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FINAL REPORT

Life histories and reproductive biology of plants in the desert and halophytic genus *Frankenia* (Frankeniaceae) in Australia.

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This final report is also available as a PowerPoint presentation at
http://www.aff.org.au/AFF2_Grants.htm/Easton_Frankenia_final_presentation.ppt

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Summary

Life histories and reproductive biology of plants in the desert and halophytic genus *Frankenia* (Frankeniaceae) in Australia.

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The aim of this thesis was to investigate basic germination requirements for Australian species of *Frankenia* in relation to seed age, light requirements, temperature preferences, salinity tolerance, and soil properties. Germination strategies play a major role in the persistence of all plant taxa, particularly in arid zone halophyte species. The evolution of germination strategies is a consequence of plant taxa responses to environmental cues. Arid zone halophytes have evolved germination strategies under selective pressures – notably in relation to seed age, light requirements, temperature preferences, salinity tolerance, and soil properties – whereby they respond to a sequence of environmental cues that indicate periods of relatively high probability of subsequent seedling survival. Elucidating these strategies is of fundamental importance to the understanding of halophyte life histories. *Frankenia* in particular has several rare and little known species, and the vulnerability of these species cannot be assessed without basic life history data. This data is also a prerequisite for the consideration of *Frankenia* in salinity remediation, mine-site remediation, and coastal revegetation projects.

The underpinning aim of this study was to investigate reproductive strategies, and in particular the large-seeded versus small-seeded strategies in relation to environmental variables that are commonly experienced by arid zone halophyte plant taxa. Previous research has shown that larger-seededness arose several times in Australian *Frankenia* as a result of evolution towards fewer ovule numbers per fruit, although both the larger- and smaller-seeded species still co-occur in biogeographical proximity. By restricting the analysis of seed packaging strategy variations to similar habitats and within a genus, it was possible to uncover ecological correlates that would otherwise have been masked by the strong effects of habitat differences and phylogenetic constraints on seed mass. I could thus test the hypothesis that large-seededness is favoured over small-seededness in drought and/or saline stressed environments.

The key finding was that overall, larger-seedness is advantageous for rapid germination after transitory water availability, and for providing resources to seedlings if resources become limiting before their successful establishment. Smaller-seeded species delay germination until both soil-water availability and cooler temperatures persist over a long time period, improving the chances of successful establishment for the more slowly growing seedlings that are reliant on their surroundings for resources.

Project Overview

This project was part of a PhD research project which investigated the life histories and reproductive strategies of Australian species in the plant genus *Frankenia* L. While *Frankenia* has a global distribution, Australia has more species of *Frankenia* than any other continent. *Frankenia* occurs in Mediterranean coastal, and arid inland regions, often on specialised soil types, notably saline and gypseous soils. The plants are small shrubs, sub-shrubs or herbs, and are found in habitats such as coastal cliffs and sand dunes, in coastal saltmarshes, and on the margins of salt lakes and salt-pans.

This project focused on the strategies that enable *Frankenia* to survive in the harsh salt- and water-stressed conditions of the Mediterranean, semi-arid, and arid regions of Australia. It is because of this geographical distribution that *Frankenia* were investigated for their use in revegetation projects, particularly in coastal zones, as well as for horticultural potential due to their tolerance to saline and drought conditions.

This project provided key data on the interspecific variation in reproductive strategies of Australian *Frankenia* species, particularly with respect to the significance of variation in seed mass/seed number on germination under different environmental conditions. Data were analysed on the association between seed mass/seed number and germination outcome (rates and success) in relation to salinity levels, ambient temperature, soil properties, and seed mineral content. Considerable interspecific variation in seed mass/seed number per fruit occurs among species of *Frankenia* in Australia. Seed mass and number are a particularly important characteristic of plant life history patterns. Larger seeds are thought to confer a greater chance of establishment in adverse conditions, (e.g. water-stressed environments). We tested whether larger-seeded species provided an advantage under various conditions that are faced by plants of the different species of *Frankenia*.

Project Aims

This project had two primary aims, namely:

1. To examine germination success across *Frankenia* species at different salinity levels at the seed and seedling stage, to determine how plant responses to salinity were influenced by seed mass. The results of this aspect of the study were of practical significance, since halophytic and saltmarsh plants – including *Frankenia* – play an important role in reclamation programs associated with increasing salinity problems, and in mine-site revegetation. The results established the suitability of *Frankenia* for cultivation in coastal and arid areas, particularly salt-affected areas.

2. To examine variation in seed mass and number (including seed mineral content) among species of *Frankenia* to test hypotheses concerning the consequences of these variations for seedling establishment under different conditions (e.g. temperature, light requirements, soil properties). This aspect of the project produced basic information on the reproductive biology of *Frankenia* including some species that are of conservation significance. The genus includes species that have limited or disjunct distributions and others about which very little is known. A species of particular conservation significance in South Australia is *F. plicata* which is considered to be nationally endangered.

Project results

The results of each facet of this project are documented in chapters of my PhD thesis entitled:

Easton, L.C. (2008) Life history strategies of Australian species of the halophyte and arid zone genus *Frankenia* L. (Frankeniaece). Flinders University, Adelaide, Australia.

This thesis is available for viewing on the National Australian Digital Theses Program web site. http://catalogue.flinders.edu.au/local/adt/public/adt-SFU20081124.105244/

Each chapter of my thesis was written as a manuscript to be published in peer review journals. These manuscripts are included as part of this final report. To date, three manuscripts have been published in peer reviewed international journals. The remaining three are currently in review. The publication status of each paper is included in its '**Abstract'**. Also available on the website is the PowerPoint presentation given at the Australian Ecology Society 2003 Armidale Conference (http://www.aff.org.au/AFF2_Grants.htm/ Easton_Armidale_Presentation.ppt). All manuscripts and presentations have acknowledged the financial support of the Australian Flora Foundation.

I declare that all information within this report is a true and accurate record. Sincere thanks to the Australian Flora Foundation for supporting this project.

Dr Lyndlee C. Easton

1st February 2009

SUMMARY

The aim of this thesis was to investigate basic germination requirements for Australian species of *Frankenia* in relation to seed age, light requirements, temperature preferences, salinity tolerance, and soil properties. Germination strategies play a major role in the persistence of all plant taxa, particularly in arid zone halophyte species. The evolution of germination strategies is a consequence of plant taxa responses to environmental cues. Arid zone halophytes have evolved germination strategies under selective pressures – notably in relation to seed age, light requirements, temperature preferences, salinity tolerance, and soil properties – whereby they respond to a sequence of environmental cues that indicate periods of relatively high probability of subsequent seedling survival. Elucidating these strategies is of fundamental importance to the understanding of halophyte life histories. *Frankenia* in particular has several rare and little known species, and the vulnerability of these species cannot be assessed without basic life history data. This data is also a prerequisite for the consideration of *Frankenia* in salinity remediation, mine-site remediation, and coastal revegetation projects. (A summary of the findings per species is given in **APPENDIX A**).

The underpinning aim of this study was to investigate reproductive strategies, and in particular the large-seeded versus small-seeded strategies in relation to environmental variables that are commonly experienced by arid zone halophyte plant taxa. Previous research has shown that larger-seededness arose several times in Australian *Frankenia* as a result of evolution towards fewer ovule numbers per fruit, although both the larger- and smaller-seeded species still co-occur in biogeographical proximity. By restricting the analysis of seed packaging strategy variations to similar habitats and within a genus, it was possible to uncover ecological correlates that would otherwise have been masked by the strong effects of habitat differences and phylogenetic constraints on seed mass. I could thus test the hypothesis that large-seededness is favoured over small-seededness in drought and/or saline stressed environments. The following summarises the six specific areas that were investigated.

1. Germination in two Australian species of *Frankenia* L., *F. serpyllifolia* Lindl. and *F. foliosa* J.M. Black – effect of seed mass, seed age, light, and temperature.

