POPULATION CHARACTERISTICS OF *FRANKENIA CONFERTA* (SILKY FRANKENIA)

A framework for monitoring change

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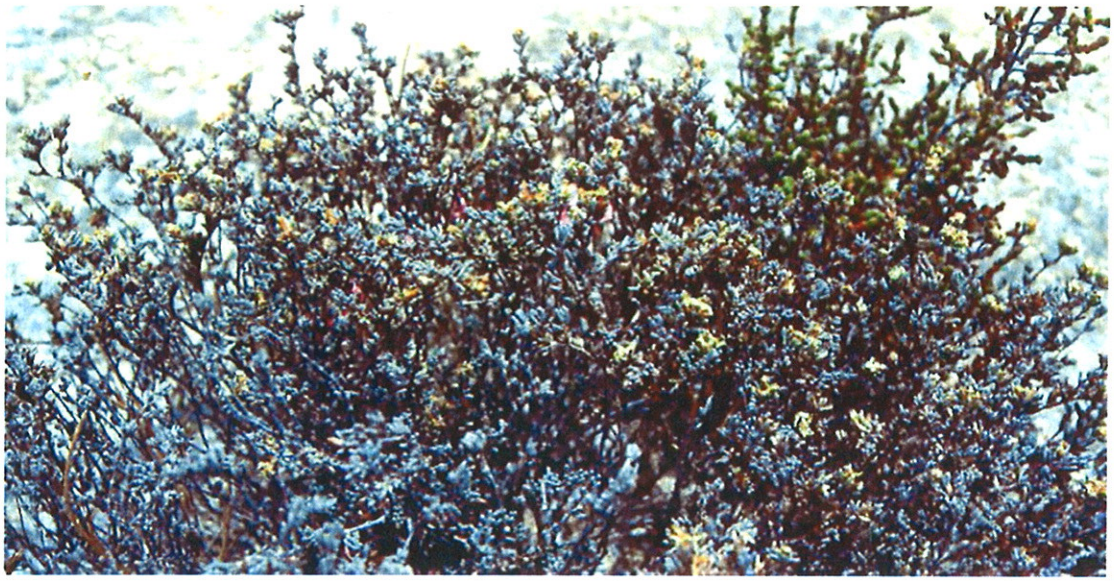

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DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

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1.0 INTRODUCTION

There are 32 described taxa of *Frankenia* found in Western Australia of which one is a weed (Paczkowska and Chapman 2000). The Department of Conservation and Land Management (CALM) currently recognises one Presumed Extinct, two Declared Rare and a further six Priority taxa that are poorly known and in need of further study (Atkins 2003).

This study focuses on one of the Declared Rare species, *Frankenia conferta,* identified as being seriously threatened by salinity and waterlogging. Funds made available through the State Salinity Strategy have enabled the study, which aims to increase the understanding of the species' biology and ecology.

Frankenia conferta occurs in seasonal wetlands within the wheatbelt of Western Australia. These wetlands have suffered marked changes due to clearing for agriculture and associated land management practices, with many wetlands, including some in nature reserves, becoming highly saline (Schofield *et al.* 1988; Halse *et al.* 1993). Salinization of inland wetlands in south-west Western Australia has caused both a decline in species richness and a marked change in the species composition, particularly for saline and hypersaline sites. Many species occur only within a restricted salinity range (Halse *et al.* 1993; Sanders 1991).

In addition to clearing, climatic change may also influence the hydrology and salinity of lake chains and this also needs to be factored into conservation consideration (Hobbs and Hopkins 1991).

1.1 History and conservation status

Frankenia conferta was first collected in 1890 by Mrs M. Heal, 'probably from the interior of the Avon district' (Diels and Pritzel 1904). The species was then not seen for 110 years and was presumed extinct until Mike Lyons[1] rediscovered it in October 2000 while establishing floristic survey quadrats as part of a 'Biological Survey of the Wheatbelt' under the Salinity Action Plan (Lyons *et al.*, in press).

The species was ranked as Critically Endangered (CR) in August 2001 but in May 2004, was recommended for ranking as Vulnerable (VU) under World Conservation Union (IUCN) Red List Criteria B1ab(iii)+ab(iii) (IUCN 2000) due to further populations having been found. Surveys undertaken by M. Lyons for this and other CR species, have so far located nine populations (Table 2) in nature reserves and on Unallocated Crown Land (UCL).

1.2 Plant description

Frankenia conferta Diels is a small shrub; stems simple, with short, spreading or retrorse hairs. Leaves sessile, linear, 2-5 mm long, clustered at nodes, puberulous; upper surface sometimes encrusted; margins recurved covering midrib; sheath ciliate, puberulous outside. Flowers in dense dichasia; bracts similar to leaves; bracteoles sessile and attached to sheath or shortly petiolate and free or adnate to inside of sheath. Calyx 3.5-4.7 mm long, 1-1.5 mm wide, puberulous. Petals 5, 6-8 mm long. Stamens 6. Style 3-branched; stigmas linear. Ovules 5-7 on each of 3 parietal placentas. Seed papillose (Barnsley 1982).

The species epithet is from the Latin *conferta,* meaning closely compressed, or crowded, referring to the tightly bunched flowers of this species.

1.3 Distribution and habitat

Populations of *Frankenia conferta* are found in the northern Wheatbelt and southern Midwest regions of south-west Western Australia. Surveys from 2000 to 2003 have located nine populations in CALM's Merredin, Moora and Geraldton districts. Sites are localised and scattered within lake chains and major drainage lines within the Yarra Yarra, Ninghan and Avon catchments.

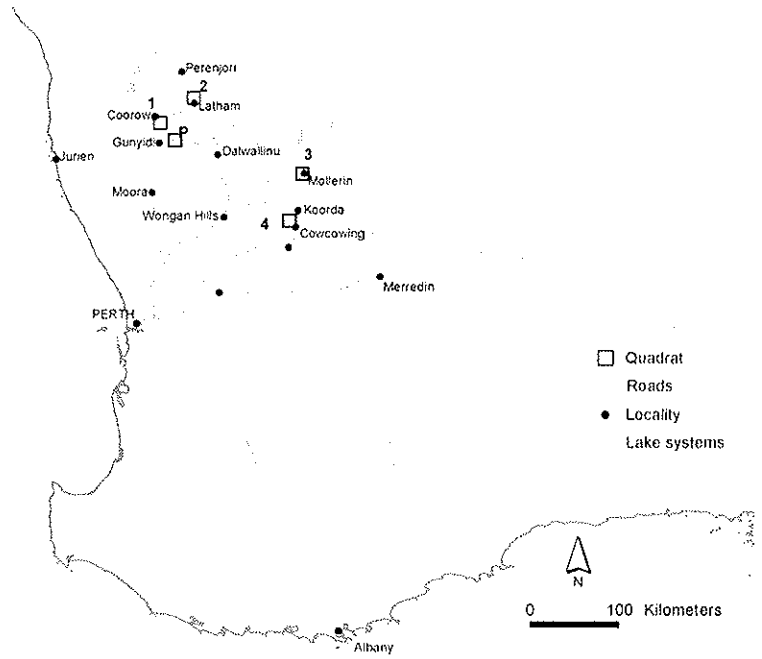
[1] Mike Lyons, Research Scientist, CALM Science Division

The preferred habitat for *Frankenia conferta* plants is around the high water mark of lake shorelines to the tops of low berms within saline pans. Plants also occur on the floor of major drainage lines within localised swales where they are subjected to seasonal inundation. Populations of *F. conferta* grow predominantly among other halophytic shrubs on clay sands with gypsum or white-grey shallow sand over clay. Associated plants include *Halosarcia* spp., *Atriplex holocarpa*, **Mesembryanthemum nodiflorum* and other ephemeral species (See site and quadrat descriptions pages 23-29).

