محمية دبي الصحراوية
DUBAI DESERT CONSERVATION RESERVE

Emirates

A comparative study of vegetation structure and regeneration between two monitoring surveys in the Dubai Desert Conservation Reserve: Initial Assessment and Baseline Data.

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Introduction

Monitoring generally involves the collection of data over time with the objective of detecting change in a particular situation. Monitoring is continuously ongoing activity, continuous monitoring gives comparable data for future comparison and helps the conservation department to make clear managerial decision. Continuous monitoring can detect if certain activities in the Dubai Desert Conservation Reserve (DDCR) are having negative impacts on the environment, and to provide timely warning of the deterioration in the conservation status of certain species, thus allowing remedial action to be taken. Monitoring is a practical exercise that must produce data to be interpreted and fed back into management mechanism. A regular frequency of monitoring “annual or biennial” with measurements taken consistently over time would be sufficient to meet the monitoring program objectives.

Following the baseline survey on the vegetation of DDCR which assessed and quantified the vegetation cover and plant communities and provided data that served as the preliminary basis for comparison; the current study policies are to implement a continuous, practical and efficient vegetation monitoring program and to apply analytical tools for the data interpretation which mainly emphasize the assessment of density, cover and diversity of the flora. Mapping the vegetation and defining lineage between different floral communities, using multivariate analysis combined with GPS techniques was also an objective for this study.

The floral diversity of DDCR changed dramatically, since the 2004 report, recording **46** species of which **22** species were not recorded before, the identification of the plant species was with the help of the book of “The comprehensive guide to the wild flowers of the United Arab Emirates” by; Marijcke Jongbloed. This study was started in July 2008 and was completed in February 2009 (eight Months of Field work and uploading data)

Aim of the work

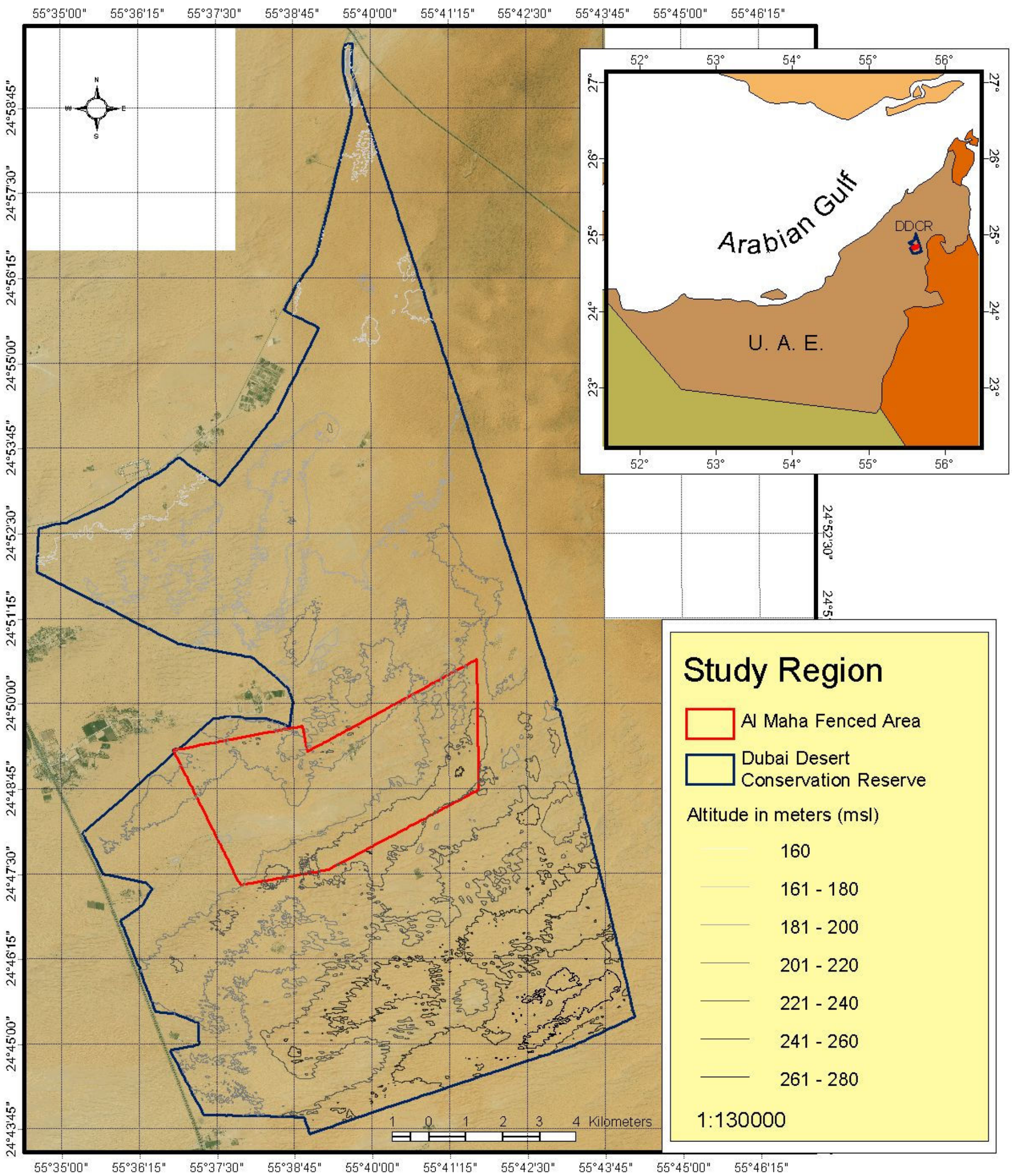
The aim of this study is to implement a continuous practical and efficient vegetation monitoring program and to apply analytical tools for easy data interpretation. This information and data is indispensable for managing the DDCR in a sustainable manner.

Study Region

Dubai Desert Conservation Reserve (DDCR) established in 2003 in a joint effort between Emirates Airlines and the Government of Dubai, a total area of 225 $km^{2,}$ was the biggest piece of land ever dedicated to a single project in Dubai, the Dubai Desert Conservation Reserve is considered the first protected area in the United Arab Emirates managed as a national park and has the main objective to conserve the natural flora, fauna and desert landscape of the emirate.

DDCR is a fenced area with a perimeter of approximately 85km.inside this fence there is another core fenced area which is Al Maha Reserve (AMR), which surrounds Al Maha Desert Resort and Spa and it has been fenced since 1999. Wild life included in the DDCR includes Arabian Oryx, Sand Gazelle and Arabian Gazelle. During the previous survey there were a number of camel farms in the DDCR, with a total of 1209 camels (Alqamy, 2004), those numbers were reduced to approximately 600 camels in March 2007, the majority moving out of the Southern half of the DDCR. In December 2008 the remaining livestock was removed from the DDCR.

