried materials

Response	Prec	Temp	Fe	N	P	K	Ca	Mg	Mn	Zn	pH	MSD	R^2 (%)	Prob.
Mean (all products)														
6 m dig		***+			*-				*+				95.9	0.000
12 m dig	**-												72.1	0.004
24 m dig	*-												57.6	0.018
6 m dig&urine	***-												87.7	0.000
12 m dig&urine	***-		**+	*+									96.4	0.001
24 m dig&urine	***-												99.4	0.000
Tampons														
6 m dig		*+											79.5	0.035
12 m dig							**+						80.2	0.001
24 m dig				*+									50.1	0.033
6 m dig&urine											***+		87.6	0.000
12 m dig&urine							*+						52.6	0.027
24 m dig&urine	*-												46.0	0.045
Tissues														
6 m dig						**-							89.1	0.001
12 m dig									**+			*+	84.8	0.004
24 m dig								*+					53.3	0.026
6 m dig&urine	**-		**+								**+		84.8	0.004
12 m dig&urine	*-												77.9	0.011
Bleached paper														
6 m dig						**-							85.9	0.003
12 m dig									*+				60.3	0.014
24 m dig								*+					53.4	0.025
6 m dig&urine	**-		***+								***+		98.6	0.000
Response	**Prec**	**Temp**	**Fe**	**N**	**P**	**K**	**Ca**	**Mg**	**Mn**	**Zn**	**pH**	**MSD**	**R^2 (%)**	**Prob.**
12 m dig&urine	***-		**+							**-			87.8	0.000
Unbleached paper														
6 m dig						**-							86.0	0.000
12 m dig									**+			*+	84.7	0.004
24 m dig	*-												52.3	0.028
6 m dig&urine											*+		71.7	0.023
12 m dig&urine	*-												78.8	0.022

Prec = mean annual precipitation, Temp = mean daily maximum summer temperature, N = total N, Ca = total Ca, Mg = natural logarithm of Mg, MSD = mean soil depth. Significance of slope: * = P < 0.05, ** = P < 0.01, *** = P < 0.001. + = positively related to decay, - = negatively related to decay. m = month.

Discussion

Unbleached toilet paper does break down faster than bleached toilet paper and tissues. However, tampons stand out as being most resistant to decay, with the other products not massively differentiated in their rates.

The independent variables that were incorporated in the models of decay (Table 18) are largely consistent with those that are associated with organic soil formation, which occurs in cold and/or waterlogged and/or acid places (Moore & Bellamy 1974). Indeed the two sites that exhibited little decay after 24 months had organic soil profiles, while the others had mineral soils with a surface organic horizon of varying depths. The generally higher decay rates during the autumn-winter 6 months than during the spring-summer 6 months may relate to the precipitation patterns during the sampling times. There was a severe drought during the autumn-winter and heavy summer rain during spring-summer. This is consistent with the general tendency for temperature to be less important in promoting decay than precipitation in inhibiting it. Temperature was only a part of two models, both autumn-winter 6 months without urine, whereas precipitation occurred in 12 out of the 27 models. The presence of cations, both measured directly, and indicated by pH, also appears more important than temperature in inhibiting breakdown for most individual products (Table 18).

A simple index can be derived from two classes of mean annual precipitation (> 1000 mm = 1, < 1000 mm = 2), mean annual temperature (< 13^{o}C = 1, > 13^{o}C = 2) and pH (< 4.5 = 1, > 4.5 =2), which reconstructs the order of mean decay using all 6 month autumn-winter, 12 month and 24 month data (Table 19). A score of 3 on this index indicates that 2 years is insufficient for decay of all paper products buried in the soil, even when fertilized with faeces or urine. A score of 6 indicates a rapid dissolution of products, whether fertilized or not. This index may be exportable to other parts of the world.

Table 19: Predictive index for mean paper product breakdown

Site	Mean decay	Precip	pH	Temp	Index
Western Alpine	1.36667	1	1	1	3
Montane Moorland	2.51667	1	1	1	3
Eastern Alpine	2.93333	1	2	1	4
Lowland Rainforest	3.20000	1	1	2	4
Subalpine Rainforest	3.55000	1	1	2	4
Montane Eucalypt Forest	3.85000	2	2	1	5
Heathy Eucalypt Forest	4.11667	2	1	2	5
Grassy Eucalypt Forest	4.11667	2	2	2	6
Coastal Eucalypt Forest	4.20000	2	2	2	6

Temp = mean maximum daily summer temperature. Precip = mean annual precipitation. Boundaries pH < 4.5 = 1, prec. > 1000 = 1, temp < 13.