Of the nine known populations, five were selected for long-term monitoring and collection of reproductive data. They occur over a 170 km range within the Shires of Perenjori, Coorow, Dalwallinu and Koorda between 150 to 280 km north and northeast of Perth (Figure 1). Population 2 grows on the shoreline of one of the lakes in Unallocated Crown Land (UCL) near the C class Gunyidi Nature Reserve (26575). Population 3 occurs within a localised swale within the drainage flats of the Cowcowing Lakes on Unallocated Crown Land (UCL). Plants in Populations 7 and 9 grow on low gypsiferous berms within small saline pans. Population 7 occurs within UCL surrounded by private property near the Latham townsite and Population 9 occurs within the C class Marchagee Nature Reserve (23601). Population 8 is located on the northern shoreline of Mollerin Lake near the border of Crown Reserve 21331 and the A class Mollerin Nature Reserve (14429).

Frankenia conferta plants in three of the study sites grow very close to or are being sheltered by samphires, perhaps receiving protection from grazing or trampling. These sites are close to farmland with inherent threats from land management practises and grazing.

Figure 1. Location of selected *Frankenia conferta* populations with established quadrats.



The Wheatbelt and Midwest regions have a dry Mediterranean climate with cool wet winters and hot dry summers. Weather data recorded at the nearest centres to the study sites were collated and are shown in the table below.

Table 1. Weather data recorded from the nearest centres to *Frankenia conferta* study sites.

Weather centre (*F. conferta* population)	Long-term mean annual rainfall (mm)	Total annual rainfall (mm). 5 year trend	Long-term mean temperatures

Dalwallinu (2, 7 & 9)	359.9	1999-672.4 2000-386 2001-346 2002-202.8 2003-316.7	Warmest month February Max – 34.5°C Min –18.5°C	Coolest month July Max - 17°C Min – 6.6°C
Kalannie (8)	313	1999-601.5 2000-389 2001-306.8 2002-180.4 2003-247.5	*January Max - 34.4°C Min - 17.8°C	*July Max - 17°C Min - 6.7°C
Koorda (3)	297.9	1999-502.7 2000-314.1 2001-232.2 2002-173.3 2003-277.1	*as per above	

*Temperature data from Wongan Hills centre was used as no temperature data is recorded at Kalannie or Koorda centres.

Rainfall is predominantly between May and September, although some rainfall recordings were consistently made in all of the above centres during the summer months. Total annual rainfall in 1999 in all centres was the highest recorded for all years since monitoring began. Lower than average rainfall was recorded in all centres between then and 2002.

Fire has not been recorded in the areas where populations of *Frankenia conferta* occur and satellite imagery available since 1985 did not show burns within nearby Nature Reserves.

2.0 REPORT OBJECTIVE AND OUTLINE

The *in-situ* conservation of rare and threatened plant species is contingent upon firstly, detecting changes in population size or condition, secondly, determining the causes of changes and thirdly, in the case of population decline implementing actions that will reverse the trend.

The aims of this project are to establish for *Frankenia conferta* a quantitative monitoring framework and data baseline to obtain information on populations and species growth characteristics and for detecting changes in population abundance, health, life stage structure and reproductive potential.

This report presents data on the characteristics of *Frankenia conferta* populations that will serve as a baseline for detecting change and determining whether management of the populations is meeting conservation objectives.

3.0 METHODS

Known populations of *Frankenia conferta* that were deemed easily accessible and those at geographical extremities were selected for long-term monitoring. Time constraints for the project did not enable the assessment of all populations prior to selection; therefore study sites were established as each population was visited.

3.1 Population details

The project involved:

1. Establishing permanently marked quadrats (5 x 5 m) within five separate populations.
2. Permanently labelling at least 100 *Frankenia conferta* plants for long-term monitoring.
3. Assessing canopy dimensions of each labelled plant by measuring width at the widest diameter and at 90° to the widest diameter.
4. Assessing the health and vigour of each plant by estimating the percentage of live canopy.
5. Counting the total number of inflorescences on each *F. conferta* plant labelled.
6. Recording life-stage classification of each plant assessed ie. mature or juvenile (juvenile plants are those <10 cm high and <5 x 5 cm widths and non-flowering).

7. Recording other ecological and biological observations relevant to *F. conferta* populations that will assist in management of the species.

A subset of 131 plants throughout five study sites was permanently identified for monitoring with labelled wire stakes placed into the ground adjacent to each one. The first site was established at Population 2 (Gunyidi) on the 5th of November 2003. Quadrats 1 and 2 were established within Populations 9 (Marchagee) and 7 (Latham) on the 6th of November, and Quadrats 3 and 4 were established within Populations 8 (Mollerin) and 3 (Cowcowing) on the 14th of November 2003.

Frankenia conferta plants at Gunyidi, the first site visited, were growing too widely apart to establish a 5 x 5 m quadrat that would contain more than a few plants. Therefore, as there were only a small number of plants within the population and it was unknown if all other populations were similar, the decision was made to label and monitor the entire population. However, when other populations were visited they were found to contain greater densities of plants and quadrats were established. Throughout the report, the Gunyidi population is referred to as Population 2 (Gunyidi), while the remaining four study sites are referred to by their quadrat number and name (Figure 1). Three of the *F. conferta* quadrats are located next to floristic survey sites established during the Wheatbelt Survey by Mike Lyons in 2000.

All plants within Population 2 (Gunyidi) and Quadrats 1 and 2 were labelled. However, as plant density was markedly higher at Populations 8 (Mollerin) and 3 (Cowcowing), a subset of 30 plants in quadrats (3 and 4) were labelled. Total plant numbers exceeded the 100 needed for the study. Plant characteristics were assessed at the time of quadrat establishment (Table 11).

Characteristics of each quadrat were also recorded at the time of establishment and are detailed in Appendix 1. Characteristics include: soil descriptions, plant community classification according to Muir (1977), estimation of percentage cover of each strata including bare ground (Table 10) and location descriptions. The method of percentage cover estimation uses that of Keighery (1994). Associated species in all quadrats and occasional plants common to each site were also noted. Samples of unknown species were collected and identified at the Western Australian Herbarium.

Photographs (transparencies are lodged with WATSCU) were taken of all study sites to monitor change (Figures 8-12). GPS readings were also taken at all populations and quadrats and at all landmarks considered relevant for the relocation of the populations for long-term monitoring (Table 12).

3.2 Plant size and vigour

Measurements taken to assess the size and vigour of the 131 labelled plants were:
1. Height.
2. Width of the canopy at the widest point and the width at 90° to the widest point.
3. Percentage of live canopy.

