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Status of the vegetation plots for the spectral library project

K Pfitzner & A Bollhöfer

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K Pfitzner & A Bollhöfer

1 Introduction

This paper summarises the status of the vegetation plots that are used to measure the spectral reflectance of vegetative ground covers for the spectral library project (File SG2005/0075). The plots are contained within three sites located at research facilities in the greater Darwin region: Berrimah Farm, CSIRO and Crocodylus Park. A brief introduction that outlines the project aims, limitations and achievements is provided below. The main purpose of the report is to summarise the 2006 and 2007 activities for each site. The species measured and frequency of data collection for each site is listed. The status of the plots as of January 2008 is given.

Since this manuscript was prepared, the spectral sampling of vegetative plots has been discontinued due to resource constraints.

1.1 Project overview

The aim of the spectral library project is to develop a spectral reflectance database of land covers pertinent to remote sensing applications in the mine environment. The focus was on vegetation components, with priority species being weeds and native ground covers that are of concern to the revegetation success at minesites. Plots of homogenous covers were established at Berrimah Farm, CSIRO and Crocodylus Park. A field spectrometer that measures reflectance continuously across the 0.35 –2.50 µm wavelength range is used to obtain the spectral data. Meteorological data, measurement metadata and cover descriptions are obtained with the spectral measurements. Where possible, sampling at fortnightly intervals is undertaken. The data are expected to provide insight into the variations between and within plant species during differing environmental conditions and over temporal variations in spectral signatures. Subtle phenological spectral changes between and within species can be used to make recommendations on the use of remote sensing for minesite assessment studies with applicability to all environments. The hypothesis is that with a well designed approach to collecting field spectral measurements and metadata, potential extraneous factors can be spectrally accounted for and accurate post-processing of spectra can be performed. Thus the first validated database of spectra relevant to the mine environment in the Top End can be developed. Further project details can be found in Pfitzner et al (2006) and Pfitzner et al (2009).

1.2 Project Innovation

Potential exists for remote monitoring of ground cover type and condition over minesites and their surrounds. Quantitative information on ground cover, such as percent species cover (including weed cover) and derived information such as fuel load, require that species can be discriminated and identified. Plant spectral data can potentially be used for this purpose but data on the spectral response of ground covers is limited.

This project addresses the following research questions:

- What are the temporal spectral responses of ground cover vegetative species?
- Can ground- cover vegetative species be di stinguished using ground based reflectance spectra, and if so, what spectral resolution is required?
- At what phenological stage is maximum separab ility detected and is there a growth or seasonal stage when plant species cannot be distinguished?
- What are the implications for remote sensing throughout the year?

Many remote sensing appl ications will remain in the research realm without a ground-based knowledge base to define species separability over time.

1.3 Known project limitations and project achievements

To achieve the required f ortnightly fre quency of spectral measurements, long travel tim es were not feas ible and site selection was therefore restricted to the greater Darwin region, an d limited to a few sites. The sites wer e chosen because they were located and supported within research facilities and unlikely to become distur bed or inaccessible. The speci es available for sampling we re dependant on these constraints, and lim itations in the project design are acknowledged, particularly with respect to th e number of species sampled and replication of the sampled species.

Suitable sites for additional speci es were con tinually bei ng sourced to disco unt potential confounding factors. Species replicati on was considered as important as s pecies variet y although m ost species were not represented more than once. Ideally , replicates of specie s were sampled at different locations.

Considering that a vegetat ive specie s spectral response is a function of a variety of factors ranging from soil ty pe and soil condition to lo cal meteorological conditions, a further known limitation was the vary ing growth m edia a nd envi ronmental co nditions prevailing duri ng sample colle ction. The spectral r esponse c an also b e expected t o vary over scale s in ti me (diurnal to se asonal) and space. It is acknowle dged t hat the spectral response measured is a function only of a point in time for a particul ar vegetation sam ple. To m inimise and accoun t for external variation, species were sa mpled fr om maintained plots that maximise a homogenous response (ie non-target species were continually weeded o ut). The soi l interspaces was sp ectrally measured wh erever a less than 100% cover was real ised. Detailed metadata w as used to define any change in lo calised conditions both within the target plant and for external condition.

Much focus to date has been on the develop m ent of protocols including accurate metadata recording so that data are comparable o ver tim e and so the data has long term value and is suitable for new applicatio ns. Detail of these pr otocols can be found in Pfitzne r et al (2006) and Pfitzner et al (2009). Despite known project li mitations, the project is expected to provide a knowledge base far greater than that ever obt ained for vegetation spectra with respect to species nu mbers, frequency of sam pling, dur ation of sampling and method and metadata documentation. The envisaged outcome of the project was a sp ectral library of vegetation reflectance s pectra, which can be used to determine the tim ing and frequency f or spectral measurements of vegetation e ndmembers. Despite vegetative sampling being discontinued, the data collected will go some way in addressing the project's aim.

2 Berrimah Farm

2.1 Summary of 2006 activities – Berrimah Farm

There were five plots established at Berrimah Farm in 2006. Four species of agricultural grasses are represented:

BF01 *Digitaria milanjiana* (Jarra Grass)

BF02 *Brachiaria humidicola* (Tully Grass)

BF03 *Brachiaria humidicola* (Tully Grass)

BF04 *Digitaria swynnertonii* (Arnhem Grass)

BF05 *Digitaria eriantha* (Pangola Grass)

While these grasses are not a high priority in terms of threat to mine rehabilitation success, these plots were established opportunistically as they represent dense and homogenous stands of introduced pastoral grasses that are also apparent in the Alligator Rivers Region (ARR). The five plots are easily accessible and can be sampled in one morning on a cloud-free day. Plots BF01 and BF02 are at a distance of less than 10 m, and plots BF03 and BF04 are within 20 m distance of each other. The distance between BF1/BF2 and BF3/BF4 is over 300 m. BF5 is approximately 200 m from BF1, BF2, BF3 and BF4.

Five complete replicates of spectral samples and metadata were taken at Berrimah Farm between September and December 2006 (Table 1). Spectral sampling was undertaken on September 26, October 9, October 30, November 15, November 30 and December 01. Where environmental conditions changed during sampling (eg winds picked up), the site or number of sites that were not sampled on that day were sampled at the next possible opportunity (eg see Table 1, where sites BF03–05 were not sampled on the 30/11/06, but were sampled on the 01/12/06). In November 2006 it was noted that the plots would need securing as cows were in the paddock.