I found differing germination patterns between a larger-seeded species (*F. serpyllifolia* has 1–2 seeds per fruit), and a smaller-seeded species (*F. foliosa* has up to 27 seeds per fruit) despite occurring in close geographical proximity. The seeds of the larger-seeded species

required less specific abiotic conditions for germination success than the smaller-seeded species. Overall, the smaller-seeded species had lower germination rates, did not germinate without exposure to light, and were more temperature specific (a cooler temperature preference) for germination success. However, while seeds of up to 7-years in age were highly viable in both seed mass categories, 7-year old seeds of the smaller-seeded species germinated as successfully as 1-year old seeds, providing the temperature was 24°C or less. The 7-year old seeds of the larger-seeded species were slightly less viable than the 1-year old seeds. After 21-days, germination success was not significantly different between the two seed mass categories. It appeared that large-seededness was only favoured during the first few days after rainfall. This suggested that the larger-seeded species could take advantage of any rainfall (albeit capricious) for germination, whereas the smaller-seeded species delayed germination pending favourable conditions for seedling establishment. As seed viability was high for 7-year old seeds, smaller-seeded species could delay germination over many years if favourable conditions were irregular. Note that cooler temperatures are associated with the rainy season (thus higher soil-water availability) in regions of *Frankenia* distribution in Australia.

(For the full report on the effects of seed mass, seed age, light, and temperature on *Frankenia serpyllifolia* and *F. foliosa*, please refer to Easton, L.C. and Sonia Kleindorfer, S (2008) Germination in two Australian species of *Frankenia* l., *F. serpyllifolia* Lindl. and *F. foliosa* J.M.Black (Frankeniaceae) – effects of seed mass, seed age, light, and temperature. Transactions of the Royal Society of South Australia, 132(1): 29–39**)**.

2. Interaction effects of seed mass and temperature on germination in Australian species of *Frankenia L.*

I further investigated the temperature/seed mass interaction effect on germination in 12 *Frankenia* species, (six larger-seeded species and six smaller-seeded species). The larger-seeded species had faster germination rates than smaller-seeded species at temperatures from 17°C to 29°C. Germination success by day 28 was not significantly different between seed mass categories at 17°C. As temperature increased, germination success in both seed mass categories decreased, but the rate of decrease was higher in smaller-seeded species. This suggested that the temperature/seed mass interaction effect was more important in smaller-seeded species than larger-seeded species, as both germination rates and germination success were delayed at higher temperatures in the smaller-seeded species. This supports the

hypothesis that smaller-seeded species are more reliant on specific abiotic conditions (specifically cooler weather and, by inference, the rainy season) for successful germination and consequent seedling establishment.

(For the full report of the interaction effects of seed mass and temperature on Australian species of *Frankenia*, please refer to Easton, L.C. and Sonia Kleindorfer, S (2008) Interaction effects of seed mass and temperature on germination in Australian species of *Frankenia* (Frankeniaceae) Folia Geobot 43:383–396.)

3. Germination requirements for Australian species of *Frankenia L.*

Within the seed mass categories there were differences in germination rates and germination success between species. I investigated germination in 17 *Frankenia* species in relation to light requirements for germination, and temperature preferences (equated as time to T_{50}), and examined seedling emergence success from soil. This information is pivotal when considering species suitability for inclusion in rehabilitation, remediation and revegetation projects. Light did not inhibit germination in any species; moreover it appeared to promote germination in many species. Consequently seeds covered or buried by soil would be less likely to germinate. Germination decreased with increasing temperature within the range 17° to 29°C in all but three species (two larger-seeded species and one smaller-seeded species), which had higher germination at 23°C than 17°C. The *F. pauciflora* complex, especially the WA varieties and including *F. confusa*, had low germination even at 17°C, suggesting that a more specific temperature cue was necessary for germination success. Seedling emergence from soil was very low for all species. While seeds from most *Frankenia* species are highly viable, the conditions for successful seedling emergence appeared far less certain. Furthermore, seedling survival to six months was variable between species, and poor overall. Significantly, species with a higher percentage of seedling survival were species with slower initial germination rates.

(For the full report on germination requirements for individual Australian species of *Frankenia*, please refer to my PhD thesis, Chapter 4: Germination requirements for Australian species of Frankenia L (Frankeniaceae).

4. Soil characteristics associated with habitats of central and southern Australian species of *Frankenia* L.

In central and southern Australia, *Frankenia* distribution is disjunct, and species rarely co-occur within a single community. I investigated whether specific soil properties influenced

species or seed mass category distribution. For soil elements, there were significant differences in the proportions of calcium, aluminium, potassium, magnesium and sulfur in the crustal and sub-crustal layers between species and between seed mass categories. For soil properties, the inter-relationship of available soil-water, exchangeable cation ratios, and incidence of calcium compounds (limestone, gypsum) were significant in assigning species and seed mass category distribution. Overall, soils associated with smaller-seeded species were more highly saline and sodic, and had a higher pH, carbonate (CO_3) content, and K^+:Na^+ ratio. However, populations of most species were distributed over saline, non-saline, sodic and non-sodic soils, suggesting that while *Frankenia* is salt-tolerant, the genus is not an obligate halophyte. *Frankenia foliosa* was the only species that appeared to be a gypsophile; however, populations of this species occurred over a wide range of soil types. *Frankenia foliosa, F. sessilis,* and the SA varieties of *F. pauciflora* were proposed to be suitable species for inclusion in salinity remediation programs due to their natural occurrence in highly saline soils, although these species did take slightly longer to establish.

(For the full report on soil characteristics associated with the habitats of central and southern Australian *Frankenia* species, please refer to my PhD thesis: Chapter 5: Soil properties associated with the habitats of central and southern Australian species of Frankenia L. (Frankeniaceae).

5. Effects of seed mass and salinity levels on germination in Australian species of *Frankenia* L.

Because *Frankenia* occurs on saline and non-saline soils, I investigated the salinity level/seed mass interaction effects on germination. Overall, germination decreased as salinity levels (as indicated by EC) increased from 0.4 dS/m to 38.87 dS/m. Previously, I had revealed that plants of the smaller-seeded species appeared to tolerate more highly saline soils than the larger-seeded species. Conversely, I also demonstrated that the larger-seeded species had higher germination rates and germination success at higher salinities. However, these results were influenced by the extremely poor germination of WA *F. pauciflora* seeds. This species germinated poorly in all experiments suggesting that the requirements for high germination success in WA *F. pauciflora* were not uncovered in this thesis. Decreased germination at high salinity levels in the smaller-seeded species, despite their natural distribution in highly saline soils, infers that they have mechanisms to delay germination under highly saline conditions. Salt stress is not conducive to successful seedling establishment. Prolonged rainfall would decrease salinity levels by diluting the saline soil-water. Prolonged rainfall would also extend

soil-water availability for the relatively more slowly growing seedlings from the smaller-seeded species.

(For the full report on the interaction effect of salinity levels and seed mass on germination in Australian *Frankenia* species, please refer to Easton, L.C. and Sonia Kleindorfer, S (2009) Effects of salinity levels and seed mass on germination in Australian species of *Frankenia* L. (Frankeniaceae) Environmental and Experimental Botany 65: 345–352**)**

6. Seed mineral contents in Australian species of *Frankenia* L.

Finally, I investigated seed mineral nutrient content to disclose any differences between species and/or seed mass categories. In general, the proportions of elements per 0.4 grams of seeds were consistent between species. Thus, seedlings of larger-seeded species would have more of the proscribed (and possibly phylogenetically constrained) proportion of resources for establishment, and by inference, tolerate more stressful environments by being less reliant on it for successful establishment. However, proportions of three elements were significantly different between seed mass categories: boron, and sodium were in higher proportions in larger-seeded species, while copper was higher in smaller-seeded species.

(For the full report on seed mineral nutrient contents of Australian species of *Frankenia*, please refer to my PhD thesis, Chapter7: Seed mineral nutrient contents in Australian species of *Frankenia* L. (Frankeniaceae).

Conclusion

Overall, larger-seedness is advantageous for rapid germination after transitory water availability, and for providing resources to seedlings if resources become limiting before their successful establishment. Smaller-seeded species delay germination until both soil-water availability and cooler temperatures persist over a long time period, improving the chances of successful establishment for the more slowly growing seedlings that are reliant on their surroundings for resources.