The habitat of DDCR is a sand dune desert ecosystem; dominated by low to medium size sand dunes, interspersed gravel plains. The altitude ranging from a maximum of 260m above sea level in the south and gradually decreases to 180m in the North. Map 1 shows the location of DDCR and the topography of the area.



Map 1: Location and Topography of the Dubai Desert Conservation Reserve

Climate

The climate of the UAE is characterized by low rainfall and high temperatures, with most of the precipitation occurring between December and April. For the last three years there has been continuous meteorological data recording from the three weather stations (north, base and south) installed across the DDCR.

Table 1 shows the mean temperature, total rainfall and average wind speed at the three weather stations. Figures 1, 2 and 3 shows the annual rainfall at the North, Base and South stations

		Temp.	Rain	wind Speed
NORTH	2006	27	52	93
	2007	28	29	105
	2008	27	49	90
BASE	2006	28	57	81
	2007	28	22	66
	2008	15	48	61
SOUTH	2006	28	30	82
	2007	28	26	90
	2008	27	52	105

Table 1: Summary of weather data for the DDCR

Figure 1: Annual Rainfall 2006

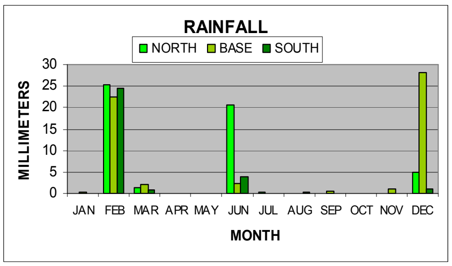


Figure 2: Annual Rainfall 2007

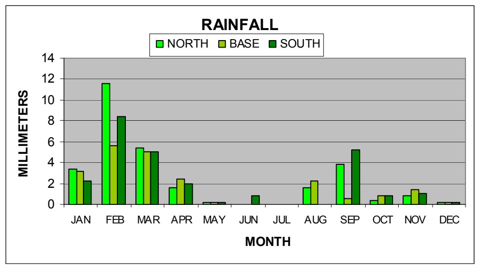
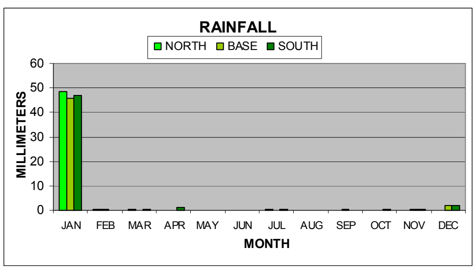


Figure 3: Annual Rainfall 2008



From the graphs and table above we could summarize that the total sum of Rain in the years 2006, 2007 and 2008 was 140mm, 76mm and 149 respectively. The temperature mean high was 28˚C and the mean low temperature was 15˚C. The highest temperature recorded during the years 2006, 2007 and 2008 was 30˚C, 48˚C and 48˚C respectively; while the lowest temperature recorded were 10˚C, 6˚C, and 4˚C respectively. The climate data is very helpful when studying vegetation to predict the habitat improvement and rehabilitation, the variation in the annual rainfall is considerable.

Methodology

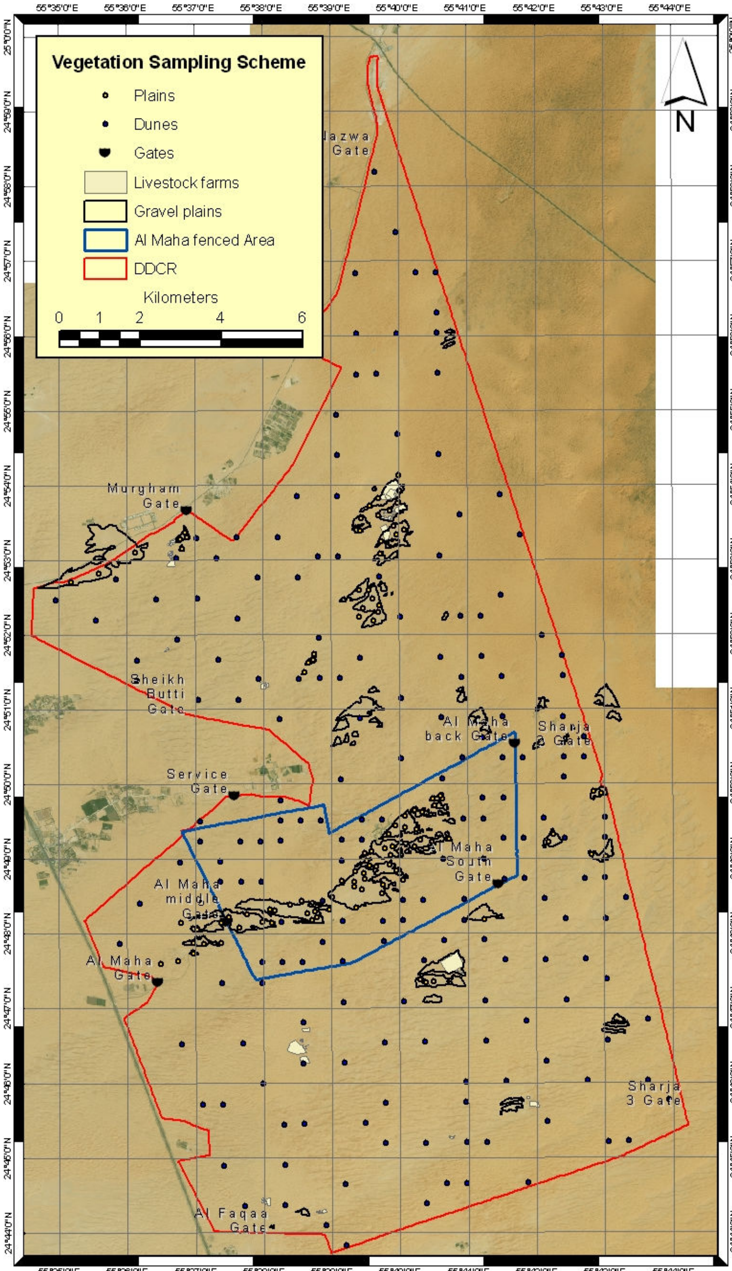
Following the same concepts and aims of the previous report titled "***Vegetation of the DDCR initial assessments and baseline data***" (Alqamy, 2004) which aimed to provide information about the status of the floral communities of DDCR which encompass two main themes of assessing the species diversity and making a comparison of floral communities in different habitats. The comparisons in the current report was specifically for the communities changes in Al Maha Reserve Gravel Plains (AMRGP), Al Maha Reserve Sand Dunes (AMRSD), Dubai Desert Conservation Reserve Gravel Plains (DDCRGP) and Dubai Desert Conservation Reserve Sand Dunes (DDCRSD) compare it to the year 2004. In addition the distribution of the individual species and species distribution patterns are also discussed.