Table 1 Spectral and metadata sample collection 2006 - Berrimah Farm

		Berrimah Farm sample				
	Date	1	2	3	4	5
2006 sampling dates	26/09/06	✔	✔	✔	✔	✔
	09/10/06	✔	✔	✔	✔	✔
	30/10/06	✔	✔	✔	✔	✔
	15/11/06	✔	✔	✔	✔	✔
	30/11/06	✔	✔			
	01/12/06			✔	✔	✔

2.2 Summary of 2007 activities – Berrimah Farm

There were no changes to the number of plots or species sampled at Berrimah Farm during 2007. Sampling of the five plots established at Berrimah Farm in 2006 was continued into 2007.

The Berrimah Farm plots were sampled 12 times in 2007 over 15 fieldtrips (Table 2). Sampling did not occur in 2007 until April (as the spectrometer was overseas for repair).

Sampling was undertaken on: April 11 and 13, April 23, May 10, May 22 and 23, June 12, July 18, August 1, September 6, September 21, October 4, October 15 and 17 and November 26.

Table 2 Spectral and metadata sample collection 2006 – Berrimah Farm

		Berrimah Farm sample				
	Date	1	2	3	4	5
2007 sampling dates	11/04/07	✔	✔	✔	✔	
	13/04/07					✔
	23/04/07	✔	✔	✔	✔	✔
	10/05/07	✔	✔	✔	✔	✔
	22/05/07	✔	✔			
	23/05/07			✔	✔	✔
	12/06/07	✔	✔	✔	✔	✔
	18/07/07	✔	✔	✔	✔	✔
	01/08/07	✔	✔	✔	✔	✔
	06/09/07	✔	✔	✔	✔	✔
	21/09/07	✔	✔	✔	✔	✔
	04/10/07	✔	✔	✔	✔	
	15/10/07	✔	✔			
	17/10/07			✔	✔	
	26/11/07	✔	✔	✔	✔	✔

Appendix 1 highlights the frequency of spectral samples taken at Berrimah Farm. The data is displayed by weeks and shows that since the establishment of these plots in 2006, the five plots have been sampled regularly, although not always fortnightly. There was a five week gap where no data were recorded during June–July 2007. No data were recorded in August 2007 and there was a six week gap in sampling during October and November. In addition, sampling was undertaken every three weeks rather than every two weeks on a number of occasions.

2.3 Status of plots – Berrimah Farm

In May 2007, warning was given that sites containing BF01, BF02 and BF03 would be grazed. By June 2007, BF01 and BF02 were completely grazed by cows. Plate 1 shows the status of plots as of November 2007. BF01 and BF02 had been fenced securely by late November 2007. The effect of grazing can be seen on BF02 in Plate 1. BF03 and BF04 were still only pegged with flagging tape and BF05 was fenced with chicken wire only. There was some mixing of grass species within these plots. Rains in late November had initiated a green flush (compare BF01–BF04 from late November with BF05 from early November in Plate 1)

BF1_2007_11-26

BF2_2007_ 11-26

BF3_2007_11-26

BF4_2007_ 11-26

BF_5_2007_11_01 (latest November image available)

Plate 1 Status of plots at Berrimah Farm (November 2007)

Plate 2 (below) illustrates the status of the Berrimah Farm plots as of December 2007. BF01, BF02, BF04 and BF05 had been fenced securely, however, BF03 still required secure fencing to be erected. BF05 shows some loss of homogeneity around the fenced perimeter.

BF1_2007_12-17 BF2_2007_ 12-17

BF3_2007_12-17 BF4_2007_ 12-17

BF_5_2007_12- 17

Plate 2 Status of plots at Berrimah Farm (December 2007)

2.4 Outlook for 2008 - Berrimah Farm

Once BF03 is s ecurely fenced, there is the need for regular maintenance of the plots. This includes checking that fencing has not been da maged by cows a nd ensuring that any alie n species are weeded out. Because it has been realised that Berrimah Farm is affected by winds in the afternoon, spectral sampling should be undertaken in the early morning to maximise the ability to capture the five plots at the same frequency. Spectral sampling should be undertaken at a fortnightly interval for 2008 to o btain a co mplete seasonal cy cle of information (as data was lost in 2007 due to inadequate fencing and grazing cows).

The five species that are ready for sampling in 2008 are:

BF01 *Digitaria milanjiana* (Jarra Grass)

BF02 *Brachiaria humidicola* (Tully Grass)

BF03 *Brachiaria humidicola* (Tully Grass)

BF04 *Digitaria swynnertonii* (Arnhem Grass)

BF05 *Digitaria eriantha* (Pangola Grass)

One new site needs to be securely fenced a nd m aintained as soon as possibl e to enable a complete seasonal cycle of information:

BF06 *Hyparrhenia rufa* (Thatch Grass)

Note that since this manuscript was pr epared, the spectral sa mpling of vegetative plots has been discontinued due to resource constraints.

3 CSIRO

3.1 Summary of 2006 activities – CSIRO

Nine plots were established at CSIRO in 2005 and six plots were maintained and sampled at CSIRO in 2006:

CS01 *Stylosanthes humilis* (Townsville Stylo)

CS02 *Sorghum stipodeum* (Sorghum)

CS05 *Pennisetum polystachion* (Perennial Mission Grass)

CS06 *Passiflora foetida* (Wild Passionfruit)

CS07 *Pennisetum pedicellatum* (Annual Mission Grass)

CS09 *Urochola maxima* (Guinea Grass or Green Panic)

Replicate plots of *S. humilis* and *S. stipodeum* were established (CS03 and CS04, respectively) in 2005 but found to not be feasible for spectral sampling in 2006 due to canopy cover casting shade over the plots in the dry season. The six species all represent important covers for minesite rehabilitation assessment in the ARR. The plot of CS05 is represented by a few individual grass clumps, and CS06 covers only a small part of the plot. The other covers are quite dense and homogenous when maintained. The sites are all located within walking distance, although CS01 and CS02 are over 100 m from the other sites.