Canopy area for each plant was calculated using the equation for an ellipse (long axis x short axis x 0.7854). Results were graphed using canopy area size classes of 0-5, 5-10, 10-20, 20-40, 40-60 and >60 m^2, which allows for adequate viewing of the size distribution over all study sites (Figure 2). Then the number of plants within each of the size classes that had 0, 1-25, 26-50, 51-75, 76-99 and 100% live canopy were calculated (Figure 3).

Plants that exhibited signs of stress were recorded on the field data forms and numbers tabled in results under 4.3 (Table 4). Signs of stress include:
1. Partial canopy death (plants within the 51-75% live canopy or less)
2. Obvious damage to plant from, for example, insects or other animals
3. Vegetation colour changes eg. Chlorosis

Frankenia conferta grows as discrete shrubs at Populations 2, 7 and 9 and as mat forming plants at Populations 3 and 8 (Figure 6). The mat forming plants were separated for labelling by determining the perimeter of each clump by shallow excavation to exclude further stem production.

Photographs were taken showing growth habit and root structure and also of stressed and healthy plants for future comparison (Figures 4, 5 and 6).

3.3 Reproductive characteristics

Reproductive characteristics were investigated over a single flowering season in 2003. It was impractical and damaging to permanently label stems or inflorescences on each plant due to their small size, fine multiple stems and in some populations mat-forming growth habit. Therefore, reproductive potential of *Frankenia conferta* plants was assessed by:

1. Identifying 10 plants within each study site for flower and fruit monitoring. The first five and the last five labelled plants were selected for randomness throughout each site.
2. Counting flowers per inflorescence for 10% of the total inflorescences on each plant. Up to a maximum of 20 inflorescences. (eg. plant number 3 at Gunyidi has 133 inflorescences, therefore 13 inflorescences have the flowers counted, whereas plant number 32 at Marchagee has 210 inflorescences with 20 of them assessed for flower production).
3. Counting fruits per inflorescence in the same manner as the flowers.
4. Collecting fruits for assessment of seed production.

Inflorescences were counted at quadrat establishment in early November and again in December 2003. Fruits were counted and collected on the 8th and 22nd of December 2003. Collections from each plant were stored separately and the seeds counted under a stereo a microscope. An assessment of viable seeds per fruit was made (Table 7). Seed viability was assessed by their size, form and firmness, as they were too small to cut. Wrinkled and flat seeds were considered unviable.

Another reproductive characteristic noted for *Frankenia conferta* was that on close inspection, stem and root arrangement suggested clonal reproduction. In order to verify this a plant at Population 8 (Mollerin) and a plant at Population 9 (Marchagee) were excavated to determine whether underground connections existed.

Also, a distinctive pattern of juvenile recruitment was observed within Population 9 (Marchagee), where a large number of juveniles (recently germinated seedlings) were found to occur around the perimeter of dead adult plants. This was not repeated at any of the other sites but was considered to be reproductively significant. Therefore, seedlings were counted and recorded separately (Table 5) for future comparison.

The mean number of flowers and fruits per inflorescence and the total number of flowers and fruits per plant for each population were then calculated (Tables 6 and 7).

3.4 Soil characteristics

Descriptions of surface soil were recorded at the time of plant assessment and soil samples were taken to analyse the salinity, pH and gypsum content on the 13th and 14th of November and the 9th of December 2003. The samples were taken at root zone depth (10-12 cms) from each corner and in the centre of Quadrats 1-4 and Population 2 using a 5 cm diameter augur. Soil from each hole was placed in labelled press lock plastic bags for transport and then stored in open bags under cover to air dry. Testing was undertaken at the CALM's research laboratory in Kensington.

Electrical conductivity (EC) and pH tests were undertaken after the samples were amalgamated for each site and then oven dried at 40°C for three days. Dried soil aggregates were broken down and passed through a 2 mm sieve then particles 2 mm or less were reduced in volume to approximately 250 ml by repeated cone and quarter method (Table 9). Further analysis to determine the percentage of gypsum in the soil was undertaken on sub-samples dried at 105°C and based on initial formation of precipitate indicating the presence of gypsum.

4.0 RESULTS AND DISCUSSION

4.1 Population size

Surveys carried out in spring of 2003 by Diana Papenfus[2] located new populations of *Frankenia conferta* (Papenfus 2004). Accurate counts of plant numbers were difficult to determine in the populations where vegetative recruitment was more obvious. Known plant numbers have increased substantially as a result of the 2003 search, however further detailed survey of each population needs to be undertaken to obtain definite numbers. Populations and plant numbers are presented in Table 2 below.

Table 2 Details of *Frankenia conferta* populations surveyed since 2000.

Population No. & (study site location)	Number of plants	Population condition
1. NW of Ballidu	50	Healthy
	76	Healthy
2. SW of Koorda – (Gunyidi)	200+	Healthy
3. SW of Koorda – (Cowcowing)	95+	Healthy
4. N of Kalannie	100+	Moderate
5. E of Kalannie	1000+	Healthy
6a. E of Kalannie	100+	Healthy
6b. E of Kalannie	100+	Healthy
7. NW of Latham – (Latham)	38	Healthy
8. W of Burakin – (Mollerin)	Not counted	Healthy
9. Marchagee	650	Moderate

4.2 Size class structure and plant health

The distribution of *Frankenia conferta* plants across size classes throughout the five study sites were skewed to the lower canopy area size classes with 83.2% measuring below 1m^2. Plants occurring within the middle and larger size classes were predominantly from Quadrats 3 (Mollerin) and 4 (Cowcowing) (Figure 2). Higher numbers of mat-forming plants were recorded at these sites. Heights ranged from 3-29 cm with the average height being 11.14 cm overall.
The total and mean canopy areas for each site are detailed in Table 3.

Figure 2. The distribution of *Frankenia conferta* plants across canopy area size classes for the five study sites.