The study was done using a plot sampling technique which randomly selected points while considering the two main habitats, Sand Dunes and Gravel Plains.

For each gravel plains in the AMR and DDCR there was a random selection of points using Random Sampling Extension in ArcView, each plain contained a different number of points depending on the plain surface area which maintain standard 10% cover. (Alqamy, 2004)

In the Sand Dune habitat a 500m x 500m grid was placed over the entire area and sampling points in each grid was generated using a randomization extension of ArcView dependent on total area of sand dune habitat.

At each point a circular plot was used for sampling which involves an area of 50m diameter and each plot in total is equivalent to 7000m^2.



Map 2: Vegetation sampling points

Plant species in each given plot were tentatively recorded in the field and put in tabulated form, giving the authentication of their identification with the help of the local floristic work (Jongbloed, 2003) and (Fawzi & Karim, 2007) Table 2 lists the species and taxa recorded.

No.	Species names	Family Names
1	*Acacia tortilis (Forssk.) Hayne*	Mimosaceae
2	*Aerva javanica (Burm.f.) Juss. Ex Schult.*	Amaranthaceae
3	*Arnebia hispidissima (Lehm.) DC.*	Boraginaceae
4	*Atractylis carduus (Forssk.) C. Chr.*	Asteraceae
5	*Bassia muricata (L.) Asch.*	Chenopodiaceae
6	*Calligonum comosum L'Her.*	Polygonaceae
7	*Calotropis procera (Aiton) W.T. Aiton*	Asclepiadaceae
8	*Centropodia forsskaolii (Vahl) Cope*	Poaceae
9	*Centaurea pseudosinaica Czerep.*	Asteraceae
10	*Chrozophora oblongfolia (Delile) Spreng.*	Euphorbiaceae
11	*Citrullus colocynthis (L.) Schrad.*	Cucurbitaceae
12	*Crotalaria aegyptiaca Benth.*	Fabaceae
13	*Cyperus conglomeratus Rottb.*	Cyperaceae
14	*Dipterygium glaucum Decne.*	Capparaceae
15	*Eremobium aegyptiacum (Spreng.) Boiss.*	Brassicaceae
16	*Fagonia indica Burm.f.*	Zygophyllaceae
17	*Fagonia Sp.*	Zygophyllaceae
18	*Farsetia linearis Decne. ex Boiss.*	Brassicaceae
19	*Haloxylon salicornicum (Moq.) Bunge ex Boiss.*	Chenopodiaceae
20	*Heliotropium digynum (Forssk.) Asch. Ex C.Chr.*	Boraginaceae
21	*Heliotropium kotschyi (Breg.) Gurke*	Boraginaceae
22	*Indigofera colutea (Burm.f.) Merr.*	Fabaceae
23	*Indigofera intricata Boiss.*	Fabaceae
24	*Leptadenia pyrotechnica (Forssk.) Decne.*	Asclepiadaceae
25	*Limeum arabicum Friedr*	Molluginaceae
26	*Lycium shawii Roem. & Schult.*	Solanaceae
27	*Moltkiopsis ciliata (Forssk.) I.M. Johnst.*	Boraginaceae
28	*Monsonia nevia (Decne.) Webb*	Geraniaceae
29	*Neurada procumbens L.*	Neuradaceae
30	*Ogastemma pusillum (Coss.&Durand ex Bonnet & Baratte) Brummitt*	Boraginaceae
31	*Panicum turgidum Forssk.*	Poaceae
32	*Pennisetum divisum (J.F.Gmel.) Henrard*	Poaceae
33	*Plantago boissieri Hausskn. & Bornm.*	Plantaginaceae
34	*Polycarpaea repens (Forssk.) Asch. & Schweinf.*	Caryophyllaceae
35	*Polygala erioptera DC.*	Polygalaceae
36	*Prosopis cineraria (L.) Druce*	Mimosaceae
37	*Rhanterium epapposum Oliv.*	Asteraceae
38	*Salvadora persica L.*	Salvadoraceae
39	*Sclerocephalus arabicus Boiss.*	Caryophyllaceae
40	*Sisymbrium erysimoides Desf.*	Brassicaceae
41	*Silene villosa Forssk.*	Caryophyllaceae
42	*Stipagrostis plumosa (L.) Munro ex T. Anders.*	Poaceae
43	*Tamarix aphylla (L.) Karst.*	Tamaricaceae
44	*Tribulus macropterus Boiss.*	Zygophyllaceae
45	*Tribulus omanense Hosni*	Zygophyllaceae
46	*Tribulus pentandrus Forssk.*	Zygophyllaceae

Table 2: Species and Taxa recorded in the DDCR

The following parameters were measured for each species in every single plot (Density, Relative Density, Frequency, Relative Frequency, Abundance, Relative Abundance, **Cover** and **Relative Cover**) by calculating these parameters the Significant Important Value Index **(SIVI)** could be identified; the species with the highest SIVI consider to be the dominant species of the Plot and the second highest species of SIVI consider to be the co-dominant species. These equations are descried in Annex (1). These parameters were used to assess in general the condition of the vegetation cover and to determine the community structure quantitatively. Diversity indices were also used to quantitatively assess the diversity of the plant communities and to compare different habitat. Many quantitative values have been developed by landscape ecologist to measure the spatial and temporal changes of species richness and diversity of ecosystems and also to compare between different habitats.

Field Method

In each map grid (500m x 500m) a varying number of circular 50m diameter plots were sampled for vegetation properties such as number of species, abundance per species, density, and cover. The number of sampling plots per map grid polygon was determined as to provide coverage of 10% of the polygon total area.

After all sampling points were uploaded to GPS receiver and navigation was done till reaching the predetermined fix. Within the site of the circular plot five 10m x 10m quadrates were sampled as follows: one central around the pole and 1 randomly situated at each of the 4 quarters of the circular plot and within 50m distance from the pole as to maintain coverage with in the 50m diameter of the circular plot (Fig 1).