Limitations of the thesis and further work

This research is the first comprehensive study on *Frankenia* ecology. The original research proposal for this study was heavily based on seedling survival in relation to water stress and salt tolerance. The proposal argued that larger seeds produce larger seedlings, and

that larger seedlings are better able to establish and survive under harsh conditions. The proposal also included investigations into pollination strategies (i.e. selfing versus out-crossing). However, it rapidly became clear that the lack of knowledge on basic *Frankenia* germination was impeding experimental protocols.

A change in supervision resulted in a revised research program mainly addressing germination in an evolutionary and ecological framework to address the relevance of differing reproductive packages (i.e. seed size/number) found in geographically co-occurring species. The outcomes of this research have raised new questions that need to be considered when expanding on future research directions. Most pointedly is the need to carry out seed physiological testing. Due to time restraints, no histology and no investigation into embryo types (*see* Martin 1946; Baskin& Baskin 2007)[1] were conducted during this study. The E:S ratios (embryo length:seed length) of the various species were not determined. The results of these tests would have been useful to confirm comments/statements made throughout the thesis on the absence of dormancy, which in this thesis is alluded to by germination results alone. The addition of imbibition curves, along with the E:S ratios, would also significantly add to research on differences in germination rates between smaller-seeded species and larger-seeded species of *Frankenia*.

Finally, the lower temperature limits for successful germination, especially in the Western Australian *F. pauciflora* group, could be extended in future studies.

[1] Baskin, C.C. & Baskin, J.M (2007) A revision of Martin's seed classification system, with particular reference to his dwarf-seed type. *Seed Science Research* **17***:* 11-20.
Martin, A.C. (1946) The comparative internal morphology of seeds. *The American Midland Naturalist* **36**: 513-660.

APPENDIX A

Summary of the effects of temperature, salinity, light, and seed age on germination, seedling mortality during the first 6 months from germination, and the soil characteristics of naturally occurring *Frankenia* populations. Table 1 is the **'KEY'** to symbols used in Tables 2 and 3.

Table 1. Key to Tables 2 and 3.

Treatment	Explanation	'*'	'**'	'***'	Other
Light requirement	'RLG' is the relative light requirement index for germination. '1' indicates light is essential for germination, '0' indicates that light is not necessary for germination.	<0.25 RLG	0.25 – 0. 79 RLG	>0.8	
Seedling mortality	The percentage of seedlings that germinated in soil, still alive at 6 months.	<50%	50 – 80%	>80%	
Salinity	Measurement of the percentage of seeds that germinated over 28 days per salinity level.	> 10% and <45%	> 45% and < 80%	>80%	'neg' is <10%
Gypsum content (%)	Note that no species had gypsum levels between 1 and 6%.	0-1		>6	'nil' indicates no gypsum recorded
CO_3	Carbonate measured as the degree of effervescence in HCl.	Low carbonate	Medium carbonate	High carbonate	'nil' indicates no carbonate recorded
EC	Electrical conductivity – measurement of salinity levels	<2 dS/m	>2 and <5 dS/m	>5 dS/m	
pH	Measurement of the degree of alkalinity	< pH 8	> pH 8 and < pH8.5	> pH 8.5	
CEC	Cation exchange capacity	<25 cmol(+)/kg	>25 and <50 cmol(+)/kg	>50 cmol(+)/kg	
ESP	Exchangeable sodium percentage - measurement of sodicity	<25%	>25% and <50%	>50%	
Seed 7 yrs	Indicates percentage of 7-year old seeds that germinated.		50 to 70%	>70%	
Temperature	Measured as the percentage of seeds that germinated over 28 days per temperature.	>10% and <50%	>50% and <80%	>80%	'neg' is <10%

Table 2. Effect of temperature, light, and seed age on germination, seedling mortality over the first 6 months post germination, and the carbonate and gypsum content of soil associated with naturally occurring *Frankenia* populations. 'L' indicates larger-seeded species, 'S' indicates smaller-seeded species. (See Table 1 for key to symbols.)

Species	**Seed mass**	**Temp 17°C**	**Temp 23°C**	**Temp 29°C**	**Light requirement**	**7 year old seed**	**Seedling mortality**	**CO_3**	**Gypsum**
F. cordata	L	***	***	***	***			nil	nil
F. planifolia	L	***	***	***		**	**	nil	nil
F. eremophila	L	***	***	**	*		***	***	*
F. serpyllifolia	L	***	***	**	**	**	***	*	*
F. gracilis	L	***	***	**	**		*	nil	nil
F. sessilis	L	***	***	**	***		**	**	nil
F. tetrapetala	L	***	***	*	***		*		
F. setosa	L	***	**	*	*		**		
F. interioris	L	**	***	**	**		**		
F. latior	L				***		**	*	*
F. connata	L					**		nil	nil
F. plicata	L							nil	nil
F. fecunda	S	***	**	**	***		***		
F. foliosa	S	***	***	**	***	***	**	*	***
F. cinerea	S	***	***	**	**		*		
F. pauciflora* var. *fruticulosa	S	***	**	*	**		**	***	nil
F. confusa	S	***	*	neg	***		***		
F. laxiflora	S	**	**	*	***				
F. magnifica	S	**	*	*	***				
F. pauciflora* var. *pauciflora	S	**	*	neg	***		*		
F. irregularis	S				***		*		
F. pauciflora* var. *gunnii	S							***	nil
F. subteres	S							**	nil

Table 3. Effect of salinity levels on germination and the pH, EC, sodicity and CEC ratios of soil associated with naturally occurring *Frankenia* populations. 'L' indicates larger-seeded species, 'S' indicates smaller-seeded species. (See Table 1 for key to symbols.)

Species	Seed mass	Salinity 0%	Salinity 10%	Salinity 20%	Salinity 30%	pH	EC (saline)	Sodic	CEC ratios
F. cordata	L	***	***	*	*	***	*	**	*
F. planifolia	L					*	*	*	*
F. eremophila	L					**	**	**	**
F. serpyllifolia	L	***	***	**	*	**	**	**	**
F. gracilis	L					**	*	*	*
F. sessilis	L	***	**	*	neg	**	***	***	***
F. tetrapetala	L	***	**	*	*				
F. setosa	L	***	***	**	**				
F. interioris	L	***	***	*	*				
F. latior	L					*	*	*	*
F. connata	L					***	*	*	*
F. plicata	L					*	*	**	**
F. fecunda	S	**	**	*	neg				
F. foliosa	S	***	**	**	neg	**	**	**	***
F. cinerea	S	***	***	*	neg				
F. pauciflora* var. *fruticulosa	S					***	*	*	*
F. confusa	S								
F. laxiflora	S	**	**	*	neg				
F. magnifica	S								
F. pauciflora var. pauciflora	S	**	*	*	neg				
F. irregularis	S								
F. pauciflora* var. *gunnii	S	***	**	**	*	***	**	**	**
F. subteres	S					***	**	*	**

APPENDIX B

Reference and voucher specimen numbers for *Frankenia* sites visited by the author. Vouchers are lodged in the School of Biological Sciences, Flinders University, South Australia.

GPS co-ordinates, general site descriptions, and other relevant information are summarized. GPS co-ordinates are given in degrees, minutes and seconds.

Mean seed weights (with standard errors) per population are listed. **PLEASE NOTE** that mass is given in μgrams.

'NR' indicates that data was not recorded.

States of Australia are prefixed as follows; 'SA' South Australia, 'WA' Western Australia, 'NT' Northern Territory, 'NSW' New South Wales, and 'Vic' Victoria.