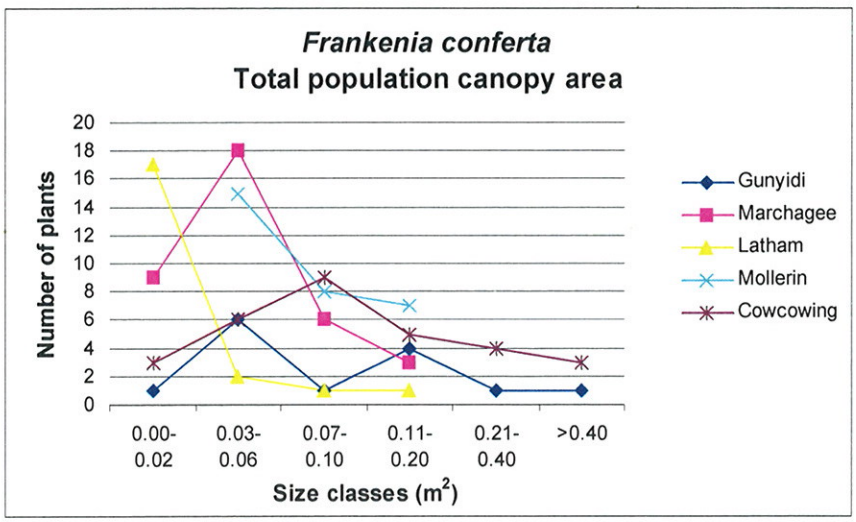


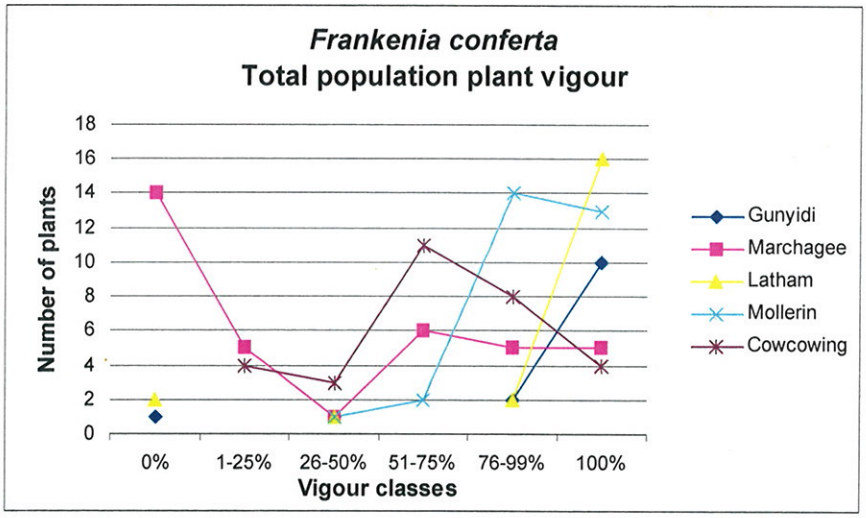
Table 3. Total and mean canopy areas of *Frankenia conferta* for the five study sites.

[2] Diana Papenfus, former Project Officer, CALM

Site/Quadrat	Total canopy area m^2	Mean canopy area m^2
Gunyidi	1.72	0.12
Marchagee/1	1.83	0.05
Latham/2	0.45	0.02
Mollerin/3	2.56	0.09
Cowcowing/4	4.88	0.16

The vigour of plants over all size classes also varied with 36.6% of plants having 100% live canopies. Conversely, 12.9% of all monitored plants were dead with 10.6% occurring within Quadrat 1 (Marchagee) (Figure 3).

Figure 3. The distribution of *Frankenia conferta* plants across vigour classes for the five study sites.



Plants in Quadrat 1 (Marchagee) showed signs of serious decline with many stressed or dead adults and juveniles within the quadrat and throughout the population as a whole. Many dead and stressed plants were also recorded for Quadrat 2 (Latham). Sixty percent of *Frankenia conferta* plants within Quadrat 4 (Cowcowing) had partial canopy deaths (51-75% live canopy vigour class or less) (Table 4). Within this population larger mat-forming shrubs were found that often had dead portions in the centre (Figure 5). The live sections of the canopies appeared healthy.

Table 4. Percentage of stressed and dead *Frankenia conferta* plants within Quadrats 1-4 and Population 2 as at 14th November 2003.

Site/Quadrat	Stressed plants (51-75% or less live canopy)	Dead plants
Gunyidi	14.2%	7.1%
Marchagee/1	41.6%	38.8%
Latham/2	23.8%	38%
Mollerin/3	10%	0%
Cowcowing/4	60%	3.3%

Plants recorded as stressed with mat-forming growth habits within Quadrats 3 (Mollerin) and 4 (Cowcowing) only showed part death of canopies, whereas the entire plant exhibited stress in Quadrats where shrub growth habits were recorded (Figure 4).

Figure 4. Stressed mat-forming *Frankenia conferta* plant from Quadrat 4 (Cowcowing).

Table 5. Number of *Frankenia conferta* juveniles recorded within Quadrats 1-4 and Population 2 as at 14th November 2003.

Site/Quadrat	Number of juveniles within Quadrats
Gunyidi	0
Marchagee/1	990
Latham/2	9
Mollerin/3	67
Cowcowing/4	5

The reason for the high number of juveniles recorded within Quadrat 1 is unknown, however a large proportion of the plants surveyed were dead (38.8%) or showing signs of stress (41.6%) (Table 4). Rainfall data obtained from the nearest weather station of Dalwallinu (~80 km east), recorded an annual average rainfall in 2002 of 202.8 mm, 157.1 mm below the long-term average. In 2003 rainfall increased and was recorded as only 43.2 mm below the long-term average. Such an increase in rainfall between the years may have produced a beneficial inundation of fresh water to enable seed germination and subsequent growth.

4.3 Population dynamics

Plant community structure in the habitat of *Frankenia conferta* was recorded as Open Dwarf Scrub D at Populations 2, 7 and 9 (Gunyidi, Marchagee and Latham), and Open to Very Open Mat Plants at Populations 3 and 8 (Mollerin and Cowcowing Lakes) (Muir 1977).

Populations of *Frankenia conferta* occur in fragmented, specialised habitats of saline soils and gypsum content, through the northern wheatbelt area where drainage channels occur. Correlations between population health, fragmentation, plant abundance and rainfall were not investigated within this study. Numbers of individuals within populations vary from 38 to 1000. Smaller sized populations may have limited variability with a smaller gene pool therefore, resulting in less tolerance to various stresses and threats. Losses of any plants within smaller populations could cause irreversible population decreases.

Excavations of two plants from Populations 2 (Marchagee) and 8 (Mollerin) showed that adult plants proliferate by producing adventitious roots that grow horizontally just under the soil surface (Figure 5). Such roots are placed for maximum benefit from fresh water (Kingsley Dixon[3] *pers. comm.)*, which enhance the ability of the plants to recruit vegetatively. *Frankenia conferta* plants appear to have annual and perennial parts of the root system with recruitment happening from perennial parts. It shows signs of replenishing nutrient reserves in these storage organs (Mark Brundrett[4] *pers. comm.)*.

[3] Kingsley Dixon, Assistant Director (Plant Science) Kings Park, Botanical Garden and Parks Authority.
[4] Mark Brundrett, Research Scientist (Plant Science) Kings Park, Botanical Garden and Parks Authority.

Figure 5. Adventitious roots on *Frankenia conferta.*

Clonal recruitment was more obvious as occurring in Quadrats 3 (Mollerin) and 4 (Cowcowing) with the growth habit recorded as mat forming groundcovers (Figure 6b). Studies undertaken by (Pereira and Kozlowski 1977) on plant responses to environmental stresses, found that in woody angiosperms, alterations in root and stem morphology and the production of adventitious roots follow stomatal closure in the responses to flooding. These adaptations to continuing environmental stresses develop relatively slowly. Although *Frankenia conferta* plants can recruit vegetatively and grow within winter wet areas the response to prolonged inundation is unknown.

Figure 6. Growth habits of *Frankenia conferta* plants.

(a) Discrete shrub at Population 2 (Gunyidi).

(b) Mat-forming plant at Population 8 (Mollerin).