Density was calculated on the basis of number of individuals within 500m² and then extrapolated to the larger 7000m² areas using the log-Series

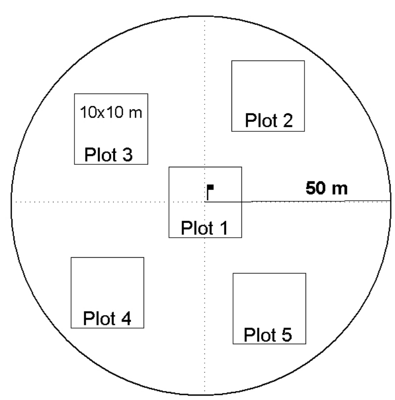


Fig (1)
In the Circular plot of 50 m diameter 5 plots of 10m x10m were sampled for floral species.

method of McAuliffe (1990). This method was preferred over conventional vegetation sampling methods (Muller –Dombois & Ellenberg, 1974) because its enhanced designed oriented to the special properties of the desert vegetation. It has the following advantages:

- The time required per plot is less when compared to time required per relevé in Braun-Blanquet sampling,
- Log-series method provides more information by including rapid estimation densities,
- The survey of large areas allows inclusion of a greater number of rare species than is possible using standard quantitative technique.

Data analysis

Alqamy, 2004 discussed that "Selecting a diversity index for a study could be a tricky task and the purpose of the study should be quite clear to enable good judgment". Peet (1974) recognized two categories of diversity indices. *Type I* indices are most sensitive to change in rare species in the community sample while *Type II* indices are most sensitive to changes in the more abundant species. An example of *Type I* indices are Shannon-Wiener index and Brillouin index. On the other hand Simpson's index is an example of *Type II* indices. In the current work representatives of both categories are used to provide wider range of monitoring possibilities for both types of changes in the future.

It is expected that there are differences in the floral communities structure between the two types of habitat (Sand Dunes and Gravel Plains) and between the two surveys done in 2004 and the one finished in 2009. Four different habitat communities are recognized in the DDCR reserve (DDCR Gravel Plains, DDCR Sand Dunes, Al Maha Gravel Plains and Al Maha Sand Dunes.

This report adopts a new methodology for data analysis added to the previous analysis which is the complementarity; covering the distinctness in species composition over a broad spectrum of environmental scales. (Colwell & Coddington, 1994) in the same reference they are discussion that using the concept of complementarity when it is appropriate and informative allows us to understand the local floral differences as positive components of biodiversity.

Comparing accurate species list for two sites, first site has a local richness of S_j species while the second has S_k species. If the number of species in common between the two lists is V_{jk} then the total richness for both sites combined is:

$S_{jk} = S_j + S_k - V_{jk}$

The number of species unique to either list (equivalently, the number of mismatches between the two lists) is:

$U_{jk} = S_j + S_k – 2V_{jk}$

Then the complementarity of the two lists is just:

$C_{jk} = U_{jk}/S_{jk}$

The complementarity is measured by C, varies from Zero (when the two lists are identical) to unity (when the lists are completely distinct); or from 0 to 100%

Result and Findings

The total number of plots sampled was 302 over the DDCR and AMR with a total area cover of 2,114,000m². The samples sites were split over the four different habitats as shown in Table 3. The survey was conducted during the period of July 2008 to February 2009.

Habitat	Sampling Points	Sampling area (m²)
AMR Gravel Plains	**52**	**364000**
AMR Sand Dunes	**46**	**322000**
DDCR Gravel Plains	**41**	**287000**
DDCR Sand Dunes	**163**	**1141000**

Table 3: Sample effort in DDCR & AMR

1.1 *Community Structure*

Following the same concept of sampling adopted by the previous report; two different sampling schemes were applied to ensure randomization and coverage. Still the results are comparable since the filed methodology and data analysis are the same for both types of habitat.

In the recent survey; the **Cover (C)** and the **Relative Cover (RC)** for each species have been added to the community structure analysis. The result considered to be Significant Important Value Index (SIVI). These added parameters increased the values of the Important Value Index (IVI) for each species for the last survey and gives another good indication for the habitat regeneration.

A table showing the vegetations parameters SIVI for 2009 survey in each habitats (AMRGP; AMRSD; DDCRGP and DDCRSD) while in the mean time the IVI for 2009 survey have been calculated to be compared with IVI of 2004 survey.

A complete data tables are shown in the Appendices

1.1.1 Al Maha Gravel Plains (AMRGP)

There was a double increase in the total number of the species recorded between this survey 2009 and the previous survey of 2004, where the total of 32 plant species were recorded on the gravel plains; A number of annual species have been recorded which indicates the positive rehabilitation of the gravel habitat during the last years. The recorded species includes trees, shrubs and herbs. Among all; the species *Heliotropium kotschyi* recorded the highest Significant Important Value Index and considered to be the dominant species of Al-Maha Gravel Plains; *Leptadenia pyrotechnica* and *Rhanterium epapposum* recorded the second and the third highest records and considered to be the co-dominant species of the gravel plains. From these data we can notice a shifting in the dominancy between *Fagonia indica* in the first survey to the *Heliotropium kotschyi* in the current survey and it shows that *Heliotropium kotschyi* have been raised in SIVI rank from Co-dominant species in the 2004 to Dominant in 2009 (*H. kotschyi* was more dispersed in the gravel plains in the 1st survey); while

Leptadenia pyrotechnica raised as well to be one of the co-dominant species where *Rhanterium* save its position as second co-dominant species in both surveys. *Fagonia indica* the dominant species in the first survey scored the fifth in the ranks of SIVI in this study.

The lowest SIVI species recorded around the gravel plains include; *Limeum arabicum* and *Citrullus colocynthis*; the abundance, frequency and the added cover measurements show very low over all occurrence, low frequency and cover; see Table 4 for the list of the recorded species on both survey along with the Important Value Index calculated for both surveys. See Figure 4 for the relative proportions of the community structure evaluated as SIVI values.

There is one species recorded in the first survey and not recorded in the current study which is (*Acacia tortilis*); while the addition of eighteen new species to this survey increased the diversity of the gravel plains.