Nine replicates of spectral and metadata samples were taken for six species at CSIRO between July and December 2006. A limited number of data were acquired between January and June 2006 while the sampling protocols were being developed. Once the protocols were established, spectral sampling was undertaken on July 3, August 30, September 12, September 27, October 10, October 25, November 6, November 7, November 20 and November 29. Spectral sampling was also undertaken on August 4 but no metadata were recorded.

Table 3 Spectral and metadata sample collection 2006 – CSIRO

		CSIRO sample					
	Date	1	2	5	6	7	9
2006 sampling dates	03/07/06	✔	✔	✔		✔	✔
	30/08/06	✔	✔	✔	✔	✔	✔
	12/09/06	✔	✔	✔	✔	✔	✔
	27/09/06	✔	✔	✔	✔	✔	✔
	10/10/06	✔	✔	✔	✔	✔	✔
	25/10/06	✔	✔	✔	✔	✔	✔
	06/11/06	✔		✔		✔	✔
	07/11/06		✔		✔		
	20/11/06	✔	✔	✔	✔	✔	✔
	29/11/06	✔	✔	✔	✔	✔	✔

3.2 Summary of 2007 activities – CSIRO

The six plots established at CSIRO in 2006 continued to be sampled in 2007 (CS01 *S. humilis* or Townsville Stylo, CS02 *S. stipodeum* or sorghum, CS05 *P. polystachion* or perennial

mission grass, CS06 *P. foetida* or wild passionfruit, CS07 *P. pedicellatum* or annual mission grass and CS09 *U. maxima* or Guinea grass).

Two new plots were established at CSIRO during 2007:

CS10 *Brachiaria humidicola* (Tully Grass)

CS12 *Melinis repens* (Red Natal Grass)

CS11, *Sorghum stipodeum*, was established, but the cover disappeared and the site was discontinued. CS11 was sampled once in 2007 on April 26.

The CSIRO plots were sampled around 8 times in 2007 over 11 field trips, although not all species were sampled on every trip. Sampling was undertaken on April 12 and 26, May 11, May 22, June 13, July 11, August 7 and 8, September 7 and 10 and October 16 (Table 4). Spectra were also recorded on July 18 and November 5, but no metadata details were recorded.

Table 4 Spectral and metadata sample collection 2007 – CSIRO

		CSIRO sample							
	Date	1	2	5	6	7	9	10	12
2007 sampling dates	12/04/07	✔		✔	✔		✔	✔	
	26/04/07	✔	✔	✔	✔		✔	✔	✔
	11/05/07	✔		✔		✔	✔	✔	
	22/05/07	✔		✔		✔	✔	✔	✔
	13/06/07	✔	✔	✔		✔	✔	✔	✔
	11/07/07	✔	✔	✔	✔	✔	✔	✔	✔
	07/08/07			✔	✔	✔	✔	✔	
	08/08/07	✔	✔						✔
	07/09/07	✔	✔	✔	✔	✔	✔	✔	
	10/09/07								✔
	16/10/07	✔						✔	

Appendix 1 highlights the frequency of spectral samples taken at CSIRO. The data is displayed by weeks and shows that since the establishment of these plots in 2006, the six plots have been sampled regularly, although not always fortnightly. In 2006, the sites were sampled fortnightly. From April 2007 – November 2007, the sites were often sampled monthly.

3.3 Status of plots – CSIRO

Plates 3 and 4 show the status of the CSIRO plots for early November and December (2007), respectively. CS01, 02, 05, 06, 10 and 12 have been pegged with flagging tape. CS07 and CS09 have not been plotted out (but urgently need to be defined). There has been an obvious flush of vegetation with rains between early November and December (compare Plates 3 and 4). All plots but CS01 (*S. humilis*) and CS10 (*B. humidicola*) show a patchy cover (Plate 3). In particular, CS05 (*P. Polystachion*) and CS06 (*P. foetida*) are quite sparse and a decision was made to transplant extra individuals into these plots.

CS01_2007_11_02 CS02_2007_11_02

CS05_2007_11_02 CS06_2007_11_02

CS07_2007_11_02 CS09_2007_11_02

CS10_2007_11_02 CS12_11_02

Plate 3 Status of plots at CSIRO (November 2007)

Plate 4 shows the CSIRO plots in December 2007 and illustrate a flush in cover compared to Plate 3. CS05 and CS06 still require new seedlings to be transplanted into these plots in an attempt to achieve a denser cover and CS07 and CS09 still need to be plotted out. Some sites

need to be maintained with flaggi ng tape and alien species weeded out. The s ites require site identification (SSD sa mple tags are att ached to infor m new co mers to the purpose of thes e plots). No spectral samples were taken after 19/10/2007 to capture the flush evident in Plate 4.

CS01_2007_12_17

CS02_2007_12_17

CS05_2007_12_17

CS06_2007_12_17

CS07_2007_12_17

CS09_2007_12_17

CS10_2007_12_17

CS12_11_02

Plate 4 Status of plots at CSIRO (December 2007)

3.4 Outlook for 2008 – CSIRO

Maintenance for the CSIRO plots needs to be continued. In particular, alien species to the plots need to be regularly weeded out. The plots require aesthetic maintenance, including neat flagging tape and waterproof site labels to ensure the purpose of the plots is clear. The eight species that will continue into 2008 are:

CS01 *Stylosanthes humilis* (Townsville Stylo)

CS02 *Sorghum stipodeum* (Sorghum)

CS05 *Pennisetum polystachion* (Perennial Mission Grass)

CS06 *Passiflora foetida* (Wild Passionfruit)

CS07 *Pennisetum pedicellatum* (Annual Mission Grass)

CS09 *Urochola maxima* (Guinea Grass or Green Panic)

CS10 *Brachiaria humidicola* (Tully Grass)

CS12 *Melinis repens* (Red Natal Grass)

Because CS05 and CS06 are sparse in cover, replicate plots, preferably at Crocodylus Park, need to be identified and plotted. Wild passionfruit is invading CS09, so this is a potential source to increase the cover of CS06. Alternatively, new dense covered sites could be established, but sampling of CS05 and CS06 should continue so that a complete annual data record is obtained.

There is potential for CS07 to be expanded into two plots, and while these plots would be adjacent to one another, extra spectra on this important species would be obtained and with little extra sampling effort required.

During flowering, confirmation of the species composition of CS09 with the NT Herbarium is still required. CS09 needs to be plotted out and any alien species weeded out.