Artificial urine was used, rather than artificial faeces, because it contains more nutrients than faeces, particularly N (Gotaas 1956), thereby representing an extreme situation. The degree of the positive impact of artificial urine addition on mean decay, as indicated by the F value for the difference between the two treatments (Table 10) is strongly related to total P (F = 19.7878 - 0.100709 Total P + 0.0002392 Tot P**2, P = 0.002, R-Sq = 87.3 %), with high total P values giving the strongest differentiation between treatments, suggesting that N/P ratios may be important in breakdown of the products. The residuals from the above equation are explained best by % sand (r = -0.842, d.f. = 8, P = 0.004), indicating that the extra N from the artificial urine may be best retained in less sandy soils. The same effects might not happen with faeces, which have a better balance of P and N and are less readily leached. Nevertheless, nutrient addition through urine in holes dug for disposal of faeces is the behavioural norm for most females and some males.

Our data suggest that, in alpine areas, there is likely to be little or no difference in the decay rates of material placed under rocks and equivalent material buried in the soil. The significant variation in mean decay rates between 5 and 15 cm by site is best explained by Cu (decay at 15 cm/decay at 5 cm = 0.808202 + 0.161380 Cu - 0.0240384 Cu**2, P = 0.026, R-Sq = 70.5 %), an indicator of poorly-drained soils (Kirkpatrick & Bridle 1998, 1999). This result is thus counterintuitive, as the soils that would appear most prone to waterlogging judging from their Cu content, have better decay rates at depth compared to the surface, while those least prone to waterlogging have the reverse. It is therefore tempting to deem the relationship of the decay ratio with Cu coincidental. In this context it is interesting to note that the sites where decay was greater at 15 cm than 5 cm were largely the same sites that were subject to bag excavation by animals or ice. This too is mysterious, as decay of unfertilised bags under rocks on the surface was greater than with burial at the well-excavated eastern alpine site. A possible explanation for this is that the bags under rocks retained some moisture, while those that were exposed on the surface were desiccated, further inhibiting decay. However, given that there were no significant differences in mean decay within sites related to burial at the two depths, the cause of the significant interactive relationship is of no practical importance.

Implications for Management

A key question in deciding the implications for management of our decay data is the social and environmental acceptability of different periods of persistence of human waste disposal products in the soil. Social acceptability relates to the probability of excavating the evidence of a past faecal burial event, when undertaking preparations for a new event. This probability can be high in some well-used places (authors pers. obs.). Environmental acceptability relates to variation from the natural condition of the soil, which would obviously be considerable where deposits remain intact over several years. In the western alpine and high altitude moorland environments decay is extremely slow. In our judgement it is both socially and environmentally undesirable to continue to advise people to bury their wastes in these environments. This would not be a major imposition on walkers, as locations in these environments are usually in close proximity to forest or scrub vegetation, which affords better privacy than buttongrass moorland and alpine vegetation.

If anything is to be carried out, tampons are an appropriate target, as prescribed in the present code. It was only at the rainforest sites and the non-heathy eucalypt sites that tampons were approaching disappearance, albeit two years after burial. Given that tampons break down faster in non-heathy eucalypt forest than toilet paper and tissues do in montane moorland and western alpine environments (Figure 12), the continuation of a blanket ban on the burial of tampons might seem like sex discrimination. However, as we are advising people not to bury any waste in high altitude moorland or western alpine environments, the recommendation to carry out tampons from all areas is consistent with the current MIB strategy. This message is a simple message to deliver to walkers, therefore, it may be desirable to leave it unchanged.

Walkers may place their wastes under rocks in alpine areas because they are reluctant to damage alpine vegetation by digging. We hope that the results of our vegetation and decay studies will convince them that it is less environmentally harmful to bury their waste than to leave it exposed.

Soil depth proved sufficient in parts of all our sites to enable burial of waste at 15 cm, as is suggested by the code. However, despite there being ample soil available, it was not always easy to dig a hole to that depth. Obstructions such as roots, rocks or very hard clay soil made it difficult to dig a hole 15 cm deep at some sites. Digging to that depth was impossible to severely challenging at most sites using plastic trowels of the kind sold in many outdoor stores. There is a need for prescriptions in the MIB guidelines on the strength and quality of trowels. Burial at 5 cm does present some relatively low chance of excavation by animals, compared to 15 cm, so the 15 cm recommendation in the code should stand.