Species List	SIVI	IVI (2009)	IVI (2004)
Acacia tortilis			**0.47**
Aerva javanica	**16.62**	**12.68**	**2.25**
Arnebia hispidissima	**57.59**	**53.98**	
Atractylis carduus	**9.80**	**9.71**	
Bassia muricata	**11.68**	**11.27**	
Calotropis procera	**42.39**	**6.94**	**2.25**
Centropodia forsskaolii	**18.31**	**18.22**	
Chrozophora oblongfolia	**14.19**	**11.86**	
Citrullus colocynthis	**3.49**	**3.28**	**0.47**
Crotalaria aegyptiaca	**24.05**	**8.12**	**17.65**
Dipterygium glaucum	**16.62**	**11.03**	**5.66**
Eremobium aegyptiacum	**30.39**	**26.39**	
Fagonia indica	**61.62**	**52.69**	**95.41**
Fagonia Sp.	**15.49**	**15.00**	
Farsetia linearis	**12.32**	**12.24**	
Haloxylon salicornicum	**16.62**	**13.85**	
Heliotropium digynum	**10.56**	**10.10**	**3.62**
Heliotropium kotschyi	**126.74**	**60.96**	**74.33**
Indigofera intricata	**10.61**	**10.59**	**3.21**
Leptadenia pyrotechnica	**75.81**	**16.15**	**9.63**
Limeum arabicum	**8.37**	**8.29**	**3.39**
Lycium shawii	**21.10**	**9.32**	**4.99**
Moltkiopsis ciliata	**31.76**	**30.84**	**36.77**
Monsonia nevia	**64.95**	**64.39**	
Neurada procumbens	**9.55**	**9.52**	
Panicum turgidum	**9.44**	**9.22**	

Pennisetum divisum	**15.62**	**9.64**	
Polycarpaea repens	**10.87**	**10.86**	
Rhanterium epapposum	**73.31**	**49.65**	**39.92**
Sisymbrium erysimoides	**9.67**	**9.67**	
Stipagrostis plumosa	**26.35**	**26.04**	
Tribulus omanense	**9.27**	**9.20**	
Tribulus pentandrus	**11.69**	**11.58**	

Table 4: Vegetation parameters of plant species recorded on the AMR gravel plains

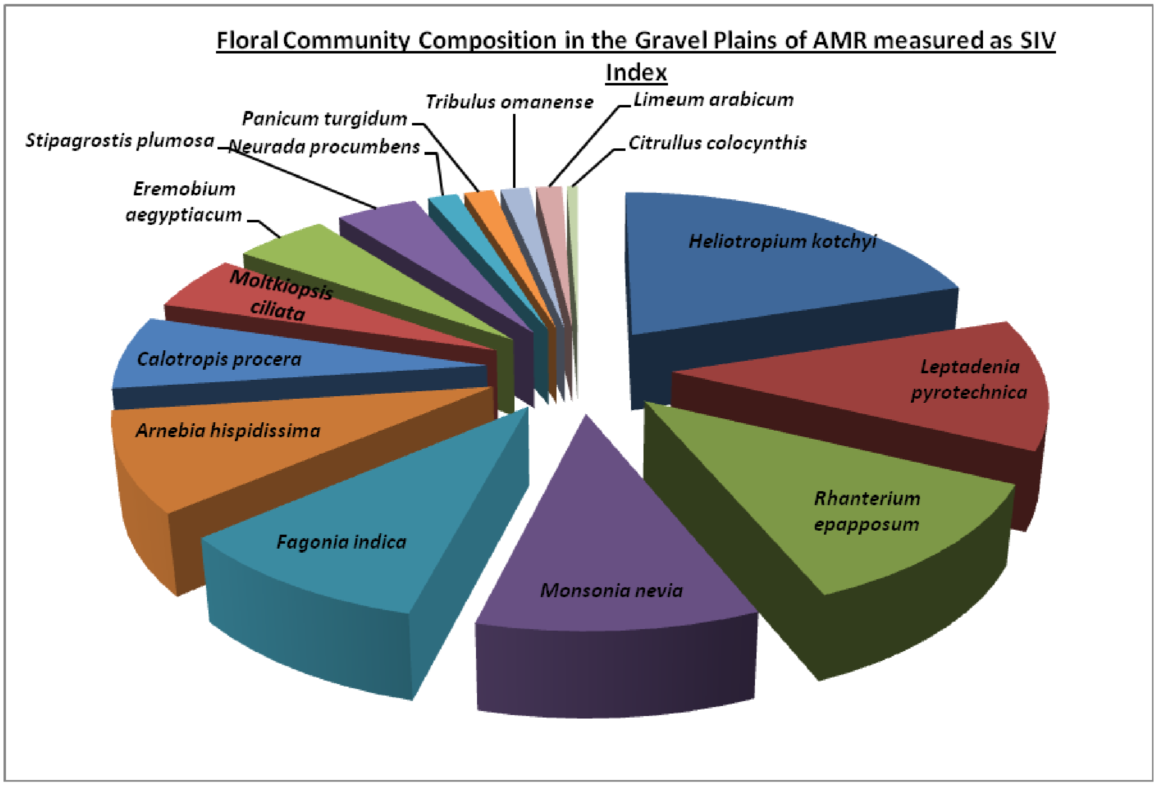


Figure 4: SIV Index of AMR Gravel Plains

Figure 4 shows the ten species with highest SIVI along with the five species with the lowest SIVI.

1.1.2 Al Maha Sand Dunes (AMRSD)

There was a two fold increase in the total number of the species recorded during the 2009 survey when compared to the previous survey of 2004, where the total of 30 plant species were recorded on the sand dunes of AMR; see Table 5 for the list of recorded species. The number of perennial species has increased dramatically; with an additional nine perennial species recorded. Five additional annual species were also recorded. This result indicates the positive rehabilitation of the Sand Dune habitat over the pervious 5 years.

Species List	SIVI	IVI (2009)	IVI (2004)
Aerva javanica	19.01	16.35	0.40
Arnebia hispidissima	27.18	26.70	
Atractylis carduus	12.55	12.54	
Bassia muricata	28.64	27.16	
Calligonum comosum	17.14	16.14	0.46
Calotropis procera	45.91	12.78	1.79
Centropodia forsskaolii	26.00	25.86	
Chrozophora oblongfolia	19.76	17.67	
Crotalaria aegyptiaca	41.77	24.99	23.59
Cyperus conglomeratus	62.68	56.70	110.82
Dipterygium glaucum	31.94	22.00	2.37
Fagonia indica	17.22	16.72	
Farsetia linearis	14.88	14.87	
Haloxylon salicornicum	47.31	25.85	1.83
Heliotropium digynum	95.39	68.31	37.51
Heliotropium kotschyi	136.06	94.29	2.86
Indigofera colutea	17.09	17.04	
Indigofera intricata	10.14	10.13	14.30
Leptadenia pyrotechnica	62.70	17.10	13.18
Limeum arabicum	57.08	35.84	44.01
Lycium shawii	18.52	14.87	0.99
Moltkiopsis ciliata	94.14	88.06	41.69
Neurada procumbens	56.33	51.46	
Panicum turgidum	12.52	11.01	2.04
Polygala erioptera	25.43	25.35	
Rhanterium epapposum	40.83	30.46	1.58
Rhynchosia minima			0.60
Salvadora persica	13.07	9.97	
Stipagrostis plumosa	19.34	19.07	
Tribulus macropterus	15.68	14.39	
Tribulus pentandrus	21.06	20.78	

Table 5: Vegetation parameters of plant species recorded on the AMR Sand Dunes

On AMR Sand Dunes *Heliotropium kotschyi* recorded the highest Significant Important Value Index (SIVI) and therefore is considered to be the dominant species; *Heliotropium digynum* and *Moltkiopsis ciliata* recorded the second and the third highest SIVI and are considered to be the co-dominant species of the

AMRSD. In comparison to the previous survey we notice a significant change in the plant community, the dominant species in 2004 was *Cyprus conglomeratus* while the 2009 dominant species *Heliotropium kotschyi* was only ranked eighth. The co-dominant species changed as well from *Limeum arabicum* in 2004 to *Heliotropium digynum* in 2009 and *Moltkiopsis ciliata* holds the same rank in both surveys.