Storage organs such as adventitious roots, which grow perennially, have greater flexibility in the economy of carbon when, during prolonged periods of adverse conditions, the plant can utilize the reserves of the same organs to establish new growth. This is significant if little or no photosynthetic gain has been made in a particular season as may occur when plants are subjected to grazing (Pate and Dixon 1982). Rabbit scats were observed within Quadrat 4 (Mollerin) and the wider population.

There have been no records kept of fires for the areas or reserves where *Frankenia conferta* populations are located, however it is unlikely that hot or frequents fires would occur within the plants habitat.

Clonal spread by vegetative means appears to dominate noticeably over the recruitment of *Frankenia conferta* plants from seed, with the exception of Population 9 (Marchagee). Multiple sized plants and life stages, non-reproductive juveniles and reproductive adults, were observed in all populations except Population 2 (Gunyidi). Between 5 and 990 seedlings were recorded as occurring within Quadrats 1-4 (Table 5).

4.4 Inflorescence, fruit and seed production

Peak flowering production occurred in November with fruits maturing from mid to late December 2003. *Frankenia conferta* plants have cymose inflorescences made up of dichasia, which occur when both axillary shoots below the terminal flower of the cyme develop. This process results in an arrangement where three branches develop with terminating flowers. For the purposes of this study each terminating arrangement of flowers was counted as a single inflorescence. This method was adopted when it was noticed that some inflorescences on each plant had not developed into a dichasium but remained simple.

The mean number of flowers and fruits per inflorescence for each monitoring site was calculated and the total number of flowers for each plant was determined using the formula: *Total number of flowers = mean number of flowers per inflorescence x inflorescences per plant* (Tables 6 and 7). Flowers per inflorescence ranged from 1-10.

The total number of inflorescences per plant counted for 131 permanently labelled plants within Quadrats 1-4 and Population 2 ranged from 0-270. Ten live adult plants did not produce any inflorescences and 17 were dead.

Table 6. Mean number of *Frankenia conferta* flowers and fruits per inflorescence.

Site/Quadrat	Mean no. of flowers per inflorescence ± SE	Mean no. of fruits per inflorescence ± SE	Total no. of flowers/plant ± SE	Total no. of fruits/plant ± SE
Gunyidi	3.96 ± 0.70	4.77 ± 0.92	404.60 ± 79.08	542.27 ± 123.69
Marchagee/1	1.23 ± 0.52	1.59 ± 0.66	119.74 ± 84.24	170.87 ± 115.93
Latham/2	1.56 ± 0.54	2.25 ± 0.78	71.39 ± 34.36	114.21 ± 55.58
Mollerin/3	3.40 ± 0.43	4.46 ± 0.57	186.41 ± 87.36	306.59 ± 142.60
Cowcowing/4	1.62 ± 0.39	2.10 ±0.54	43.81 ± 16.26	82.79 ± 31.58

Each *Frankenia conferta* flower may form one fruit that can produce many seeds. Results of flower and fruit analysis show a higher fruit to flower ratio. This is because random inflorescences were counted when monitoring sites were established and a different random set counted when fruits were collected, which resulted in more fruits being recorded than inflorescences.

Flowers of *Frankenia conferta* plants are not self-pollinating due to the different maturation times for stigmas and anthers, however no specific pollinators were observed on flowers at any of the monitoring sites. Caterpillars that encased themselves into webs woven around inflorescences were recorded at three sites. Ants were also present and active within populations.

Results showed a variable relationship between plant canopy area and inflorescences per plant for each monitoring site. While populations with larger total canopy areas recorded high numbers of inflorescences it was not consistent. Plants within Quadrat 4 (Cowcowing) have the largest total canopy area of 4.88 m^2, which produced 1383 inflorescences, while Quadrat 2 (Latham) plants, which have the smallest canopy area of 0.45m^2 produced 974 inflorescences. The highest number of inflorescences (2115) was produced by plants within Quadrat 3 (Mollerin), from a total canopy area of 2.56 m^2. Mean inflorescence density for all sites ranged from 0.03-0.15/m^2.

There was not a peak flowering time observed throughout all *Frankenia conferta* monitoring sites, but more an ongoing inflorescence production and fruit maturation. This may explain why the fruit numbers were higher than the inflorescences for the times of monitoring and the variable inflorescences per plant canopy relationship.

The proportion of *Frankenia conferta* fruits that produced viable seed over the five monitoring sites was 24.9%. Results varied between sites with plants in Quadrat 1 (Marchagee) having the highest amount of 44.9%, and plants in Population 2 (Gunyidi) and Quadrat 3 (Mollerin) having the least with 10% and

11% respectively. The total seed production for each site is shown in Table 7 below. Mean fruit set over the total population was 28.5%.

Table 7. Total number of *Frankenia conferta* collected fruit, viable seeds and total amount of seed produced for each monitoring site – December 2003.

Site/Quadrat	Total fruits collected	No. of fruits with viable seed	Total seed produced	% viable seed
Gunyidi	1922	194	3136	25.06
Marchagee/1	403	181	1026	90.55
Latham/2	497	96	499	87.17
Mollerin/3	1001	111	555	59.10
Cowcowing/4	249	98	627	66.83

Predation of flower calyces and mature fruits was observed within three of the *Frankenia conferta* populations (Table 8). Weevils were found to occur within some fruits collected for seed analysis. Webbing around inflorescences that contained caterpillars was also recorded. The effects of predation by weevils and the relationship between the caterpillars and fruit and seed production is unclear. Caterpillars are the larval stage of the order Lepidoptera (moths and butterflies) and are known nectar feeders and plant pollinators. Identification of the caterpillar and weevil to species level has not been undertaken. In a revision of *Frankenia* spp., Whalen (1980) observed considerable predation of Frankenia flowers by moth larvae, which also were not determined to species level.

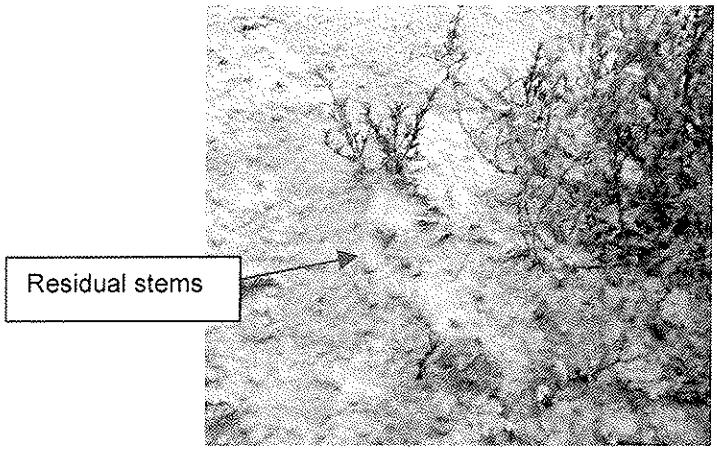
Table 8. Percentage of *Frankenia conferta* fruits collected with seeds and the percentage of fruits that were buds, empty, immature or predated.