The above results suggest that the minimum impact bushwalking code should be amended to:

1. recommend no disposal of faeces, toilet paper or tissues in treeless vegetation above 800 m in western Tasmania;
2. emphasise that placement of waste under rocks causes more environmental harm than disposal by burial, even in alpine environments;
3. emphasise that strong metal trowels are necessary to excavate holes for defecation in most wild places.

The overall ban on the disposal of tampons in the bush should remain.

Given the high degree of non-compliance with the MIB guidelines for the disposal of human waste that is evident in parts of the Tasmanian bush (von Platen 2002), it is probably time to consider enforceable regulations, rather than non-enforceable guidelines.

Chapter 5

Conclusions

This project did not cover the public health aspects of disposal of human wastes in different environments or the degree to which codes of practice actually influence individual human waste disposal behaviour in the wild. These questions are currently being addressed by us in another STCRC project, to be completed in 2003.

The index we derived for predicting the speed of decay of human waste disposal products requires testing outside Tasmania, to determine its potential universality.

Communication

The project was initiated with a steering committee, and has involved constant propagation of results and their management implications through a web site, papers at various conferences, many of which included stakeholders, and the mass media. This study has attracted a great deal of interest from the media, including national (ABC) and local television and radio, and local newspapers. It is our aim to publish this work in refereed journals such as the *Journal of Environmental Management*. We will also communicate our results directly to managers and bushwalkers in the form of the present publication and the web site (www.utas.edu.au/faecalmatters). A media release detailing the completed report and our recommendations will be issued once the report has been finalised.

Face-to-face discussions with interest groups (bushwalking clubs, interpretive and management personnel at Parks and Wildlife) have been successful in determining target recommendations for particular user groups.

We have been contacted by numerous agencies and individuals within Australia and overseas. Exposure will be on-going through the continuation of our other human waste project, due to finish in 2003.

References

Bridle, K. & Kirkpatrick, J.B. (1997). 'Local environmental correlates of variability in the organic soils of moorland and alpine vegetation, Mt Sprent, Tasmania', *Australian Journal of Ecology*, vol. 22, pp. 196-205.

Bridle, K.L., Kirkpatrick, J.B., Cullen, P. & Shepherd, R.R. (2001). 'Recovery in alpine heath and grassland following burning and grazing, eastern Central Plateau, Tasmania', *Arctic, Antarctic and Alpine Research*, vol. 33, pp. 348-356.

Calais, S.S. & Kirkpatrick, J.B. (1986). 'The impact of trampling on the natural ecosystems of the Cradle Mt. - Lake St. Clair National Park', *Australian Geographer*, vol. 17, pp. 6-15.

Cole, D.N., Watson, A.E., Hall, T.E., & Spildie, D.R. (1997). 'High-use destinations in wilderness: Social and biophysical impacts, visitor responses, and management options', General Technical Report. INT-496. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Cilimburg, A., Monz, C. & Kehoe, S. (2000). 'Wildland recreation and human waste: A review of problems, practices and concerns', *Environmental Management*, vol. 25, pp. 587-598.

Connor, D.J. & Wilson, G.L. (1968). 'Response of a coastal Queensland heath community to fertilizer application', *Australian Journal of Botany*, vol. 16, pp. 117-123.

Drake, R. (1995). 'Backcountry human waste disposal at Mount Rainier National Park', Proc. Environmental Ethics and Practices in Backcountry Recreation, Nov 12-14, 1995, University of Calgary.

Duncan, F. & Brown, M.J. (1985). 'Dry sclerophyll vegetation in Tasmania: Extent and conservation status of the communities', Wildlife Division Technical Report 85(1), National Parks and Wildlife Service, Tasmania.

Ells, M. D. (1999). 'The fate of feces and fecal microorganisms in human waste smeared on rocks in an alpine environment and its impact on public health', viewed March 2002, http://research.nols.edu/wild_instructor_pdfs/1999Alpinestudy.pdf

Ells, M. D. (2000a). 'The fate of feces and fecal microorganisms in human waste smeared on rocks in a temperate forest environment and its impact on public health, viewed March 2002, http://research.nols.edu/wild_instructor_pdfs/2000Longmire.pdf

Ells, M.D. (2000b). 'The fate of feces and fecal microorganisms in human waste smeared on rocks in an arid environment and its impact on public health', viewed March 2002, http://research.nols.edu/wild_instructor_pdfs/2000Naches.pdf

Gibson, N. (1984). 'Impact of trampling on bolster heath communities of Mt Field National Park', Papers and Proceedings of the Royal Society of Tasmania, vol. 118, pp. 47-52.