Note that since this manuscript was prepared, the spectral sampling of vegetative plots has been discontinued due to resource constraints.

4 Crocodylus Park

4.1 Summary of 2006 activities – Crocodylus Park

There were 21 plots established at Crocodylus Park in 2006:

CP01 *Hyptis suaveolens* (Hyptis)

CP02 *Stylosanthes humilis* (Townsville Stylo)

CP03 *Hyptis suaveolens* (Hyptis)

CP04 *Pennisetum pedicellatum* (Annual Mission Grass)

CP05 *Calopogonium mucunoides* (Calopo vine)

CP06 *Urochloa mutica* (Para grass)

CP07 *Stachytarpheta cayennensis* (Snake weed – white flowers)

CP08 *Sida cordifolia* (Flannel weed)

CP09 *Stachytarpheta australis* (Snake weed – purple flowers)

CP10 *Panicum mindanese*

CP11 *Panicum mindanese*

CP12 *Chloris inflata* (Purple top chloris)

CP13 *Cynodon dactylon* (Couch)

CP14 *Heteropogon contortus*

CP15 *Schizachyrium* sp

CP16 *Crotalaria goreensis* (Gambia Pea)

CP17 *Stylosanthes hamata* (Caribbean stylo)

CP18 *Senna* sp (Sicklepod)

CP19 *Lemna* sp (Duckweed)

CP20 *Stachytarpheta cayennensis* (Snake weed – white flowers)

CP21 *Andropogon gayanus* (Gamba grass)

Combined with the Berrimah Farm and CSIRO plots, the species mix established at Crocodylus Park incorporated many of the species important for minesite rehabilitation studies. All species except CP05, CP06, CP07, CP09, CP19 and CP20 were located in the upper western paddock of Crocodylus Park. Species in plots CP05, CP06, CP07, CP09, CP19 and CP20 were often collected on one sampling trip (Table 5), as the equipment had to be packed and unpacked to sample these sites. The majority of plots were not sampled until late August/early September. The data collection appears patchy in Table 5, but this is a function of the two different trips required to capture the spectral data. Appendix 3 displays the data by weeks (data collected during the same week is combined into the one row), illustrating that fortnightly data was mostly collected.

Limited data was collected April 5, 18 and 24 and May 18 and 24. More intensive sampling was undertaken on the following dates: June 08, June 21, June 23, July 04, July 21, August 02, August 31, September 01, September 13, September 14, September 28, September 29, October 12, October 13, October 26, October 31, November 01, November 03, November 13, November 14, November 15 November 27, November 28, November 30 and December 01 (Table 5).

Species in plots CP05, CP06, CP07, CP09, CP19 and CP20 were located away from the remaining plots and often sampled in isolation to the remaining plots in the upper western paddock. The data sampling appears patchier because those species in the upper western paddock were captured at different dates to those plots external from the paddock.

Table 5 Spectral and metadata sample collection 2006 – Crocodylus Park

	Crocodylus Park sample																				
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
05/04/06	✔																				
18/04/06	✔																				
24/04/06						✔															
18/05/06		✔																			
24/05/06						✔			✔												
08/06/06	✔	✔	✔	✔																	
21/06/06	✔	✔	✔	✔																	
23/06/06						✔															
04/07/06	✔	✔	✔	✔																	
21/07/06	✔																				
02/08/06																✔					
31/08/06		✔				✔	✔	✔		✔			✔						✔	✔	
01/09/06	✔		✔	✔							✔	✔		✔	✔		✔	✔	✔		
13/09/06		✔	✔	✔				✔				✔	✔	✔							
14/09/06	✔					✔	✔		✔	✔	✔					✔	✔		✔	✔	
28/09/06		✔	✔	✔				✔		✔		✔	✔				✔	✔			
29/09/06	✔					✔	✔		✔		✔								✔	✔	
12/10/06			✔	✔				✔		✔		✔	✔	✔		✔	✔	✔			
13/10/06						✔	✔		✔		✔								✔	✔	
26/10/06		✔	✔	✔				✔													
31/10/06						✔			✔											✔	
01/11/06		✔	✔					✔				✔									
03/11/06	✔									✔			✔								
13/11/06						✔	✔		✔										✔	✔	
14/11/06		✔	✔	✔				✔				✔	✔	✔				✔			
15/11/06	✔						✔			✔	✔					✔	✔				
27/11/06		✔		✔				✔				✔		✔				✔			
28/11/06	✔					✔	✔			✔	✔						✔		✔		
30/11/06						✔		✔													
01/12/06																					✔

4.2 Summary of 2007 activities – Crocodylus Park

Six plots of the 21 plots established at Crocodylus Park in 2006 continued to be sampled from April 2007 (CP02 *S. humilis*, CP03 *H. suaveolens*, CP04 *P. pedicellatum*, CP12 *C. inflata*, CP13 *C. dactylon* and CP14 *H. contortus*).

Some plots were not fenced securely and either donkeys destroyed these plots or the samples were collected until the s pecimen sen esced a nd the location of t he plot became unknow n: C P22 (*H. suaveolens* o r Hypt is), CP 23 (Morning Glory), CP 24 (*C. mucunoides* o r Calopo vin e), CP25 (*Digitara bicornis)*, CP 26 (*Aeschynomene americana* or Joint vetch), CP27 (*Spermacoe leptoloba*

or purple sedge), CP28 (*Setaria apiculata*), C29 (*Cyperus Rotundus*), CP 30 (*P. foetia* or wild passionfruit vine) CP 31 (*S. australis)*, CP32 (*S. cayennensis)* and CP33 (*Sida cordifolia*).

To rationalise time spent in the field, a decision was made to abandon those sites not located within the western top paddock because an extra day of sampling had been spent at times during 2006 to capture those sites. Those sites were: CP05 (*C. mucunoides* or Calopo vine), CP06 (*U. mutica* or Para grass), CP07 and CP20 (*S. cayennensis* or Snake weed - white flowers), CP09 (*S. australis* or snake weed – purple flowers) and CP19 (*Lemna* sp. Duckweed). *C. mucunoides*, *S. cayennensis* and *S. australis* could be sampled from the top paddock and new sites were identified (CP 24, CP32 and CP33 respectively). CP24 was discontinued, but two new sites were identified which were characterised as a single shrub of:

CP31 *Stachytarpheta cayennensis*

CP32 Stachytarpheta australis

CP06 had not been an ideal patch of *U. mutica*, as the site was difficult to access and had been grazed by donkeys. Because *U. mutica* is considered a priority species, an easily accessible site was identified along a drain near Palmerston. The advantages of the Palmerston site were that the para grass patch was large and would allow a number of samples to be collected. In addition, there was a gradient in soil moisture away from the drain, which would allow spatio-temporal samples to be collected. Unfortunately this site was not sampled at all in 2007 and no spectra of Para grass were obtained.