The species with the lowest SIVI recorded on the AMRSD included; *Indigofera intricata* and *Panicum turgidum*; which showed very low over all occurrence, low frequency and cover.

There is one species recorded in the first survey and not recorded in the current study which is (*Rhynchosia minima*); while the addition of fourteen new species to this survey increased the diversity of the sand dune habitat.

Figure 5 illustrates the relative proportions of the community structure evaluated as SIVI values.

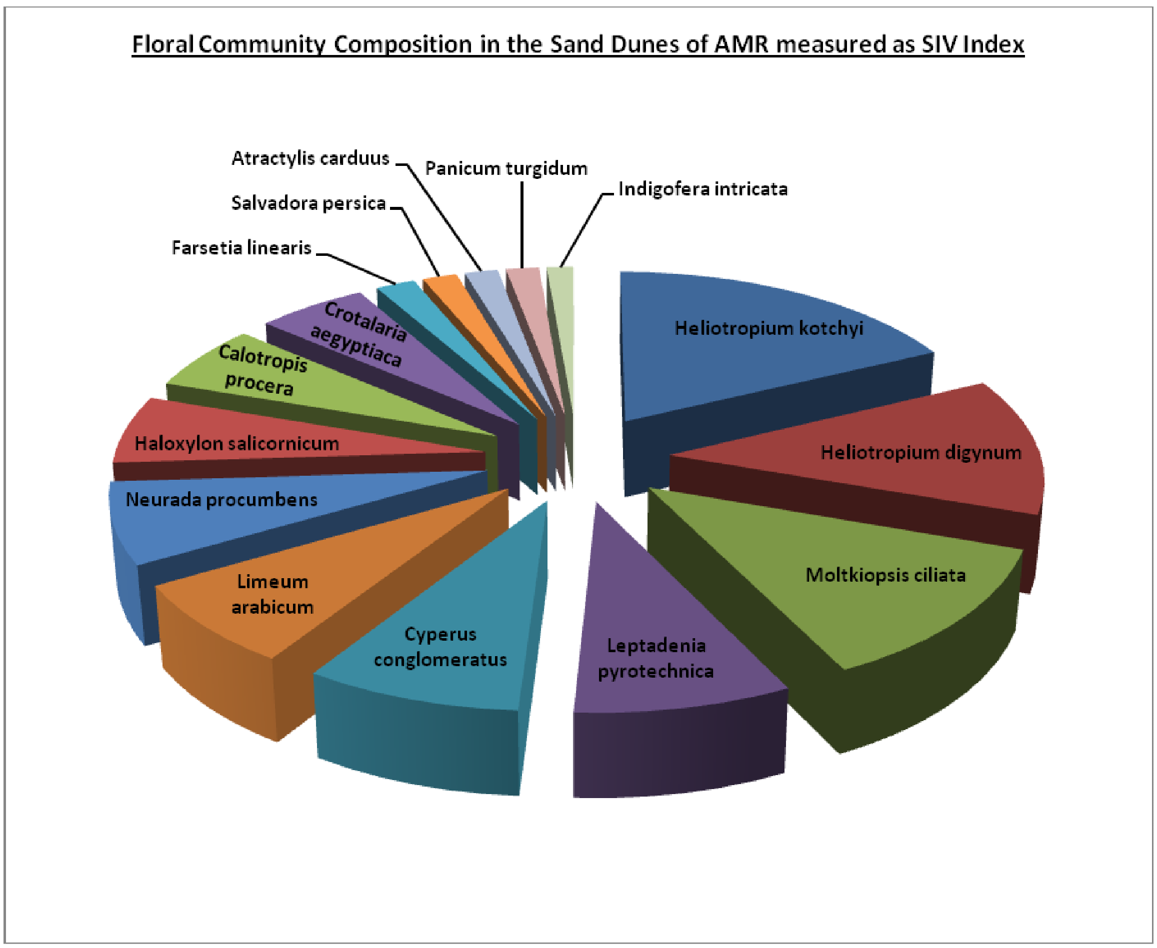


Figure 5: Significant Important Value Index of AMR Sand Dunes

1.1.3 DDCR Gravel Plains (DDCRGP)

The total number of species recorded in 2009 increased from the previous survey of 2004, when 15 species were recorded to a total of 27 plant species on the gravel plains of DDCR. .Eleven additional perennial species have been recorded in this survey as well as four additional annual species. There were three plant species recorded in the first survey that were absent in the 2009 survey (*Limeum arabicum*, *Acacia ehrenbergiana* and *Crotalaria retusa*)

However these results still indicate the positive rehabilitation of the Gravel Plains habitat during the past five years. Table 6 lists the recorded species

Species List	SIVI	IVI_09	IVI_04
Acacia ehrenbergiana			1.19
Acacia tortilis	89.24	44.12	30.76
Arnebia hispidissima	39.04	37.27	
Atractylis carduus	9.41	9.36	
Calotropis procera	66.51	28.73	21.41
Centropodia forsskaolii	91.59	84.41	
Citrullus colocynthis	69.93	39.92	4.75
Crotalaria aegyptiaca	63.34	58.22	1.19
Dipterygium glaucum	61.44	38.03	
Fagonia indica	124.72	107.11	5.36
Farsetia linearis	19.67	19.07	
Haloxylon salicornicum	152.96	94.33	8.31
Heliotropium digynum	29.11	28.28	7.74
Heliotropium kotschyi	29.34	26.69	1.19
Indigofera colutea	30.35	28.45	
Indigofera intricata	35.89	33.09	19.23
Leptadenia pyrotechnica	109.30	42.02	33.29
Limeum arabicum			5.36
Lycium shawii	86.59	58.27	24.94
Monsonia nevia	63.35	62.62	
Moltkiopsis ciliata	24.44	23.74	
Panicum turgidum	8.98	8.94	23.52
Pennisetum divisum	91.94	76.22	
Polycarpaea repens	47.02	46.45	
Rhanterium epapposum	65.10	45.58	87.64
Stipagrostis plumosa	74.95	68.65	
Tamarix aphylla	50.52	34.75	
Tribulus omanense	9.24	9.21	
Tribulus pentandrus	61.26	55.63	