Site/Quadrat	% fruit with seed/plant	% fruit as buds/plant	% immature fruit/plant	% empty fruit/plant	% predated fruit/plant
Gunyidi	19.67	9.16	0.05	39.13	32
Marchagee/1	45.66	0.25	0	49.88	4.22
Latham/2	20.12	4.63	4.63	57.75	12.88
Mollerin/3	13.39	13.49	0.50	54.05	18.58
Cowcowing/4	43.78	5.62	0	42.97	7.63

The relationship between seed viability and germination for *Frankenia conferta* was not studied during this survey. Experiments undertaken by Whalen (1980) with *Frankenia johnstonii* recorded 88% germination within five to eight days. The species exhibited reduced germination at and above 1.1% salinity but when the seeds were soaked in a 3.4% saline solution for 30 days, then transferred to distilled water for one week 56% germination occurred. Juveniles of *F. conferta* were recorded at four populations (Table 5) with a mass recruitment occurring at Quadrat 1.

Investigations of soil stored seed was not possible within the time frame for this project, however observations of juvenile recruitment suggest that seeds are not immediately dehisced upon fruit maturity but are held until circumstances are favourable for germination. This may include the burial of retained inflorescences on lower stems during periods of inundation, which then allows the held seeds to germinate in such a pattern as was observed in Quadrat 1 (Marchagee) (Figure 7). The period of time that the seeds can be held for is not known and requires further research.

Figure 7. Recruitment of *Frankenia conferta* juveniles around stressed adult plant in Quadrat 1 (Marchagee).



Investigations into the reproductive biology of *Frankenia johnstonii* in Texas U.S.A. by Whalen (1980), found that although the seeds are held in a hard semi-impermeable calyx tube (similar to *F. conferta),* they germinate readily after a few days exposure to fresh water. Whalen suggests that the hard calyx tube may encase the seeds until a strong rain can wash them from the fruits and also ensure enough soil moisture for early seedling growth, which is an important factor in a semi-arid climate. *F. johnstonii* also occurs in a saline scrub community with varying percentages of gypsum content.

4.5 Soil structure

Descriptions of the surface soil differed between populations with sand recorded for Quadrats 3 (Mollerin) and 4 (Cowcowing), and fine, light brown, beige to buff coloured sandy clay recorded for Quadrats 1 and 2 (Marchagee and Latham) and Population 2 (Gunyidi).

Table 9 below shows the results of electrical conductivity, pH and gypsum content analysis of the bulked soil samples for each site or quadrat. The gypsum content was determined only if there was an initial formation of precipitate indicating the presence of gypsum.

Table 9. Results of soil analysis for salinity, pH and gypsum content from *Frankenia conferta* study sites – 2004.

Site/Quadrat	pH (H_20)	pH (CaC_{12})	Salinity (mSm^{-1})	Gypsum (%)
Gunyidi	7.57	7.18	1233	0 (no precipitate)
Marchagee/1	8.08	7.99	1413	9.37
Latham/2	8.37	8.35	1770	9.9
Mollerin/3	7.73	6.90	277	0 (no precipitate)
Cowcowing/4	7.30	6.59	107.2	0 (no precipitate)

All samples were taken in November and December 2003. It is probable that the salinity readings will increase before the next winter rainfall occurs. The relationship between salinity, pH and the decline in health of the *Frankenia conferta* plants in Quadrats 1 and 2 is unknown. Results presented above serve as a baseline for comparison against any further research. Sites where Lyons located *Frankenia conferta* recorded salinity levels ranging from 20 to 975 mSm^{-1}. These samples were taken from early to late spring in 1999/2000.

Research on salinity levels of agricultural soils and water bodies utilised by livestock is readily available, however information on inland salt lakes and halophytic plants is limited.

Gypsum deposition and accumulation occurs within the Wheatbelt salt lakes in areas of sluggish drainage. It is not deposited in all salt lakes but is dependent on the local geology and hydrology. The types and amounts of gypsum precipitates vary from scattered, thin and impure deposits on lake-beds

to very pure (90-99%) deposits on wind formed dunes (Mattiske 1995). Soils were not analysed for the gypsum content within the Mattiske study but were mechanically assessed on the physical structure of the soils at each site. In the study, seven species of *Frankenia* were found to occur on gypsum soils, but only one was categorised as gypsophylic (ie. majority of sites at which they occurred had gypsiferous soils).

Below 10% gypsum content was recorded at Quadrat 1 and 2. Studies undertaken on the physical properties of gypsiferous soils in Iraq, by Smith and Robertson (1962), found that 3 to 10 percent of gypsum does not interfere significantly with soil characteristics such as structure, consistency and water holding capacity. As the gypsum content rises however, the continuity of the soil mass is broken by the gypsum crystals, and that soils with more than 25% gypsum do not provide a good medium for plant growth. These studies also have been undertaken within an agricultural perspective. Sites where Lyons located *Frankenia conferta* recorded gypsum contents ranging from 0 to 96%. These samples were taken from early to late spring in 1999/2000.

4.6 Relocation information

Table 12 details all GPS readings taken in and around the *Frankenia conferta* populations. Waypoints in degrees, minutes and seconds using WGS 84 datum were recorded from all quadrats and at road intersections where necessary, to relocate sites.

4.7 Associated vegetation

Associated species growing within Quadrats 1-4 and at the site of Population 2 were recorded. Samples of unknown species were collected and identified using voucher specimens lodged at the Western Australian Herbarium and by enlisting the aid of Mike Lyons, Paul Wilson[5] for Chenopodiaceae and Asteraceae specimens, Frank Obbens[6] for *Calandrinia* sp. and Rob Davis[7] and Mike Hislop[8] for confirmation of preliminary identifications.

Species collected for each location are provided in Appendix 1 under Site and Quadrat Descriptions. A total of 26 taxa from 10 families and 18 genera were recorded for all five study sites. The most species diverse families were Chenopodiaceae (8 taxa) and Asteraceae (6 taxa). Two weed species were recorded from the families Poaceae and Aizoaceae and are identified within the species lists with an asterisk. They occurred in low numbers and are therefore not considered to be a threat to the *Frankenia conferta* populations.

Frankenia conferta grows within vegetation communities of Open Dwarf Scrub D and Open to Very Open Mat Plants (Muir 1977) in close association with halophytes, predominantly *Halosarcia* spp., and a few perennial and ephemeral species. At the time of establishment some annual species had senesced and were therefore unable to be identified. These were recorded under dead shrubs/litter in cover percentages, which are detailed in Table 10 below.

Cover of *Frankenia conferta* plants was highest in Quadrats 4 and 5 where the plants appeared to exhibit more clonal recruitment via mat forming growth habits. Native plant coverage was highest within Population 2 where the *F. conferta* plants were growing within the canopies of *Halosarcia* spp. Quadrat 1 recorded the barest ground of 90%. The condition of plants within this quadrat was Poor with a large number of mature and juvenile plants recorded as stressed and dead. The soil surface was also salt encrusted.

Table 10. Percentage cover of *Frankenia conferta,* native plants, weeds, dead shrubs/litter and bare ground within Quadrats 1-4 and Population 2- November 2003.