In early 2007 a number of potential new plots were identified in the western top paddock at Crocodylus Park. These included native grasses (*Bothriochloa bladhii, Digitaria bicornis, Setaria apiculata)*, introduced grasses, sedge and cypress (*A. gayanus*, *Cyperus rotundus, Dactyloctenium aegyptium, Melinus repens, Spermacoe leptoloba* or purple sedge, *Sporobolus jacquemontii, Urochloa pubigera),* native shrub (*Euphorbia heterophylla)*, introduced shrubs (*Aeschynomene americana* or Joint vetch, *Desmodium tortuosum, Hibiscus sabdariffa, H. suaveolens*, *Indigofera tinctoria, S. australis, S. cayennensis, Scroparia dulcis, Sida Cordifolia, Spermacoce leptoloba*), native vine (*Ipomoea pes-tigridis)* and introduced vines (*C. mucunoides* or Calopo vine, *P. foetia* or wild passionfruit vine). Opportunistic readings (frequency between 1–3) were taken for a further 6 samples which were of isolated grass clumps or shrubs. These included:

CP21 *A. gayanus* (Gamba grass clump)

CP23 potted example of Morning Glory

CP25 Digitara bicornis

CP26 Aeschynomene americana or American Joint Vetch

CP33 Sida cordifolia

CP35 Hibiscus sabdariffa (or Rosella).

No complete sets of data were recorded for 2007 and there are large gaps (up to 6 weeks) between data collection events (see Appendix 3).

A number of Crocodylus Park plots were sampled in 2007 over 18 field trips (Table 6). Sampling was undertaken on April 18,19 and 20, May 15, 17, 18, 30 and 31, June 14, July 23 and 25, August 9, 10 and 18, September 5 and 19, October 15 and 31.

Table 6 Spectral and metadata sample collection 2007 – Crocodylus Park

		Crocodylus Park sample																			
	Date	2	3	4	12	13	14	21	23			25	26			31	32	33	35		
Trip 2007	18/04/07	✔			✔																
	19/04/07			✔		✔		✔											✔		
	20/04/07		✔								✔	✔	✔				✔				
	15/05/07	✔	✔	✔	✔																✔
	17/05/07					✔		✔								✔	✔				
	18/05/07					✔							✔						✔		
	30/05/07	✔		✔	✔	✔		✔													
	31/05/07		✔													✔	✔				✔
	14/06/07	✔			✔	✔		✔								✔	✔				
	23/07/07	✔			✔																
	25/07/07			✔		✔		✔								✔					
	09/08/07	✔		✔	✔											✔					
	10/08/07					✔		✔													
	18/08/07	✔			✔	✔		✔													
	05/09/07				✔	✔		✔									✔				
	19/09/07	✔		✔	✔	✔		✔		✔						✔					
	15/10/07	✔		✔	✔	✔		✔									✔				
	31/10/07					✔		✔													

CP23 – a pot of morning glory, CP25 Digitara, CP26 Joint Vetch, CP33 Sida Cordifolia, CP35 – Rosella

CPO2, 03, 04, 12, 13, 14 and 31 were the only samples collected regularly in 2007 (*Stylosanthes humilis*, *Hyptis suaveolens*, *Pennisetum pedicellatum*, *Chloris inflate*, *Cynodon dactylon*, *Heteropogon contortus* and *Stachytarpheta* sp, respectively).

4.3 Status of plots – Crocodylus Park

Plate 5 shows the status of the plots at Crocodylus Park as of early November 2007. Only eight plots remained, with six original plots (CP02, CP03, CP04, CP12, CP13, CP14) and two new plots with individual shrubs of snakeweed (CP31 and 32).

CP02, a dense and homogenous patch of *S. humilis*, with a good perimeter, makes for a very suitable plot for temporal sampling. The plot required a more sturdy fence, as chicken wire has proven inadequate for keeping out grazing donkeys.

CP03, CP04, CP12, CP13, CP14, CP31 and CP32 all required secure fencing to be erected so that the donkeys do not graze the remaining plots. The snakeweed specimens were being measured but had not been fenced out (Plate 5). CP21 (Gamba grass) had been burnt, but a secure plot was required and a replicate plot of this priority species was to be established nearby.

CP02_2007_11_01

CP03_2002_05_31 (died off by November)

CP04_2007_11_01 CP12_2007_

11_01

CP13_2007_10_31 CP14_2007_

10_31

CP31_2007_11_01 CP32_2007_

10_15

Plate 5 Status of plots at Crocodylus Park (November 2007)

The rains had caused a flush and CP03 appeared dense and homogenous, although it was noted that some alien species needed to be removed as soon as possible to avoid any competition. In December 2007, five species had been contained in one large fenced plot (Plate 6).

Plate 6 Image of the larger plot containing CP03 (closest green dense patch) and CP04 (background dense green patch) as well as new identified species (Rattlepod, American Joint Vetch and Gambia Pea)

Plate 7 shows the status of the plots at Crocodylus Park as of December 2007. CP02 has been securely fenced (note the perimeter to the Stylo within the plot has flushed and this will require frequent maintenance). Referring to Plate 7, the image representing CP03 shows a dense patch of hyptis that is part of this larger plot. The larger fence was convenient to erect and will make access into these plots for weeding easier. However, concern is that these 'plots' within the larger fenced plot will easily become merged and mixed and thus frequent maintenance and weeding of this plot is indispensable.

CP04 is also contained within the larger plot. Concern is that until flowering, the grass is unidentifiable and keeping this patch homogenous will be difficult (note the other sterile grasses next to the 'plot' of mission grass). The chicken wire fence marking the plot of CP12 was taken down in November and the location of the chloris grass lost. CP13 (couch) still requires that alien species be eliminated so that the couch is not out competed before the rains. CP 14 has been securely fenced and makes for a good plot for temporal sampling. CP31 and CP32 have been fenced within the one secure plot.