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia ambita					
LE01040	Anna Plains, WA	S19°22'01" E121°32'06"	saline	Between Anna Plains turnoff &Sandfire R/H.	272 ±5
Frankenia cinerea					
LE01984	WA	NR			82 ±3
LE03006a	Widgemooltha, WA	S31°29'29" E121°35'51"	pink swales, salt lake, clay pan		75 ±5
LE03022	Lake Austin, WA	S27°34'50" E117°53'60"	red clayey sand	Lake between Mt Magnet & Cue	NR
LE03037a	Shark Bay, WA	S26°01'18" E113°35'07"	soft orange sand ridges around salt pan	13km E of Denham	61 ±2
LE03038a	Shark Bay, WA	S26°10'10" E113°40'55"	yellow orange clayey sand	Road to Denham from Overland Corner	NR
LE03057	Lake King, WA	S35°05'24" E119°36'37"	very saline		95 ±3
LE03062	Scadden, WA	S33°24'32" E121°42'15"	salt crust over claypan	Huge mat around edge of salt pan	115 ±2
Frankenia* cf. *cinerea					
LE02014	Hattah, Vic	S34°44'27" E142°09'50"	gypseous salt pan	11km W of Hattah PO, gypsum mine	117 ±4
Frankenia confusa					
LE03041	Pt Gregory, WA	S28°11'40" E114°17'08"	grey sandy loam	Roadside near a salt lake, much grass	67 ±2
Frankenia connata					
LE01025	Roxby Downs, SA	S30°02'55" E137°04'34"		60km from Roxby Downs on Borefield Track	571 ±19
LE01032b	Oodnadatta Track, SA	S30°14'31" E138°20'45"		Ochre Cliffs turn-off, near Marree	614 ±30
LE03073	Andamooka, SA	S30°29'06" E137°02'04"	red/orange sand, ironstone shale	Andamooka road 20km from Roxby Downs turnoff	784 ±27
LE07002	Roxby Downs, SA	S30°02'55" E137°04'34"	water course	60km N of Roxby Downs on Borefield Track	NR
Frankenia cordata					
LE05006	Ormiston Gorge, NT	S23°40'45" E132°42'42"	pink/orange clayey sand, clay pan, scree	Egde of clay pan with stoney scree.	391 ±18
LE05007a	Rainbow Valley, NT	S24°19'57" E133°37'53"	pink/orange clay pan	At base of cliffs around clay pan	295 ±16
LE05011	Curtin Springs, NT	S25°21'01" E131°50'47"	red sand	Water course/flood out on side of road	375 ±9
Frankenia crispa					
LE02015	Hattah, Vic	S34°43'53" E142°06'33"	saline, salt lake	16.5km W of Hattah PO	527 ±13
Frankenia desertorum					
LE03008	Coolgardie, WA	S30°58'19" E121°02'33"	dry creek bed	W of Coolgardie	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia desertorum (cont.)					
LE03025	Lake Austin, WA	S27°39'51" E117°52'11"	white saline sand		140 ±3
LE03048	Hines Hill, WA	S31°32'30" E118°03'40"	salt lake edge		298 ±7
LE03051a	Lake Julia, WA	S31°01'10" E119°38'02"	edge of salt lake		180 ±10
LE03054a	Warralakin, WA	S31°00'29" E118°45'18"	clay pan	Lake Baladjie – Bullfinch/Mukinbudin Rd.	NR
LE03054b	Warralakin, WA	S31°00'40" E118°42'34"	clay pan	As above	NR
Frankenia eremophila					
LE01006	Cactus Beach, SA	S32°04'49" E132°59'31"	sand dunes		449 ±9
LE03001c	Head of Bight, SA	S31°28'28" E131°05'41"	limestone cliff top	Road to observation area	NR
LE03069	Cactus Beach, SA	S32°04'49" E132°59'31"	white saline sand dune		396 ±9
Frankenia fecunda					
LE03013a	Malcolm–Leonora, WA	S29°01'59" E121°29'13"	red clayey sand	Kookynie-Malcom Road near Malcolm	52 ±2
LE03018	Lake Miranda, WA	S27°41'58" E120°32'32"	orange sandy clay	47km N of Leinster to Wiluna	48 ±2
LE03019	Lake Way, WA	S26°44'44" E120°13'44"	claypan, ironstrone, laterite	17km S of Wiluna	91 ±3
LE03023	Lake Austin, WA	S27°35'15" E117°53'55"	red clayey sand, salt pan	Between Cue & Mt Magnet	82 ±2
LE03024	Lake Austin, WA	S27°36'07" E117°53'31"	white, gypseous, saline crust	Sandy rise on edge of salt lake	72 ±3
Frankenia foliosa					
LE01004	Oodnadatta Track, SA	S29°30'05" E137°24'29"	saline white gypseous sand	Dead Boy Springs (Finnis Springs)	115 ±4
LE01005	Oodnadatta Track, SA	NR			72 ±1
LE01009	Oodnadatta Track, SA	S30°18'44" E136°56'02"		28km W of Marree	NR
LE01013	Oodnadatta Track, SA	S29°36'05" E137°24'29"	saline, green clayey bog		NR
LE01014	Oodnadatta Track, SA	S29°39'34" E137°40'19"		40km W of Marree	NR
LE01015	Strzelecki Track, SA	S29°33'15" E139°25'16"			NR
LE01019	Strzelecki Track, SA	S30°11'54" E138°38'31"		28km N of Lyndhurst	NR
LE01020	Oodnadatta Track, SA	S29°30'05" E137°24'29"	clay	West Finnis Springs mound springs	NR
LE01028	Oodnadatta Track, SA	S29°30'05" E137°24'29"	white sand, traventine, highly saline, green	Dead Boy Springs (Finnis Springs)	NR
LE01037	Birdsville Track, SA	S29°20'13" E139°19'32"	pale cream sandy loam, ironstone & sandstone gravel	44km N of Marree	81 ±4
LE02004	Birdsville Track, SA	NR			NR
LE02006	Oodnadatta Track, SA	S29°27'17" E136°51'25"	saline white gypseous sand	Blanche Cup, dominant around mound springs	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia foliosa (cont.)					
LE03078	Oodnadatta Track, SA	S27°28'36" E135°23'35"	clayey saline limestone ridge	On sand dunes, 10km N of Oodnadatta	63 ±4
LE04001	Strzelecki Track, SA	S29°33'27" E139°25'08"	orange clay sand, clay crust, limestone pellets	Roadside verges, water run-offs	43 ±1
LE05003	Birdsville Track, SA	S29°20'15" E138°19'24"	white to orange clayey sand, limestone conglomerate	Roadside verges	58 ±1
LE05004	Oodnadatta Track, SA	S29°22'15" E136°46'39"	pink/orange clayey sand, salt pan	Coward Springs, 70km S of William Creek	NR
LE05012	Oodnadatta Track, SA	S30°15'01" E138°20'39"		W of Lyndhurst	NR
LE05013	Oodnadatta Track, SA	S30°05'24" E138°17'07"	gypseous	W of Lyndhurst	89 ±2
LE05014b	Oodnadatta Track, SA	S29°59'37" E138°16'27"	pink/orange clayey sand	W of Lyndhurst	NR
LE05015	Oodnadatta Track, SA	S29°15'60" E136°40'38"		Beresford Bore	NR
LE05016	Oodnadatta Track, SA	S29°05'28" E136°32'04"	pink/orange clay; gypsum	Kewston Hill mound springs	NR
LE05017	Oodnadatta Track, SA	S28°42'30" E135°58'39"	white/orange clayey sand, ironstone conglomerate	Old Woman Creek, S of Oodnadatta	NR
LE05018	Oodnadatta Track, SA	S27°54'59" E135°48'50"	gypseous sand; pebble, ironstone scree	S of Neale Creek ford; base of hills.	NR
LE05019	Oodnadatta Track, SA	S27°47'19" E135°41'12"	braided creek	35km S of Oodnadatta	NR
LE05020	Oodnadatta Track, SA	S29°39'24" E137°40'19"	pink/orange clayey sand	40km W of Marree.	NR
LE05021b	Oodnadatta Track, SA	S29°38'51" E137°38'17"			NR
Frankenia glomerata					
LE01042	Little Sandy Desert, WA	S25°02'20" E120°43'29"	saline, red loam over gypsum	S side of Lake Kerrylyn.	NR
LE03040	Kalbarri, WA	S27°45'23" E114°08'21"	coastal cliffs, shingle slopes	Mushroom Rock NP.	832 ±28
LE03045a	Mortlock East River, WA	S31°39'09" E116°59'23"	very compact white sandy clay, laterite	River bank, plants in white sand	935 ±32
Frankenia gracilis					
LE01002	Roxby Downs, SA	S30°03'28' E137°04'11"		Borefield Track	358 ±7
LE01012	Roxby Downs, SA	S30°03'28" E137°04'11"	red clayey sand	Borefield Track, 5.5km N of LE01011	NR
LE01026	Roxby Downs, SA	S30°03'28" E137°04'11"	red clayey sand	91km from Roxby Downs, Borefield Track	578 ±20
LE01027	Roxby Downs, SA	S29°42'32" E137°15'59"	red clayey sand, gibber	120km from Roxby Downs, Borefield Track	381 ±9
LE01031	Oodnadatta Track, SA	NR	red clayey sand	15km N of Lyndhurst	382 ±12
LE01034a	Parachilna, SA	NR		In watercourse 1km S of Beltana	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
LE01033	Beltana, SA	NR	red clayey sand, ironstone conglomerate	By railway xing on track to old Beltana	454 ±19
LE01039	Birdsville Track, SA	S29°01'09" E138°27'28"	stony brown loam	Dulkaninna Creek	454 ±19
LE02003	Birdsville Track, SA	S27°57'30" E138°39'36"	gypsum, pale, ironstone conglomerate	3km of N of Kalamanna H/S	NR
LE02005	Birdsville Track, SA	S29°01'09" E138°27'28"	sandy rise	Dulkaninna Creek.	NR
LE03071	Lake Torrens, SA	S31°37'32" E137°36'07"	red sand, ironstone conglomerate, gypsum	1km W of South Gap H/S, near Gypsum Dam	705 ±55
LE03072	Lake Torrens, SA	S31°27'07" E137°24'59"	red sand, ironstone conglomerate	Pernatty Station; dry creek bed.	464 ±80
LE03074b	Oodnadatta Track, SA	S28°26'10" E135°50'53"	orange red sand, limestone outcrops	72km N of William Creek	869 ±22
LE04003	Salisbury Lake, NSW	S29°41'16" E142°38'58"	orange clayey sand, saline, salt lake	Wanaaring Road, 150km W of Tibooburra	NR
LE05022	Birdsville Track, SA	S29°01'05" E138°27'30"	pink/orange sand	Dulkinna Creek, braided creek bed	678 ±19
Frankenia interioris					
LE03007	Coolgardie, WA	S30°58'20" E121°03'11"	clay pan	Side of road amongst mallee	343 ±9
LE03009	Kalgoorlie, WA	NR	red clay sand, dry creek bed	30km N of Kalgoorlie	302 ±7
LE03010	Kalgoorlie-Menzies Rd, WA	S30°33'27" E121°25'33"	clay pan	Claypan 110km S of Menzies	NR
LE03011c	Kalgoorlie-Menzies Rd, WA	S30°32'03" E121°24'45"	red clay pan	110km S of Menzies	NR
LE03012a	Lake Goongarrie, WA	S30°00'56" E121°09'46"	soft clayey, prob. gypseous, quartz	40km S of Menzies	320 ±85
LE03065	Mundrabilla, WA	S31°54'37" E127°21'26"	orange sandy clay	Clay pan 77km W of Mundrabilla	286 ±67
Frankenia irregularis					
LE03004	Boulder, WA	S38°48'44" E121°32'23"	red clayey salt pan	20km E of Kalgoorlie-Boulder	NR
LE03011a	Kalgoorlie-Menzies Rd, WA	S30°32'03" E121°24'45"	red clay pan	110km S of Menzies	61 ±1
LE03049	Southern Cross, WA	S31°13'15" E119°19'55"	saline crust over orange clay, salt lake		64 ±3
LE03059	Lake Grace, WA	S33°06'35" E118°24'24"	white saline sand over brown grey clayey sand	Large salt lakes, Rhynie	71 ±2
Frankenia latior					
LE01003	Pt Augusta, SA	S31°35'23" E137°08'22"		South of Pimba, Pt Augusta road	539 ±19
LE01011	Roxby Downs, SA	S30°18'44" E136°56'02"	heavy clay	Borefield Rd, 89.4km N of PS1	NR
LE01023	Woomera, SA	S30°57'25" E136°54'22"		48km S of Roxby Downs, Woomera road	NR
LE01029	Oodnadatta Track, SA	S29°38'51" E137°38'17"	clayey sand	By railway bridge, 45km W of Marree	400 ±9
LE04004	Fords Bridge, NSW	S29°42'27" E145°28'22"	pale red brown clay pan	7km N of Fords Bridge, N of Bourke	NR
LE05021a	Oodnadatta Track, SA	S29°38'51" E137°38'17"		Dog Fence 45km W of Marree	563 ±15