[5] Paul Wilson, Contract Consultant, Western Australian Herbarium
[6] Frank Obbens, Consultant and Volunteer, Western Australian Herbarium
[7] Rob Davis, Technical Officer, Western Australian Herbarium
[8] Mike Hislop, Contract Consultant, Western Australian Herbarium

Site/Quadrat	Number of tagged *F. conferta* plants	COVER %				
	(+untagged juveniles and mature plants)	*F. conferta*	Native plants	Weeds	Dead shrubs/litter	Bare ground
Gunyidi	14	<1	<50	0.5	<2	>50
Marchagee/1	36 (+ 990J)	1.5	8	0.5	0	90
Latham/2	21 (+ 9J)	1	20	0	5	73
Mollerin/3	30 (+ 111M & 67J)	25	3	0	2	70
Cowcowing/4	30 (+ 10M & 1J)	7	15	0.2	5	73

5.0 CONCLUSIONS

This project established a quadrat based monitoring framework for *Frankenia conferta*.

1. Recent surveys have increased the number of known *F. conferta* populations.
2. Smaller sized populations may have limited variability with a smaller gene pool, resulting in less tolerance to various stresses and threats. Losses of any plants within smaller populations could cause irreversible population decreases.
3. Regular monitoring using the framework established by this project is necessary to quantify population trends and verify that some populations may be in decline (namely Populations 7 and 9).
4. A high proportion of plants from lower size classes were also in low vigour classes, the reasons for this are unknown.
5. The high number of juveniles present in one population suggests that recruitment of plants may be associated with episodic events. Further monitoring to determine the survival rate of the seedlings is recommended.
6. The greater proportion of plants (78.6%) produced flowers but fruit set was low. Viable seed production was also low with a high proportion of empty and predated fruits. Reasons for these results are unknown, and as a consequence the reproductive potential of the population cannot be assessed without further monitoring.
7. The pattern of recruitment by seed of juveniles in clumps around adult plants along residual stems suggest that seeds are held in fruits on the plant for at least one season and are not immediately dehisced until conditions for germination are favourable.
8. *F. conferta* recruits both sexually and vegetatively. Clonal reproduction dominates in four of the five populations by the proliferation of plants from adventitious roots.
9. The production of adventitious roots on *F. conferta* plants is advantageous for survival through unfavourable seasons, however the effects of prolonged inundation, rising salinity levels and drought are unknown.
10. Soil analysis undertaken within this project to provide a baseline needs to be repeated during differing seasons to more adequately assess the affect of salinity and pH on population condition.

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APPENDIX 1

Table 11. Plant dimensions (height, width at widest point and at 90°), percentage of live canopy, number of inflorescences per plant and life stage classification for *Frankenia conferta* – November 2003.

Population/ Quadrat number	Plant number	Height (cm)	Width @ widest point (cm)	Width @ 90deg (cm)	% Live canopy	Number of inflorescences	Mature (M) or Dead (D) plants
2	1	12	14	9	90	0	M
	2	17	25	20	100	70	M
	3	15	25	18	100	133	M
	4	9	60	38	30	72	M
	5	5	97	65	0	0	D
	6	14	48	41	100	99	M
	7	19	54	49	100	270	M
	8	19	54	46	100	234	M
	9	19	34	15	100	39	M
	10	17	20	16	100	127	M
	11	18	30	30	100	134	M
	12	20	63	33	80	140	M
	13	17	20	28	100	110	M
	14	20	30	24	100	56	M
9/1	1	11	21	20	60	15	M
	2	10	23	20	0	0	D
	3	7	19	14	0	0	D
	4	12	25	22	0	0	D
	5	19	41	26	0	0	D
	6	12	30	23	70	52	M
	7	13	28	27	70	5	M
	8	15	38	18	2	2	M
	9	9	24	23	0	0	D
	10	8	20	16	0	0	D
	11	11	26	23	0	0	D
	12	7	18	17	0	0	D
	13	8	20	18	0	0	D
	14	7	11	5	100	8	M
	15	14	33	30	85	97	M
	16	13	41	32	0	0	D
	17	10	9	8	0	0	D
	18	13	36	27	0	0	D
	19	15	46	35	40	80	M
	20	12	22	14	90	21	M
	21	11	26	19	100	75	M
	22	12	22	21	98	78	M
	23	11	34	23	70	41	M
	24	13	7	24	10	63	M
	25	11	20	20	60	16	M
	26	13	27	20	10	5	M
	27	10	15	7	100	3	M

Population/ Quadrat number	Plant number	Height (cm)	Width @ widest point (cm)	Width @ 90deg (cm)	% Live canopy	Number of inflorescences	Mature (M) or Dead (D) plants
9/1	28	12	39	34	5	17	M
	29	8	10	6	100	1	M
	30	13	23	22	80	0	M
	31	12	26	22	0	0	D
	32	16	42	41	90	210	M
	33	15	47	46	65	146	M
	34	12	39	29	10	6	M
	35	9	10	7	100	0	M
	36	13	25	19	0	0	D
7/2	1	14	18	9	100	52	M
	2	5	6	5	0	0	D
	3	9	9	4	100	0	M
	4	8	13	7	100	0	M
	5	10	18	12	90	0	M
	6	13	14	12	100	1	M
	7	20	35	25	95	102	M
	8	11	14	11	100	10	M
	9	29	44	33	100	600	M
	10	11	13	10	100	3	M
	11	9	13	10	100	5	M
	12	8	14	10	100	11	M
	13	7	14	7	100	3	M
	14	8	7	7	100	0	M
	15	9	14	14	100	15	M
	16	22	29	12	100	8	M
	17	12	23	10	0	0	D
	18	8	17	14	100	39	M
	19	10	25	24	50	15	M
	20	11	18	16	100	94	M
	21	13	11	9	100	16	M
8/3	1	10	31	25	100	210	M
	2	8	31	26	80	35	M
	3	9	30	26	85	15	M
	4	10	60	28	90	125	M
	5	10	52	46	70	42	M
	6	9	36	33	80	155	M
	7	12	46	42	80	240	M
	8	11	58	45	98	180	M
	9	10	38	20	85	210	M
	10	9	56	37	95	220	M
	11	11	43	30	85	110	M
	12	10	46	42	50	40	M
	13	6	27	17	98	62	M
	14	9	50	41	95	10	M
8/3	15	5	20	18	100	58	M
	16	6	39	30	98	35	M

Population/ Quadrat number	Plant number	Height (cm)	Width @ widest point (cm)	Width @ 90deg (cm)	% Live canopy	Number of inflorescences	Mature (M) or Dead (D) plants
	17	5	18	18	100	15	M
	18	12	39	29	90	180	M
	19	5	34	30	100	14	M
	20	6	22	19	98	0	M
	21	5	25	21	100	20	M
	22	7	30	25	100	9	M
	23	5	31	31	100	15	M
	24	4	38	32	100	27	M
	25	5	26	22	100	32	M
	26	3	20	19	100	1	M
	27	5	37	32	100	5	M
	28	5	26	24	100	39	M
	29	4	26	20	100	4	M
	30	5	29	25	60	7	M
3/4	1	8	15	11	60	0	M
	2	10	26	24	80	33	M
	3	9	25	13	10	0	M
	4	7	36	29	75	52	M
	5	7	26	11	60	7	M
	6	10	38	30	100	25	M
	7	8	39	30	60	27	M
	8	11	52	33	60	98	M
	9	8	42	23	80	4	M
	10	9	56	32	30	39	M
	11	11	44	33	50	23	M
	12	11	55	43	75	71	M
	13	12	98	76	60	175	M
	14	6	23	17	85	7	M
	15	15	68	65	80	13	M
	16	11	68	62	55	47	M
	17	12	37	28	85	25	M
	18	12	97	35	60	117	M
	19	8	33	26	75	27	M
	20	10	28	17	100	12	M
	21	8	32	23	98	23	M
	22	7	19	11	100	16	M
	23	10	52	40	25	17	M
	24	12	117	72	60	270	M
	25	12	104	67	80	180	M
	26	9	35	24	100	33	M
	27	7	76	40	30	32	M
	28	8	80	35	20	5	M
	29	4	42	23	20	0	M
	30	5	34	23	98	5	M