Note that the fencing of CP12 was taken down and the sample 'lost' between November and December.

CP02_2007_12_17 CP03_2007_12_17

CP04_2007_12_17 CP13_2007_10_31

CP14_2007_10_31

CP31_2007_11_01 and CP32_2007_10_15 (snake weed)

Plate 7 Status of plots at Crocodylus Park (December 2007)

4.4 Outlook for 2008 – Crocodylus Park

Regular maintenance is required for the remaining Crocodylus Park plots. In particular, alien species to the plots need to be regularly weeded out. The plots require regular inspection for damage to plot fences, and prompt fence maintenance.

The seven species of plots that will continue into 2008 are:

CP02 *S. humilis*

CP03 *H. suaveolens*

CP04 *P. pedicellatum*

CP14 *H. contortus*

CP21 *A. gayanus* (Gamba grass)

CP31 *S. cayennensis*

CP32 *S. australis*

New species in the larger plot containing CP3 and CP4 include the following three species:

CP23 *Ipomoea* sp (Morning Glory vine) – formerly CP01

CP26 *Aeschynomene americana* (American Joint Vetch)

CP34 *Crotalaria pallida* (Rattlepod) (established January 2008)

CP36 *Crotalaria goreensis* (Gambia pea) (established January 2008)

Any new species identified as potential plots require that immediate fencing is erected. Effort to identify and erect secure fences for the priority species that have previously been identified at Crocodylus Park should be undertaken as soon as feasible (ie when flowering of grasses begins or as soon as annuals appear). Sites should not be abandoned when plants die off, but any obvious aliens of non-target species should be weeded out and the site reassessed when a new ground cover emerges.

Note that since this manuscript was prepared, the spectral sampling of vegetative plots has been discontinued due to resource constraints.

5 Summary

5.1 Berrimah Farm

Five plots of introduced agricultural grasses were established at Berrimah Farm in 2006. Spectral sampling at Berrimah Farm began in late September 2006. While these species are not of the highest priority for minesite rehabilitation studies, the pastoral grasses are common in the landscape and found around the ARR minesites. The plots at Berrimah Farm are easily accessible and all plots can be sampled in one morning on a cloud-free day. Sampling has not always been undertaken at fortnightly intervals. There was a one month gap in data collection between June–July 2007. The vegetation covers in the plots are dense, but need frequent monitoring for homogeneity and weeding out of non-target species. Since 2006, some cover has been lost due to grazing. As of December 2007, all but one of the plots was securely fenced to minimise disturbance through grazing. A new site of *Hyparrhenia rufa* (Thatch Grass) has been identified and will be fenced and ready for sampling during 2008. All sites require regular maintenance. It is important that the 2008–09 season of data collection is made now that the plots have been securely fenced and contain dense homogenous covers.

5.2 CSIRO

Nine plots were established at CSIRO in 2005 with six of these plots being maintained and sampled though 2006 and 2007. Two additional plots were established and sampled in 2007. The species at CSIRO represent some of the vegetation covers pertinent for minesite rehabilitation assessment studies. Limited spectral samples were acquired between January and July 2006 as the measurement protocols were being developed. Fortnightly data was captured from April 2006 – November 2006 and April 2007 – May 2007. From June through October 2007, much of the CSIRO data was captured monthly. Two of the plots are very sparse in cover and require specimens to be transplanted in to increase cover. No sites at CSIRO have been fenced as there are no grazing animals. Most sites are marked by star pickets and flagging tape. Two sites are still unmarked and require delineation and all sites require regular maintenance.

5.3 Crocodylus Park

There were 21 plots established at Crocodylus Park in mid 2006. The mix and number of species were very pertinent to minesite rehabilitation studies. Most plots were established in the upper paddock, where species diversity was apparent. Six sites were located away from the top paddock. All sites within the upper paddock were easily accessible and in close proximity. The six sites external from the upper paddock were reached by vehicle and the equipment needed to be packed and unpacked to sample these plots. Spectral sampling was undertaken fortnightly between August 2006 and November 2006. Some sites were not sampled regularly in 2006. Six of the 21 plots established at Crocodylus Park in 2006 were sampled in 2007. The main reason for loss of plots was a loss of cover due to grazing by donkeys due to inadequate and/or a lack of fencing. Some annual species were out competed. The six external plots (from the top paddock) were discontinued in 2007 because of their location, as up to a whole day was being spent sampling these six sites, and four of these species were available in the top paddock. A further 24 sites were identified in the upper paddock at the start of 2007. None of these sites were plotted or fenced and little data was obtained. No complete sets of data were recorded for 2007 and there were large (up to 6 weeks) gaps in data collection. As of late 2007, there were seven plots continuing for 2008 and four new plots being developed.

5.4 Plots ready for sampling – 2008

The twenty-five sites (Plate 8) ready for sampling in 2008 are:

BF01 *Digitaria milanjiana* (Jarra Grass)

BF02 *Brachiaria humidicola* (Tully Grass)

BF03 *Brachiaria humidicola* (Tully Grass)

BF04 *Digitaria swynnertonii* (Arnhem Grass)

BF05 *Digitaria eriantha* (Pangola Grass)

CP02 *S. humilis*

CP03 *H. suaveolens*

CP04 *P. pedicellatum*

CP13 *C. dactylon*

CP14 *H. contortus*

CP21 *A. gayanus*

CP22 *H. Suaveolens*

CP23 *Ipomoea* sp (Morning Glory vine) – formerly CP01

CP26 *Aeschynomene americana* (American Joint vetch) (established January 2008)

CP31 *S. cayennensis*

CP32 *S. Australis*

CP34 *Crotalaria pallida* (Rattlepod) (established January 2008)

CP36 *Crotalaria goreensis* (Gambia pea) (established January 2008)

CS01 *Stylosanthes humilis* (Townsville Stylo)

CS02 *Sorghum stipodeum* (Sorghum)

CS05 *Pennisetum polystachion* (Perennial Mission Grass)

CS07 *Pennisetum pedicellatum* (Annual Mission Grass)

CS09 *Urochola maxima* (Guinea Grass or Green Panic)

CS10 *Brachiaria humidicola* (Tully Grass)