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia latior (cont.)					
LE05008	Coober Pedy, SA	S29°02'16" E134°49'12"	scree over pink/orange sand	William Creek road, from Coober Pedy	NR
LE05030	Pt Augusta Road, SA	S31°19'48" E136°51'44"			686 ±24
LE07003	Pt Augusta Rd, SA	S31°35'23" E137°08'22"	red clay/ironstone	North of Pt Augusta on Pimba road	NR
Frankenia laxiflora					
LE03003	Ponton River, WA	S31°02'22" E123°47'04"	sandy clay		59 ±2
LE03012b	Lake Goongarrie, WA	S30°00'56" E121°09'46"	soft clayey, prob. gypseous, quartz	40km S of Menzies	65 ±3
LE03013c	Malcolm-Leonora, WA	S29°01'59" E121°29'13"	red clay pan, sandy clay	Kookynie-Malcom Road near Malcolm	69 ±4
LE03014	Leonora-Agnew Road, WA	S28°16'52" E121°07'26"	claypan, brown/orange, ironstone, laterite, sandstone	72km N of Leonora, WA	86 ±4
LE03015	Leonora-Agnew Rd, WA	S28°15'28" E121°06'13"		76km N of Leonora	NR
LE03016	Sandstone, WA	S27°58'00" E120°26'35"	red sand, sandstone conglomerate	Along road towards Sandstone.	NR
LE03017	Agnew, WA	S27°59'04" E120°34'45"	stoney clay pan	5km S of Agnew.	NR
LE03021	Lake Annean, WA	S26°53'15" E118°17'21"	clayey sand near salt lake	S of Meekatharra; S of Nannine cemetery	67 ±2
LE03032a	Curbur Station, WA	S26°27'45" E115°56'26"	red clay	Monoculture	NR
LE03047	Hines Hill, WA	S31°34'55" E117°58'37"	salt crust over clay, saline claypan	Bandee Road.	72 ±1
Frankenia magnifica					
LE01044a	Granite Peake H/S, WA	S25°31'06" E121°15' 01"	red sandy loam	Forbes Outcamp track	NR
LE03030b	Murchison County, WA	S28°02'55" E115°40'48"	dry creek bed	Road from Mullewa to Murchison R/H	55 ±1
LE03031	Mt Narryer Station, WA	S28°42'13" E115°53'24"	yellow orange sand	Monoculture	105 ±4
LE03033	Kennedy Ranges, WA	S24°39'42" E115°10'37"	black ironstone		93 ±6
LE03034	Gascoyne Junction, WA	S24°45'29" E115°18'53"	red sand, quartz, ironstone	40km N of Gascoyne Junction	91 ±3
Frankenia pauciflora* var. *fruticulosa					
LE01010	Thevernard, SA	S32°08'33" E133°40'35"	limestone	Growing in rock crevasses	147 ±3
LE03001b	Head of Bight, SA	S31°28'28" E131°05'41"	limestone cliff top	Road to observation area	NR
LE03070	Thevernard, SA	S32°08'33" E133°40'35"	limestone cliff		NR
LE04007	Yorke Peninsula, SA	S34°53'47" E137°00'38"	white sand over limestone, cliff top	Corny Point lighthouse	121 ±4
LE04008	Yorke Peninsula, SA	S35°16'05" E136°50'44"	pink sand over limestone	Cliff top, Innes NP, Pondalowie Bay.	NR
LE04010	Yorke Peninsula, SA	S35°16'12" E136°50'24"	sand over limestone	Cliff top	141 ±22