Table 6: Vegetation parameters of plant species recorded DDCR gravel plains

Haloxylon salicornicum recorded the highest Significant Important Value Index and is considered the dominant species of the DDCR Gravel Plains; *Fagonia indica* and *Leptadenia pyrotechnica* recorded the second and the third highest records and are the co-dominant species of the Gravel Plains. These results show a significant change in the plant communities while comparing the two surveys; in 2004 the dominant species were *Rhanterium epapposum* while the co-dominant species were *Leptadenia pyrotechnica* and *Acacia tortilis* respectively. *Haloxylon salicornicum*, the 2009 dominant species, was only ranked eighth in 2004

The species with the lowest SIVI recorded on the DDCR Gravel Plains include; *Tribulus omanense* and *Panicum turgidum* which show very low over all occurrence, low frequency and cover.

Acacia ehrenbergiana and *Limeum arabicum* were recorded in the first survey and but were not present in the 2009 survey.

An additional fourteen species to this survey increased the diversity of the DDCR Gravel Plains.

Figure 6 show the relative proportions of the community structure evaluated as SIVI values.

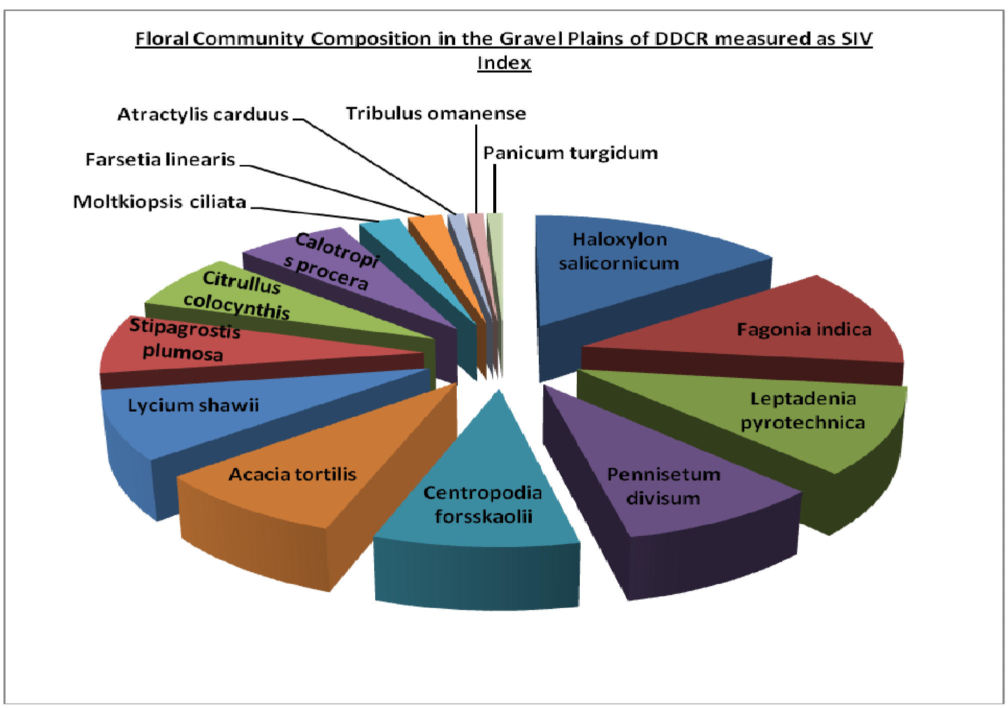


Figure 6: SIV Index of DDCR Gravel Plains

1.1.4 DDCR Sand Dunes (DDCRSD)

A total of 34 species were recorded in DDCR Sand Dunes adding 16 species to the 2004 survey. Table 7 lists the recorded species.

Species List	SIVI	IVI_09	IVI_04
Arnebia hispidissima	9.90	9.75	
Aerva javanica			0.11
Calligonum comosum			0.11
Calotropis procera	49.67	22.72	7.63
Centaurea pseudosinaica	27.48	26.65	
Centropodia forsskaolii	59.19	58.88	
Chrozophora oblongfolia	36.04	35.20	
Cistanche tubulosa			0.13
Citrullus colocynthis	47.12	18.00	2.68
Crotalaria aegyptiaca	18.36	17.09	2.68
Cyperus conglomeratus	149.35	115.57	162.54
Dipterygium glaucum	37.80	29.67	
Eremobium aegyptiacum	205.37	187.25	
Erucaria hispanica			0.79
Fagonia indica	28.81	22.69	
Farsetia linearis	7.71	7.71	
Haloxylon salicornicum	66.08	34.88	13.46
Heliotropium digynum	29.00	27.95	31.38
Heliotropium kotschyi	39.23	36.54	0.64
Indigofera colutea	33.6	33.03	4.68
Indigofera intricata	14.17	14.07	4.33
Leptadenia pyrotechnica	102.05	34.07	21.27
Limeum arabicum	81.37	53.63	12.37
Lycium shawii			0.68
Moltkiopsis ciliata	39.89	39.47	19.83
Monsonia nevia	32.21	32.15	
Neurada procumbens	17.30	17.23	
Ogastemma pusillum	30.01	29.98	
Panicum turgidum	17.86	15.87	6.57
Pennisetum divisum	27.20	22.12	0.11
Plantago boissieri	30.29	30.25	
Polycarpaea repens	21.30	21.23	
Prosopis cineraria	41.79	41.75	0.72
Rhanterium epapposum	38.37	34.83	3.89
Rhynchosia minima			0.64
Silene villosa	7.18	7.18	
Stipagrostis plumosa	34.87	34.45	
Tribulus macropterus	18.73	18.62	2.07
Tribulus omanense	8.94	8.87	0.72
Tribulus pentandrus	20.29	20.12	

Table 7: Vegetation parameters of plant species recorded on the DDCR Sand Dunes

Surprisingly, *Eremobium aegyptiacum* was the dominant species with the highest SIV Index with the highest dynasty, frequency and abundance among the recorded species; though it recorded the lowest cover but still the overall score was greater than the other species. *Cyperus conglomeratus* and *Leptadenia pyrotechnica* recorded the second and the third high SIVI and are considered the Co-Dominant species. The lowest SIVI species recorded on the DDCR Sand Dunes included; *Farsetia linearis* and *Silene villosa*; showing very low over all occurrence, low frequency and cover.

There are six species recorded in the 2004 survey and not recorded in the 2009 survey *Aerva javanica; Calligonum comosum; Cistanche tubulosa; Erucaria hispanica; Lycium shawii & Rhynchosia minima*.