CS12 *Melinis repens* (Red Natal Grass)

As well as the yet to be established:

BF06 *Hyparrhenia rufa* (Thatch Grass)

BF1_2008_01-23

BF2_2008_ 01-23

BF3_2008_01-23

BF4_2008_ 01-23

BF5_2008_01-23

CP02_2008 -03_05

CP03_2008_03_04 CP04_2008_

03_04

CP13_2008_02_01 CP14_2007_

10_31

CP21_2007_10_15 CP22_2008_

01_30

CP23_2008_03_05 CP26_2008_

03_04

CP32_2008_03_05 CP34_2008_

03_04

5.5 Missing priority species – expanding activities at Crocodylus Park

The new sites identified for *Urochloa mutica* (Para grass) were not established or sampled with the cessation of sampling in the lower grounds of Crocodylus Park. The documentation of these sites, including herbarium identification must be done with priority so that this species can be sampled. Investigation into the sample at the lower dam of Crocodylus Park should be undertaken.

Species sampled in 2008 (see Section 5.4) require replicates where possible. Of priority for Crocodylus Park are *P. pedicellatum, P. ploystachion* and *P. foetida*. Also of importance are: *C. inflate, C. dactylon* and *A. gayanus* (Gamba grass).

Because *Heteropogon contortus* is so morphologically variable, a number of plots within the three sampled sites would be very useful. Important species pertinent to minesite assessment and that have been identified at the top paddock at Crocodylus Park should be established as soon as possible and this includes: *C. mucunoides* (Calopo vine), *S. cordifolia* (Flannel weed), *P. mindanese*, *C. inflata* (Purple top chloris), *Schizachyrium* sp, *S. hamata* (Caribbean stylo) and P. foetida (wild passionfruit vine).

Others species of high interest that have been identified at the top paddock of Crocodylus Park, and their presence, if found again, noted for possible plot examples (even if for a short phenological cycle) include: native grasses (*Bothriochloa bladhii, Digitaria bicornis, Setaria apiculata)*, introduced grasses, sedge and cypress (*A. gayanus*, *Cyperus rotundus, Dactyloctenium aegyptium, Melinus repens, Spermacoe leptoloba* or purple sedge, *Sporobolus jacquemontii, Urochloa pubigera),* native shrub (*Euphorbia heterophylla)*, introduced shrubs (*Aeschynomene americana* or Joint Vetch, *Desmodium tortuosum, Hibiscus sabdariffa, H. suaveolens*, *Indigofera tinctoria, S. australis, S. cayennensis, Scroparia dulcis, Sida cordifolia, Spermacoce leptoloba*), native vine (*Ipomoea pes-tigridis)* and introduced vines (*C. mucunoides* or Calopo vine, *P. foetia* or wild passionfruit vine).

Species also on the priority list that have yet to be sited at the existing sites include: *Cenchrus cilaris* (Buffel grass), *Cenchrus echinatus* (Mossman River grass), *Chloris virgata* (Feather Top Rhodes Grass), *Themeda quadrivalvis* (Grader grass), *Centrosema pubescens* (Centro vine), and *Macroptilum atropureum* and *M. lathyroides* (Siratro and Phasey bean, respectively).

5.6 Important lessons learnt

- Securely fence a site as soon as a potential plot is realised;
- Regularly inspect and maintain fences of plots;
- Regularly inspect plots for alien species and weed these from the plot to maximise the chance of maintaining a homogenous plot;
- Maintain plots where the target species disappears. Weed out any obvious non-target species to minimise out competition of the target species;
- As soon as species are identifiable, search for those species of priority, ensuring any new species are confirmed with the NT Herbarium: and,
- Ensure that species are being sampled fortnightly

References

Pfitzner K, Bollhöfer A & Carr G 2006. A standard design for collecting vegetation reference spectra: Implementation and implications for data sharing. *Journal of Spatial Sciences* 52 (2), 79–92.

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Appendix 1 Spectral sampling – Berrimah Farm