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia pauciflora* var. *fruticulosa (cont.)					
LE04011	Yorke Peninsula, SA	S35°05'45" E136°25'11"°	saline, clay	Claypan behind sand dunes, Warooka intersection	NR
LE04012	Yorke Peninsula, SA	S34°18'36" E137°30'00"	yellow silty sand, limestone conglomerate	Cliff top, Balgowen; Tipara Rocks.	113 ±4
LE04013	Yorke Peninsula, SA	S34°40'47" E137°29'24"	white soft sand	In sand dunes, Pt Rickaby	122 ±3
LE04014	Pt Gawler, SA	S34°38'35" E138°26'22"	shelly sand over clayey sand	Swampy, near beach.	256 ±9
LE05024	Yorke Peninsula, SA	S34°35'53" E137°00'00"	limestone cliff top	Corney Point lighthouse.	159 ±9
LE05025	Yorke Peninsula, SA	S34°40'50" E137°29'37"	sand dune	Pt Rickaby.	145 ±7
LE05026	Pt Gawler, SA	S34°38'35" E138°26'22"	shelly sand grit	Swamp type, near mangroves.	128 ±8
Frankenia pauciflora* var. *gunnii					
LE01001	Goolwa, SA	S35°31'56"E138°49'37"	saline	Goolwa barrages	NR
LE03084	Goolwa, SA	S35°31'56"E138°49'37"	salt marsh		94 ±2
LE03085	Kangaroo Island, SA	S35°48'01" E137°44'24"	shelly sand beach, saltmarsh	*"Independence"* carpark	NR
LE03086	Kangaroo Island, SA	S35°47'22" E137°45'58"	shelly sand, saltmarsh	American River; *"Rememberance"* carpark	NR
LE03087	Kangaroo Island, SA	S36°03'32" E136°42'06"	cliff limestone	Cape de Coedic, on cliff face & islands	NR
LE04005	Yorke Peninsula, SA	S34°08'00" E138°03'50"	saline, boggy silty clay	Pt Clinton NP	64 ± 1
LE04006	Yorke Peninsula, SA	S33°54'26" E137°38'30"	sandy clay, swamp	N of Wallaroo, on road to North Beach	141 ±3
LE04009	Yorke Peninsula, SA	S35°11'50" E136°52'20"	swamp - clay	Browns Lake.	88 ±7
LE04015	Little Dip NP, SA	S37°16'48" E139°48'04"	limestone, sand overburden	Cliff top, Long Gully campsite	NR
LE04016	Beachort, SA	S37°29'02" E139°59'59"	sand around salt lake	Pool of Siloam	140 ±3
LE04017	Robe, SA	S36°09'00" E139°44'34"	sand over limestone	Growing in limestone outcrops.	NR
LE04018	Robe, SA	S37°09'00" E139°44'32"	beach pebbles	Doorway Rock lighthouse, cliff top	NR
LE04019	Kingston SE, SA	S36°49'45" E139°52'13"	white/grey sand, shelly inclusions, boggy	Swamp at drain outlet.	146 ±3
LE04020	Coorong NP, SA	S36°19'47" E139°45'00"	grey boggy, clayey sand, swampy clay pan	100km N of Kingston SE.	NR
LE04021	Coorong NP, SA	S36°03'20" E139°35'21"	swamp - clay	Lake 2km N of Policemans Point	106 ±2
LE06001	Robe, SA	S37°09'00" E139°44'32"	sand near base of cliff	Adjacent to Robe lighthouse	112 ±3
LE06002	Beachport, SA	S37°29'02" E139°59'59"	sand	Pool of Siloam	127 ±3
LE06003	Kingston SE, SA	S36°49'45" E139°52'13"	boggy sand	Maria Creek Drain.	148 ±3