Gilfedder, L. & Kirkpatrick, J.B. (1998). 'Factors influencing the integrity of remnants in subhumid Tasmania', *Biological Conservation*, vol 84, pp. 89-96.

Gotaas, H. B. (1956). *Composting: Sanitary disposal and reclamation of organic wastes*, World Health Organisation, Geneva.

Jarman, S.J., Brown, M.J. & Kantvilas, G. (1984). *Rainforest in Tasmania*, National Parks and Wildlife Service, Tasmania.

Jarman, S.J., Kantvilas, G. & Brown, M.J. (1988). 'Buttongrass moorland in Tasmania', Research Report 2. Tasmanian Forest Research Council Inc., Hobart.

Kirkpatrick, J.B. (1997). *Alpine Tasmania: An Illustrated Guide to the Flora and Vegetation*, Oxford University Press, Melbourne.

Kirkpatrick, J.B. & Bridle, K.L. (1998). 'Environmental relationships of floristic variation in the alpine vegetation of south-east Australia', *Journal of Vegetation Science*, vol. 9, pp. 251-260.

Kirkpatrick, J.B. & Bridle, K. (1999). 'Environment and floristics of ten Australian alpine vegetation formations', *Australian Journal of Botany*, vol. 47, pp. 1-21.

Kirkpatrick, J.B. & Brown, M.J. (1987). 'The nature of the transition from sedgeland to alpine vegetation in South West Tasmania: I. Altitudinal vegetation change on four mountains', *Journal of Biogeography*, vol. 14, pp. 539-50.

Kirkpatrick, J.B. & Gilfedder, L. (1995). 'Maintaining integrity compared with maintaining rare and threatened taxa in remnant bushland in subhumid Tasmania', *Biological Conservation*, vol. 74, pp. 1-8.

Kirkpatrick, J.B. & Gilfedder, L. (1998). 'Conserving weedy natives: Two Tasmanian endangered herbs in the Brassicaceae', *Australian Journal of Ecology*, vol. 23, pp. 466-473.

Kirkpatrick, J.B. & Harris, S. (1999). *The Disappearing Heath Revisited*, Tasmanian Environment Centre, Hobart.

Kirkpatrick, J.B., Nunez, M., Bridle, K. & Chladil, M. (1996). 'Explaining a sharp transition from sedgeland to alpine vegetation on Mount Sprent, south-west Tasmania', *Journal of Vegetation Science*, vol. 7, pp. 763-768.

Lachapelle, P.R. (2000). 'Sanitation in wilderness: Balancing minimum tool policies and wilderness values'. In: D.N. Cole, S.F. McCool, W.T. Borrie, & J. O'Loughlin, 'Wilderness ecosystems, threats and management', *Proceedings of the Wilderness Science in a Time of Change Conference Volume 5*, USDA Forest Service, Rocky Mountain Research Station.

Leonard, R.E. & Plumley, H.J. (1979). 'Human waste disposal in eastern backcountry', *Journal of Forestry*, vol. 77, pp. 349-352.

Leung, Y-F. & Marion, J.L. (2000a). 'Characterizing backcountry camping impacts in Great Smokey Mountains National Park, USA', *Journal of Environmental Management*, vol. 57, pp. 193-203.

Leung, Y-F. & Marion, J.L. (2000b). 'Recreation impacts and management in wilderness: A state of knowledge review'. In: D.N. Cole, S.F. McCool, W.T. Borrie, & J. O'Loughlin, 'Wilderness ecosystems, threats and management', *Proceedings of the Wilderness Science in a Time of Change Conference Volume 5*, USDA Forest Service, Rocky Mountain Research Station.

Liddle, M. (1997). *Recreation ecology: The ecological impact of outdoor recreation and ecotourism*, Chapman and Hall, London.

Marion, J.L. & Cole, D.N. (1996). 'Spatial and temporal variation in soils and vegetation impacts on campsites', *Ecological Applications*, vol. 6, pp. 520-530.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. & Hopkins, M.S. (1984). *Australian soil and land survey - field handbook*, Inkata Press, Melbourne.

Marsden-Smedley, J. B. (1999). 'Changes in southwestern Tasmanian fire regimes since the early 1800s', *Papers and Proceedings of the Royal Society of Tasmania*, vol. 132, p. 15.

Meyer, K. (1994). *How to shit in the woods: An environmentally sound approach to a lost art*, Ten Speed Press, Berkeley.