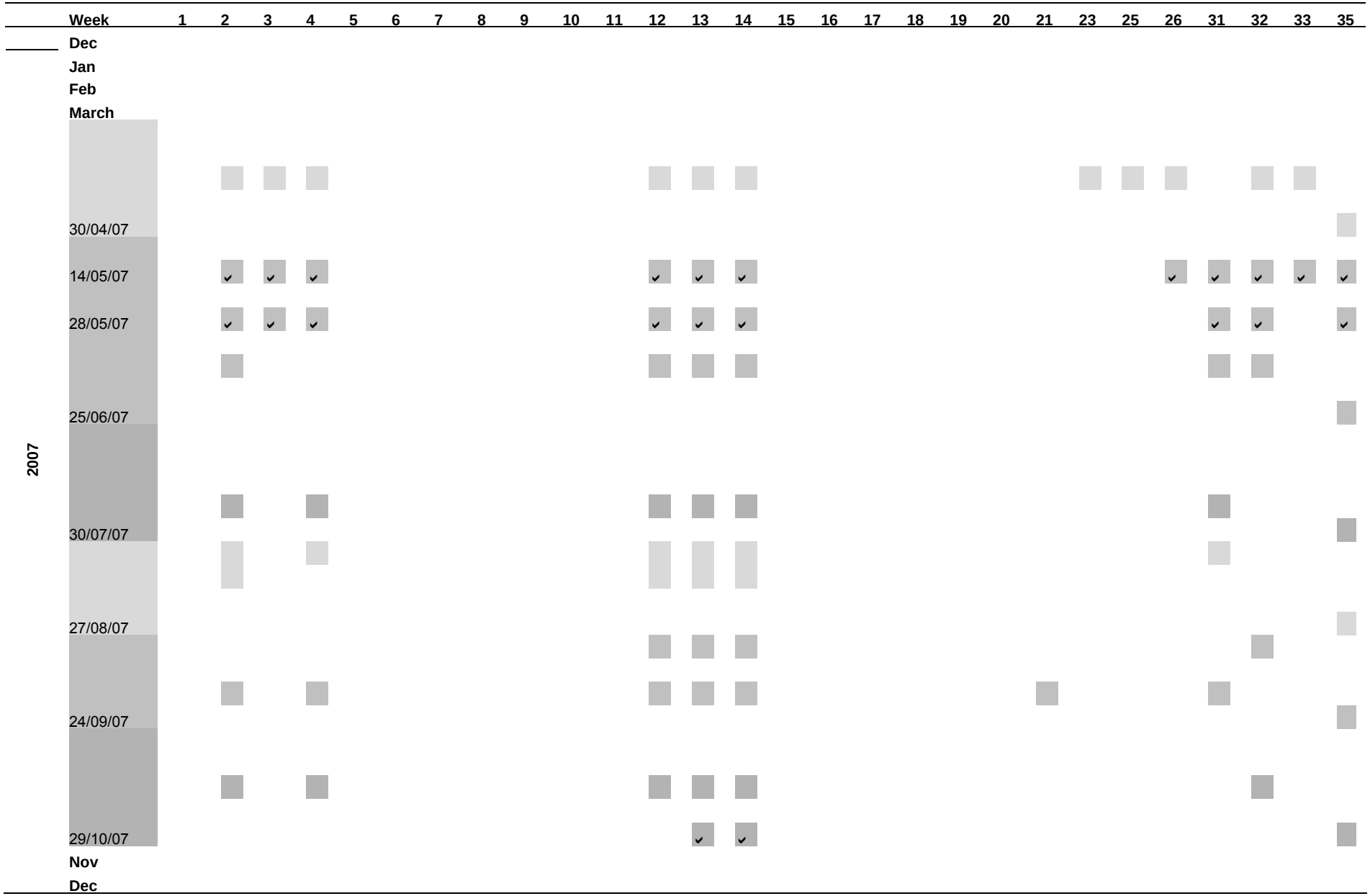
	Week starting	01	02	03	04	05
2006	April					
	May					
	June					
	July					
	Aug					
	25/09/06	✔	✔	✔	✔	✔
	09/10/06	✔	✔	✔	✔	✔
	30/10/06	✔	✔	✔	✔	✔
	13/11/06	✔	✔	✔	✔	✔
	27/11/06	✔	✔	✔	✔	✔
	Dec					
2007	Jan					
	Feb					
	March					
	09/04/07	✔	✔	✔	✔	✔
	23/04/07	✔	✔	✔	✔	✔
	30/04/07					
	07/05/07	✔	✔	✔	✔	✔
	21/05/07	✔	✔	✔	✔	✔
	28/05/07					
	11/06/07	✔	✔	✔	✔	✔
	25/06/07					
	16/07/07	✔	✔	✔	✔	✔
	30/07/07	✔	✔	✔	✔	✔
	27/08/07					
	03/09/07	✔	✔	✔	✔	✔
	17/09/07	✔	✔	✔	✔	✔
	24/09/07					
	15/10/07	✔	✔	✔	✔	
	29/10/07					
	05/11/07					
	12/11/07					
	19/11/07					
	26/11/07	✔	✔	✔	✔	✔
	Dec					

Appendix 2 Spectral sampling – CSIRO

	Week starting	01	02	05	06	07	09	10	12
2006	April								
	May								
	June								
	03/07/06	✔	✔	✔		✔	✔		
	10/07/06								
	17/07/06								
	24/07/06								
	31/07/06								
	07/08/06								
	14/08/06								
	21/08/06								
	28/08/06	✔	✔	✔	✔	✔	✔		
	04/09/06								
	11/09/06	✔	✔	✔	✔	✔	✔		
	18/09/06								
	25/09/06	✔	✔	✔	✔	✔	✔		
	02/10/06								
	09/10/06	✔	✔	✔	✔	✔	✔		
	16/10/06								
	23/10/06	✔	✔	✔	✔	✔	✔		
	30/10/06								
	06/11/06	✔	✔	✔	✔	✔	✔		
	13/11/06								
	20/11/06	✔	✔	✔	✔	✔	✔		
	27/11/06	✔	✔	✔	✔	✔	✔		
	Dec								
2007	Jan								
	Feb								
	March								
	02/04/07								
	09/04/07	✔		✔	✔		✔	✔	
	16/04/07								
	23/04/07	✔	✔	✔	✔		✔	✔	✔
	30/04/07								
	07/05/07	✔		✔		✔	✔	✔	
	14/05/07								
	21/05/07	✔		✔		✔	✔	✔	✔
	28/05/07								
	04/06/07								
	11/06/07	✔	✔	✔		✔	✔	✔	✔
	18/06/07								
	25/06/07								
	02/07/07								
	09/07/07	✔	✔	✔	✔	✔	✔	✔	✔
	16/07/07								
	23/07/07								
	30/07/07								
	06/08/07	✔	✔	✔	✔	✔	✔	✔	✔
	13/08/07								
	20/08/07								
	27/08/07								
	03/09/07	✔	✔	✔	✔	✔	✔	✔	
	10/09/07								✔
	17/09/07								
	24/09/07								
	01/10/07								
	08/10/07								
	15/10/07	✔						✔	
	22/10/07								
	29/10/07								
	Nov								
	Dec								

Appendix 3 Spectral sampling – Crocodylus Park

	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	23	25	26	31	32	33	35
2006	March																												
	03/04/06	✓																											
	10/04/06																												
	17/04/06	✓																											
	24/04/06					✓																							
	01/05/06																												
	08/05/06																												
	15/05/06		✓																										
	22/05/06						✓			✓																			
	29/05/06																												
	05/06/06	✓	✓	✓	✓																								
	12/06/06																												
	19/06/06	✓	✓	✓	✓		✓																						
	26/06/06																												
	03/07/06	✓	✓	✓	✓																								
	10/07/06																												
	17/07/06	✓																											
	24/07/06																												
	31/07/06																✓												
	07/08/06																												
	14/08/06																												
	21/08/06																												
	28/08/06		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓								
	04/09/06																												
	11/09/06	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓								
	18/09/06																												
	25/09/06	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓				✓	✓	✓	✓								
	02/10/06																												
	09/10/06			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓								
	16/10/06																												
	23/10/06		✓	✓	✓				✓																				
	30/10/06	✓	✓	✓		✓			✓	✓	✓		✓	✓							✓								
	06/11/06																												
	13/11/06	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓								
	20/11/06																												
	27/11/06	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓			✓	✓	✓		✓							



CP23 – a pot of morning glory, CP25 Digitara, CP26 Joint Vetch, CP33 *Sida cordifolia*, CP35 – Rosella