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
***Frankenia pauciflora* var. *pauciflora* (coastal)**					
LE03036	Monkey Mia, WA	S25°48'55" E113°39'19"	clay pan	5km SW of Monkey Mia	78 ±5
LE03037b	Shark Bay, WA	S26°01'18" E113°35'07"	soft orange sand ridges around salt pan	13km E of Denham	61 ±1
LE03038b	Shark Bay, WA	S26°10'10" E113°40'55"	yellow orange clay sand	Road to Denham from Overland Corner	59 ±5
LE03039	Leeman, WA	S29°41'23" E114°57'50"	pan between grey/white sand dunes, gypseous	Rubbish tip 3km S of Knobby Head.	59 ±2
LE03043	Leeman, WA	S29°55'29" E114°58'48"	coastal cliff face, rock, white sand	Growing in rock crevasses	123 ±4
LE03044	Jurien Bay, WA	S30°11'15" E115°01'10"		Roadside population.	110 ±6
***Frankenia pauciflora* var. *pauciflora* (inland)**					
LE03005	Kambalda, WA	S31°13'20" E121°39'01"	saline	Rubbish tip.	57±2
LE03029	Pindar, WA	S28°28'29" E115°47'27"	yellow clay grading to grey, claypan		40 ±2
LE03032b	Byro Station, WA	S26°21'03" E115°59'33"		Monoculture	57 ±4
LE03042	Lake Inoon, WA	S29°51'06" E115°11'13"	clay pan		NR
LE03045	Mortlock East River, WA	S31°39'09" E116°59'23"	very compact white sandy clay, laterite	River bank, plants in white sand, not clay	128 ±2
LE03046	Cunedin, WA	S31°36'41" E117°05'58"	white sand, saline	Causeway over salt lake, Hopkins Road.	NR
LE03053	Lake Julia, WA	S30°58'21" E119°28'49"	sand over brown/grey clay	On side of road 16km S of Koolyanobbing	38 ±3
LE03055	Lake Polaris, WA	S31°12'39" E119°18'54"	clay and saline		NR
LE03063b	Salmon Gums, WA	S32°36'13" E121°33'58"	white yellow sand over orange brown clay	Lake Gilmore 51km N of Norseman	NR
Frankenia planifolia					
LE01016	Strzelecki Track, SA	S29°40'50" E139°33'14"		Murnpeowie Station, track to Public House Springs	NR
LE01024	Roxby Downs, SA	S30°10'05" E137°00'57"	red clay	Stuart Creek turn-off	NR
LE02007b	Oodnadatta Track, SA	S28°16'33" E135°50'16"	red, ironstone inclusions	Bungadillina Creek	626 ±14
LE02008b	Oodnadatta Track, SA	S27°40'38" E135°32'36"	ironstone inclusions	Next to' Alandale 10km' sign	532 ±10
LE02009a	Oodnadatta Track, SA	S27°35'74" E135°26'38"	orange claypan	~200m towards Coober Pedy from turnoff	NR
LE02010	Oodnadatta Track, SA	S27°36'07" E135°25'50"	wetland, gidgee, grasses	~1km toward Coober Pedy from LE02009	NR
LE02011	Oodnadatta Track, SA	S28°10'12" E134°24'07"	slope of ironstone scree	Evelyn Downs Station.	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia planifolia (cont.)					
LE02012	Oodnadatta Track, SA	S28°12'40" E134°48'13"	pebbly crust	Evelyn Downs Station.	545 ±94
LE03074a	Oodnadatta Track, SA	S28°26'10" E135°50'53"	orange red sand, limestone outcrops	72km N of William Creek	583 ±49
LE03075b	Oodnadatta Track, SA	S28°16'33" E135°50'16"	yellow orange sand, ironstone, sandstone	Bungadillina Creek; in water run-off.	623 ±34
LE03076b	Oodnadatta Track, SA	S27°40'38" E135°32'37"	red gibber, sandy run-offs	Next to 'Alandale 10km' sign	NR
LE03079	Oodnadatta Track, SA	S27°35'41" E135°26'26"	sand	Braided creek bed, Coober Pedy road	601 ±17
LE03080	Oodnadatta Track, SA	S27°36'09" E135°25'48"	yellow brown sand, sandstone	*Acacia* grasslands.	521 ±10
LE05005	Oodnadatta Track, SA	S27°29'28" E138°24'29"	pink/orange, gibber, red ironstone conglomerate		NR
LE05023b	Oodnadatta Track, SA	S28°16'33" E135°50'16"		Bungadillina Creek	NR
Frankenia plicata					
LE05009	Anna Creek Station, SA	S29°38'57" E135°45'19"	dunes and scree	North Creek, near Dog Fence	290 ±61
LE05010a	Anna Creek Station, SA	S29°40'22" E135°46'07"	dunes and limestone, rock scree	North Creek, near Dog Fence	352 ±23
Frankenia punctata					
LE03051b	Lake Julia, WA	S31°01'10" E119°38'02"	saline, edge of lake		55 ±4
LE03052	Lake Seabrooke, WA	S30°59'13" E119°38'43"	extremely saline, white sand	Very white saline lake, sand dunes.	83 ±2
Frankenia serpyllifolia					
LE01018	Strzelecki Track, SA	S30°02'02" E138°56'51"	red clayey sand	70km N of Lyndhurst	NR
LE01021	Pimba, SA	S31°15'20" E136°48'15"		Next to petrol station.	NR
LE01022	Pimba, SA	S31°18'56" E136°51'11"		10km S of Pimba, Pt Augusta road	415 ±21
LE01035	Leigh Creek, SA	NR		Bridge, 35km S of Leigh Creek	NR
LE01038	Birdsville Track, SA	S29°12'38" E138°23'58"	pale red loam, surface ironstone	60km N of Marree	452 ±9
LE02001	Birdsville Track, SA	S27°13'39" E138°45'44"	red sand, ironstone	Mt Gason A*cacia* recovery site	NR
LE02002	Birdsville Track, SA	S27°25'52" E138°41'55"	red sandy clay, red ironstone	4km N of Kilander Bore	NR
LE02007a	Oodnadatta Track, SA	S28°16'33" E135°50'16"	red sand ironstone	Bungadillina Creek	724 ±21
LE02008a	Oodnadatta Track, SA	S27°40'38" E135°32'36"	ironstone	Next to Alandale '10km' sign	551 ±11
LE02009b	Oodnadatta Track, SA	S27°35'74" E135°26'38"	orange clay pan	200m towards Coober Pedy from turnoff	NR
LE02013	Oodnadatta Track, SA	S28°12'40" E134°48'12"	red clay, pebbly, dam run-off	Mt Barry Station	537 ±16
LE03075a	Oodnadatta Track, SA	S28°16'33" E135°50'16"	yellow orange sand, ironstone, sandstone	Bungadillina Creek; water run-off	636 ±15
LE03076a	Oodnadatta Track, SA	S27°40'38" E135°32'37"	red gibber, sandy run-off	Next to ‘Alandale 10km' sign	NR
LE03081	Arckaringa Station, SA	S27°46'34" E135°13'16"	yellow brown clayey sand, limestone	Gidgee, grasses	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia serpyllifolia (cont.)					
LE03077	Oodnadatta Track, SA	S27°38'20" E135°29'58"	gibber	13km SE of Oodnadatta, Oodnadatta Track	454 ±11
LE03082	Arckaringa Station, SA	S27°51'21" E135°03'33"	hard red clayey sand, ironstone, sandstone conglomerate	Painted Desert, side of creek bed	NR
LE03083	Oodnadatta Track, SA	S27°56'40" E134°22'43"	dry creek bed	70km N of Oodnadatta	NR
LE04002	Tibooburra, NSW	S29°06'26" E131°55'48"	gibber, mesa	42km N of Tibooburra	621 ±24
LE05007b	Rainbow Valley, NT	S24°19'57" E133°37'53"	pink/orange clay pan	At base of cliffs around clay pan	NR
LE05010b	Anna Creek Station, SA	S29°40'22" E135°46'07"	gypseous dune and limestone, rock scree	Flood wash on North Creek, near Dog Fence	643 ±19
LE05014a	Oodnadatta Track, SA	S29°59'37" E138°16'27"	pink/orange clayey sand	W of Lyndhurst	NR
LE05023a	Oodnadatta Track, SA	S28°16'33" E135°50'16"		Bungadillina Creek	618 ±9
LE05027	Oodnadatta Track, SA	S27°40'38" E135°32'36"		Next to 'Alandale 10km' sign.	638 ±29
LE05028	Pt Augusta Rd, SA	S31°35'25" E137°08'22'		Just south of the South Gap turn-off	517 ±36
LE05029	Anna Creek Station, SA	S29°13'26" E135°16'58"		Track along dog fence	444 ±31
LE07001	Pimba, SA	S31°18'56" E136°51'11"	red clay/ironstone; watercourse	10km south of Pimba	NR
Frankenia sessilis					
LE01007	Cactus Beach, SA	S32°03'56" E132°59'37"	sandy silty clay, limestone		239 ±9
LE01008	Fowlers Bay, SA	NR	brown red silty sand, crust, saline		159 ±4
LE01997	Eyre Peninsula, SA	NR			139 ±4
LE03001a	Head of Bight, SA	S31°28'28" E131°05'41"	limestone cliff top	Road to observation area	194 ±25
LE03002	Nullabor Plain, SA	S31°38'17" E129°25'48"	cliff top, limestone	45km E of Border Village	NR
LE03064	Madura Pass, WA	S31°53'59" E127°00'32"	limestone shingle	Top of escarpment, very little soil	199 ±4
LE03066	Eucla, WA	S31°42'49" E128°53'06"	marsh, white sand over orange clayey sand	In saltmarsh behind sand dunes	138 ±3
LE03067	Fowlers Bay, SA	S31°57'42" E132°26'12"	white sand over grey clayey sand, limestone outcrops		175 ±3
LE03068	Cactus Beach, SA	S32°03'56" E132°59' 7"	saline white sand		235 ±73
Frankenia setosa					
LE01041	Carnarvon Range, WA	S25°08'44" E120°14'20"		Track to Mt Methwin H/S	688 ±22
LE01043	Little Sandy Desert, WA	S25°07'32' E120°42'56"	red loam, quartz gravel	Mt Methwin to Carnarvon Ranges track	629 ±15
LE01044b	Granite Peake H/S, WA	S25°31'06" E121°15'31"	red sandy loam	Forbes Outcamp track	NR
LE03006b	Widgemooltha, WA	S31°29'29" E121°35'51"	pink swales, salt lake	Dry clay pan	NR

Voucher No.	Location	GPS co-ordinates	Site description	Comments	mass µg (±se)
Frankenia setosa(cont.)					
LE03011b	Kalgoorlie-Menzies Rd, WA	S30°32'03" E121°24'45"	red clay pan	110km S of Menzies	334 ±15
LE03013b	Malcolm-Leonora, WA	S29°01'59" E121°29'13"	red clay pan, sandy clay	Kookynie-Malcom Road near Malcolm	483 ±32
LE03026	Mt Magnet, WA	S28°00'29" E117°48'51"	quartz hill slope, ironstone		NR
LE03027	Mt Magnet, WA	S28°00'07" E117°51'12"	white sand, gypseous, saline	The Granites, N of Mt Magnet	NR
LE03028	Pindar, WA	S28°28'29" E115°47'27"	yellow clay grading to grey		776 ±52
LE03030a	Murchison County, WA	S28°02'55" E115°40'48"	dry creek bed, clay pan	Road from Mullewa to Murchison R/H	NR
LE03035	Gascoyne Junction, WA	S24°51'18" E115°18'20"	red sand, sandstone conglomerate	28km N of Gascoyne Junction	1214 ±34
LE03050	Yellowdine, WA	S31°17'29" E119°41'30"	saline over clay	Lake 3km E of Yellowdine to Coolgardie	NR
Frankenia subteres					
LE01017	Moolawatanna Station, SA	S29°51'01" E139°39'53"	limestone conglomerate, no soil	Twelve Springs, Murnpeowie Station	NR
LE01030	Oodnadatta Track, SA	S29°12'38" E138°23'58"	white sand, saline	63km N of Lyndhurst	99 ±11
LE01032a	Oodnadatta Track, SA	S30°14'31" E138°20'45"		Ochre Cliffs turn-off, near Marree	196 ±2
LE05001	Leigh Creek, SA	S30°25'59" E138°22'13"	pink/orange clayey sand & gravel to stone conglomerate		155 ±24
LE05002	Lyndhurst, SA	S30°16'45" E138°20'57"	pink/orange clayey sand, rock conglomerate		113 ±2
Frankenia tetrapetala					
LE03056	Lake Newton, WA	S32°57'39" E119°36'33"	white sand over grey sandy clay	Edge of lake, rubbish tip	135 ±3
LE03058	Newdegate, WA	S33°11'29" E119°12'49"	white sand over grey sandy clay, salt pan	Old Ravensthorpe Road	135 ±3
LE03060	Esperence, WA	S33°34'46" E121°45'44"	clayey sand with laterite, salt pan	35km N of Esperence	202 ±11
LE03061	Grasspatch, WA	S33°25'09" E121°42'32"	saline over clay	Huge mat around edge of salt pan	185 ±11
LE03063a	Salmon Gums, WA	S32°36'13" E121°33'58"	white yellow sand over orange brown clay	Lake Gilmore 51km N of Norseman	266 ±8