SITE AND QUADRAT DESCRIPTIONS

POPULATION 2
NB-LOCATIONAL INFORMATION IS CONFIDENTIAL – NOT FOR PUBLICATION

SITE 1 – GUNYIDI AREA: ~52m^2

DATE ESTABLISHED: 5/11/2003

LOCATION: On east edge of minor salt lake ~ intersection.

SOIL: Fine gypsiferous sand over fine sandy clay.

COVER: Frankenia - <1%
Native plants - <50%
Weeds – 0%
Bare ground - >50%
Dead shrubs/litter - <2%

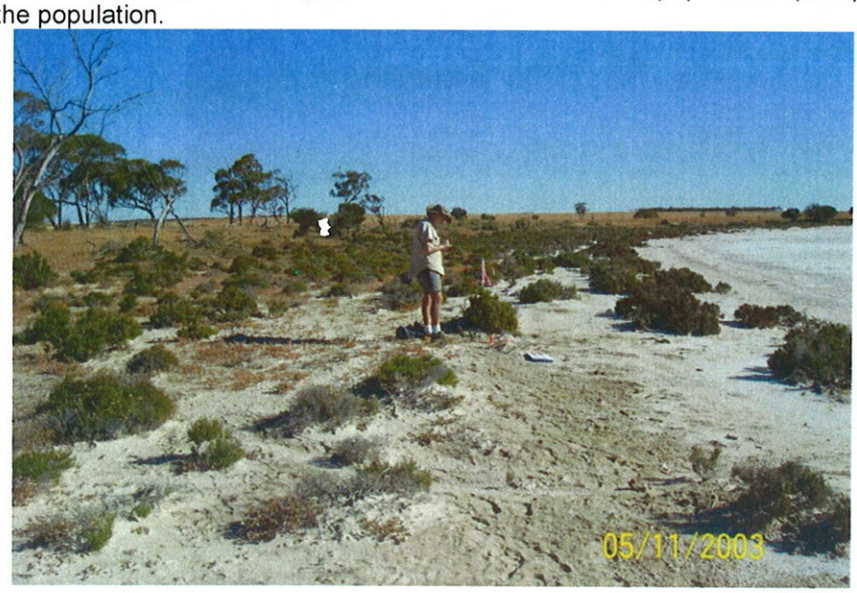
PLANT COMMUNITY CLASSIFICATION (Muir 1977): Open Dwarf Scrub D.

NUMBER OF FRANKENIA PLANTS: 14

CONDITION: Healthy

ASSOCIATED SPECIES AT SITE:
**Parapholis incurva*
**Mesembryanthemum nodiflorum*
Calandrinia aff. *polyandra*
Halosarcia fimbriata
Halosarcia peltata
Waitzia acuminata

Figure 8. Population 2 at Gunyidi. Photograph taken from north side of population. (The peg represents the centre of the population.



POPULATION 3
NB-LOCATIONAL INFORMATION IS CONFIDENTIAL – NOT FOR PUBLICATION

QUADRAT 1 – MARCHAGEE AREA: 5 x 5 m
$25m^2$

DATE ESTABLISHED: 6/11/2003

LOCATION: In the Marchagee Nature Reserve.

SOIL: Buff-coloured gypsiferous soil at surface over clay. Salt encrusted.

COVER: Frankenia – 1.5%
Native plants - 8%
Weeds –0%
Bare ground – 90.5%

PLANT COMMUNITY CLASSIFICATION (Muir 1977): Open Dwarf Scrub D.

NUMBER OF FRANKENIA PLANTS: 36 (990 juveniles extra counted within the quadrat)

CONDITION: Poor

ASSOCIATED SPECIES IN QUADRAT:
**Parapholis incurva*
**Mesembryanthemum nodiflorum*
Calandrinia aff. *polyandra*
Halosarcia peltata
Triglochin mucronata

COMMON SPECIES IN AREA:
Grevillea biformis

Figure 9. Quadrat 1 established within Population 1 north of Marchagee townsite. Photograph taken from northeast corner of quadrat – 12/12/04.

POPULATION 4
NB-LOCATIONAL INFORMATION IS CONFIDENTIAL – NOT FOR PUBLICATION

QUADRAT 2 – LATHAM

AREA: 5 x 5 m
$25m^2$

DATE ESTABLISHED: 6/11/2003

LOCATION: In the Marchagee Nature Reserve.

SOIL: Buff-coloured gypsiferous soil at surface over clay.

COVER: Frankenia - 1%
Native plants - 20%
Weeds – 0%
Bare ground - 73%
Dead shrubs/litter – 5%

PLANT COMMUNITY CLASSIFICATION (Muir 1977): Open Dwarf Scrub D.

NUMBER OF FRANKENIA PLANTS: 21 (9 juveniles extra counted within the quadrat)

CONDITION: Moderate - Poor

ASSOCIATED SPECIES IN QUADRAT:
Halosarcia doleiformis
Halosarcia halocnemoides

Figure 10. Quadrat 2 established within Population 7 south-east of Latham townsite. Photograph taken from southeast corner of quadrat.

POPULATION 5
NB-LOCATIONAL INFORMATION IS CONFIDENTIAL – NOT FOR PUBLICATION

QUADRAT 3 – MOLLERIN LAKE AREA: 5 x 5 m
$25m^2$

DATE ESTABLISHED: 14/11/2003

LOCATION: Mollerin Lake, at the end of a track that runs south from

SOIL: White sand.

COVER: Frankenia – 25%
Native plants - 3%
Weeds –0%
Bare ground – 70%
Dead shrubs/litter – 2%

PLANT COMMUNITY CLASSIFICATION (Muir1977): Open to Very Open Mat Plants.

NUMBER OF FRANKENIA PLANTS: 30 tagged (111 mature and 67 juveniles extra counted within the quadrat)

CONDITION: Healthy

ASSOCIATED SPECIES IN QUADRAT:
Angianthus micropodioides
Atriplex holocarpa
Centrolepis cephaloformis
Crassula exserta
Eragrostis dielsii
Gnephosis acicularis
Gnephosis angianthoides
Gnephosis multiflora
Senecio glossanthus
Triglochin calcitrapa

COMMON SPECIES IN AREA:
Calandrinia aff. *primulifera*
Frankenia setosa
Halosarcia leptoclada
Isotoma scapigera

Figure 11. Quadrat 3 established within Population 8 at Mollerin Lake. Photograph taken from north corner of quadrat.