Minchin, P.R. (1990). *DECODA user's manual*, Research School of Pacific Studies, ANU, Canberra.

Minitab Inc. (2000). 'Minitab Statistical Software', Release 13.20.

Moore, P. D. & Bellamy, D. J. (1974). *Peatlands*, Elek Science, London.

Nunez, M., Kirkpatrick, J. B. & Nilsson, C. (1996). 'Rainfall estimation in south west Tasmania using satellite images and phytosociological calibration', *International Journal of Remote Sensing*, vol. 17, pp. 1583-1600.

O'Loughlin, T. (1988). 'Evaluating the effectiveness of a minimal impact bushwalking campaign', Wilderness Education Project Report to the Tasmanian Parks and Wildlife Service and the Australian Parks and Wildlife Service.

Poll, M. (2002). *World Heritage walking: Overnight bushwalking opportunities in the Tasmanian wilderness*, Parks and Wildlife Service, Hobart.

Pyrke, A. (1994). 'Soil disturbance by native mammals and the germination and establishment of plant species', PhD Thesis, University of Tasmania, Hobart.

Reeves, H. (1979). 'Human waste disposal in the Sierran wilderness'. In: J.T. Stanley, H.T. Harvey, & R.J. Hartesfeldt (Eds), *Wilderness impact study*, Sierra Club Outing Committee, San Fransisco, pp. 129-162.

Rayment, G.E. & Higginson, F.R. (1992). *Australian laboratory handbook of soil and water chemical methods*, Inkata Press, Melbourne.

Rochefort, R.M. & Swinney, D.D. (2000). 'Human impact surveys in Mount Rainier National Park: Past, present, and future'. In: D.N. Cole, S.F. McCool, W.T. Borrie & J. O'Loughlin, 'Wilderness ecosystems, threats and management', *Proceedings of the Wilderness Science in a Time of Change Conference Volume 5*, USDA Forest Service, Rocky Mountain Research Station.

Specht, R.L. (1963). 'Dark Island heath (Ninety-Mile Plain, South Australia). Vll. The effect of fertilizers on composition and growth, 1950-60', *Australian Journal of Botany*, vol. 11, pp. 67-94.

Sun, D. & Walsh, D. (1998). 'Review of studies on environmental impacts of recreation and tourism in Australia', *Journal of Environmental Management*, vol. 53, pp. 323-338.

von Platen, J. (2002). 'Human waste disposal in remote natural areas: Is there a public health risk?', Honours Thesis, University of Tasmania, Hobart.

Whinam J. & Chilcott, M. (1999). 'Impacts of trampling on alpine environments in central Tasmania', *Journal of Environmental Management*, vol. 57, pp. 205-220.

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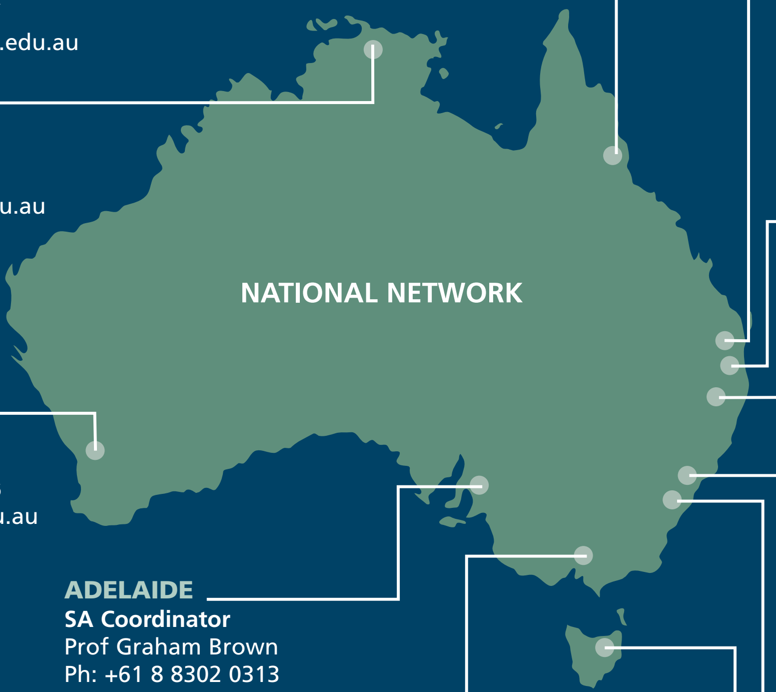

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