Part of Project Funded by Australian Flora Foundation

Western Australia Field Trip Undertaken by Lyndlee Easton and Andrew Craigie from 31/1/03 to 28/2/03

Purpose of Field Trip To collect seeds, herbarium specimens and leaf samples from wild populations of the arid zone genus *Frankenia*, for experimentation at Flinders University.

Route Adelaide — Ceduna — Cocklebiddy — Rawlinna — Kalgoorlie — Wiluna — Mt Magnet — Mullewa— Gascoyne Junction —Carnarvon — Overlander Corner— Denham — Geraldton — Jurien Bay— Moora — Northam — Southern Cross — Merredin — Hyden — Lake King —Lake Grace — Ongerup — Ravensthorpe — Esperence — Norseman — Balladonia — Eucla — Fowlers Bay — Point Sinclair — Adelaide

Summary of costs

Item	Cost ($)
Petrol	1400
Accommodation/food	955
Miscellaneous	310
Consumables	3552
TOTAL	**6217**

1. Petrol for Vehicle (Toyota Rav 4 @ $0.40/km)

Invoice No.	Date	Station	Distributor	Cost ($)	Litres	Odometer (km)	Accumulated cost ($)
1	28/2/03	Adelaide	To fill tank	83.00	Ref Uni car log	4339	83
2	1/2/03	Pt Wakefield	Mobil	25.89	27.57	4591	107
3	1/2/03	Wudinna	Mobil	41.21	41.21	5050	151
4	2/2/03	Ceduna	Mobil	62.12	61.57	5274	214
5	3/2/03	Border Village	BP	65.20	51.09	5817	280
6	3/2/03	Cocklebiddy	BP	37.65	28.66		318
7	5/2/03	Kalgoorlie	BP	40.02	40.06	6654	358
8	7/2/03	Leonora	Shell	48.19	41.94	7253	407
9	7/2/03	Wiluna	unspecified	54.05	49.136	7817	461
10	8/2/03	Meekatharra	Ampol/Caltex	21.00	Ref Uni car log		782
11	11/2/03	Mt Magnet	BP	35.94	31.01	8243	521
12	11/2/03	Mullewa	BP	31.35	Ref Uni car log	8516	553
13	12/2/03	Murchison Roadhouse	BP	26.75	Ref Uni car log	8717	579
14	13/2/03	Gascoyne Junction	BP	53.00	Ref Uni car log	9137	632
15	14/2/03	Carnarvon	Caltex	23.36	21.73	9347	656
16	15/2/03	Denham	Ampol	46.27	Ref Uni car log	9740	702
17	16/2/03	Kalbarri	Ampol	51.15	Ref Uni car log	10222	754
18	18/2/03	Geraldton	Shell	29.00	Ref Uni car log	10464	783
19	19/2/03	Moora	Shell	21.74	36.75	10837	805
20	19/2/03	Cunderdin	Mobil	21.74	21.15	11080	827
21	20/2/03	Southern Cross	BP	24.65	Ref Uni car log	11297	852
21a	21/2/03	Newdegate	Ampol	47.40	Ref Uni car log		900
22	21/2/03	Merredin	Shell	46.54	Ref Uni car log	11673	947
22a	22/2/03	Lake Grace	Shell	27.85	Ref Uni car log		975
23	22/2/03	Munglinup	BP	50.00	Ref Uni car log	12535	1025
24	23/2/03	Esperence	Caltex	15.12	14.1	12672	1040
25	23/2/03	Norseman	Ampol	23.75	20.75	12897	1064
26	24/2/03	Caiguna	BP	66.70	Ref Uni car log		1131
27	24/2/03	Border Village	Mobil	61.51	46.88	13711	1193
28	25/2/03	Penong	Caltex	42.88	44.99	14411	1236
29	26/2/03	Ceduna	Mobil	28.91	30.33	14371	1265
30	26/2/03	Wudinna	Mobil	22.58	21.32	14578	1288
31	26/2/03	Pt Wakefield	Mobil	30.32	30.35	15041	1318
32	28/2/03	returned	To fill tank	83.00	Ref Uni car log	15210	**TOTAL 1400**

2. Accommodation

Date	Place	Cost ($)	Accumulated cost ($)
1/2/03	Ceduna	20.00	20.00
2/2/03	Border Village	15.00	35.00
3/2/03	Rawlinna	15.00	50.00
4/2/03	Chifley	15.00	65.00
5/2/03	Kalgoorlie	20.00	85.00
6/2/03	Leonora	16.00	101.00
7/2/02	Leonora	16.00	117.00
8/2/03	Meekatharra	15.00	132.00
9/2/03	Mt Magnet	19.80	152.00
10/2/02	Mt Magnet	19.80	172.00
11/2/03	Murchison Roadhouse	10.00	182.00
12/2/03	Gascoyne Junction	18.00	200.00
13/2/03	Carnarvon	18.00	218.00
14/2/03	Monkey Mia	27.00	245.00
15/2/03	Kalbarri	19.00	264.00
16/2/03	Geraldton	27.50	291.50
17/2/03	Geraldton	17.50	309.00
18/2/03	Moora	17.00	326.00
19/2/03	Merredin	18.00	344.00
20/2/03	Merredin	18.00	362.00
21/2/03	Lake Grace	15.00	377.00
22/2/03	Esperence	30.00	407.00
23/2/03	Balladonia	18.00	425.00
24/2/03	Border Village	15.00	440.00
25/2/03	Cactus Beach	15.00	455.00
Food			500.00
		TOTAL	**$955.00**

***Food was budgeted at $20 per day**

3. Miscellaneous

Receipt #	Date	Place	Item	Cost ($)	Accumulated cost ($)
1	6/2/03	Leonora	Distilled water	7.52	7.52
2	7/2/03	Leonora	Batteries/camping supplies	19.20	26.72
3	8/02/03	Leonora	Distilled water	2.84	29.56
4	10/2/03	Mt Magnet	Supplies	8.20	37.76
5	11/2/03	Mt Magnet	Photocopies	4.80	42.56
6	17/2/03	Geraldton	Distilled water/brush	6.05	48.56
Car log	18/2/03	Geraldton	Carwash	13.00	61.13
Car log	18/2/03	Geraldton	Tyre	169.00	230.13
7	21/2/03	Hyden	Park fee	6.00	236.13
8	24/02/03	Border Village	Films etc	43.65	279.79
9	24/2/03	Cocklebiddy	Supplies	29.95	309.74
				TOTAL	**309.74.**

4. Consumables

Description	Cost ($)	Accumulated cost ($)
2003 - Containers for soil and seed samples, foam test tube racks, labels, chemicals, stationary, printer cartridges, soil, laboratory consumables, etc	60	60
2004 -As above	231	291
2005 - As above	684	975
2006 - As above	100	1075
2007 -As above	771	1875
2-way radios (Dick Smith)	100	1946
Soil analyses/freight to CSBP Bibra Lakes (WA)	912	2858
Grow lights (Silvanian)	350	3208
Sandisk Smart Media	124	3332
Smoults garden pots/tags	120	3552
	TOTAL	**3552**