However the addition of sixteen new species to this survey increased the diversity of the DDCR Sand Dunes.

See Figure 7 for the relative proportions of the community structure evaluated as SIVI values.

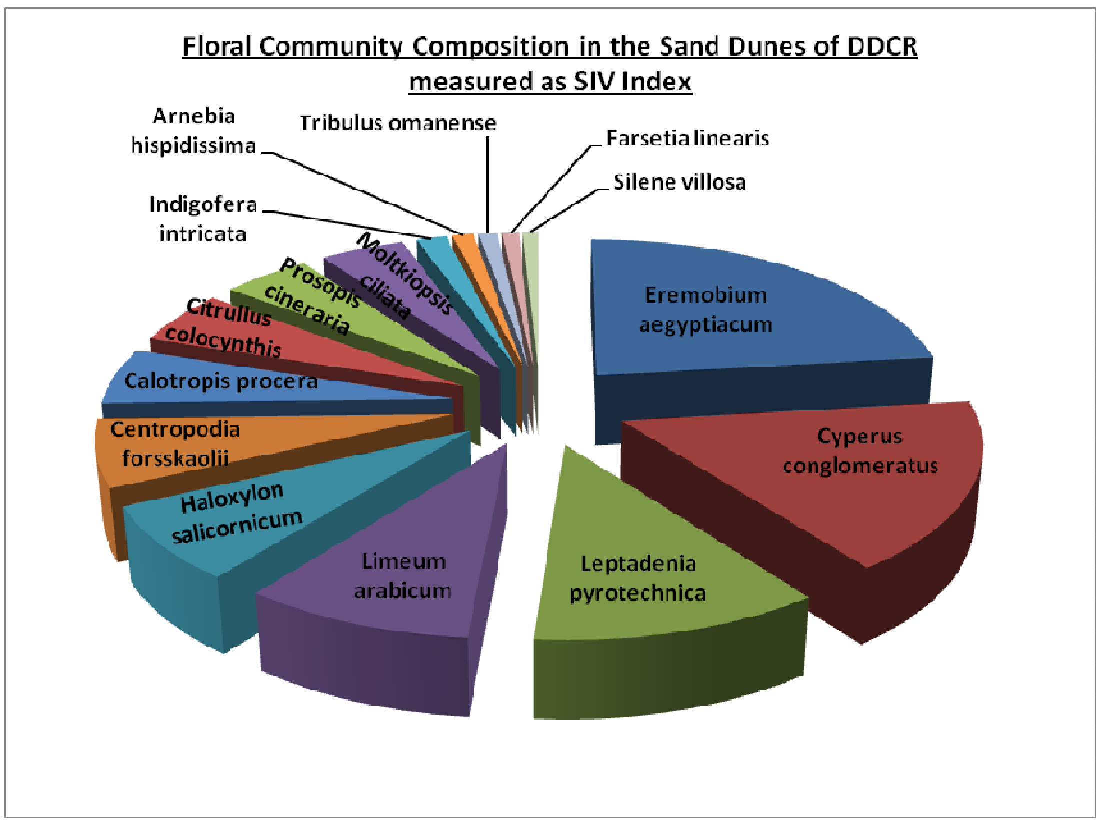


Figure 7: SIV Index of DDCR Sand Dunes

The 2009 survey results clearly show the positive differences in the floral composition of both habitat types (Sand Dunes and Gravel Plains) when compared to the survey in 2004.

The habitat has shown an overall recovery especially in the southern range of the DDCR, were domestic livestock was removed in March 2007. The species richness by the mean of the total number of species and the new species recorded indicates positively on the conservation of the DDCR vegetation and it bodes well for the future of the DDCR vegetation as all the domestic livestock was removed in December.

1.2 Floral Diversity and Species Richness

The flora of UAE is lacking any endemic species and characterized with low diversity in most of UAE vegetation habitat (Alqamy, 2004).

	Species	**AMRGP**	**AMRSD**	**DDCRGP**	**DDCRSD**
1	*Acacia tortilis*				
2	*Aerva javanica*				
3	*Arnebia hispidissima*				
4	*Atractylis carduus*				
5	*Bassia muricata*				
6	*Calligonum comosum*				
7	*Calotropis procera*				
8	*Centaurea pseudosinaica*				
9	*Centropodia forsskaolii*				
10	*Chrozophora oblongfolia*				
11	*Citrullus colocynthis*				
12	*Crotalaria aegyptiaca*				
13	*Cyperus conglomeratus*				
14	*Dipterygium glaucum*				
15	*Eremobium aegyptiacum*				
16	*Fagonia indica*				
17	*Fagonia Sp.*				
18	*Farsetia linearis*				
19	*Haloxylon salicornicum*				
20	*Heliotropium digynum*				
21	*Heliotropium kotschyi*				
22	*Indigofera colutea*				
23	*Indigofera intricata*				

24	*Leptadenia pyrotechnica*				
25	*Limeum arabicum*				
26	*Lycium shawii*				
27	*Moltkiopsis ciliata*				
28	*Monsonia nevia*				
29	*Neurada procumbens*				
30	*Ogastemma pusillum*				
31	*Panicum turgidum*				
32	*Pennisetum divisum*				
33	*Plantago boissieri*				
34	*Polycarpaea repens*				
35	*Polygala erioptera*				
36	*Prosopis cineraria*				
37	*Rhanterium epapposum*				
38	*Salvadora persica*				
39	*Silene villosa*				
40	*Sisymbrium erysimoides*				
41	*Stipagrostis plumosa*				
42	*Tamarix aphylla*				
43	*Tribulus macropterus*				
44	*Tribulus omanense*				
45	*Tribulus pentandrus*				

Table 8: Species distribution by habitat within the DDCR

Table 8 displays the distribution of the recorded species in the four habitat categories. A total of 45 species were recorded during the survey.17 species were common in all habitats types and 12 were unique to only one habitat type.

A total of 38 species (21 species in 2004 Survey) were naturally occurred in both the AMR gravel plains and sand dunes. Gravel plains harbored 33 different species (15 species in 2004 survey) while the sand dunes contained 30 species (17 species in 2004 survey). 25 species were common to both the habitats. Two species were unique to AMRGP and three species were unique to AMRSD.

A total of 38 species were naturally occurring in both DDCR Gravel Plains and Sand Dunes habitat; gravel plains harbored 27 species and the sand dunes harbored 34 species. 23 species were common to both the habitats. Two species were unique to DDCRGP and five species were unique to DDCRSD

However species numbers gives little indication about the true diversity of any community. Following the methodology adopted in the previous report; the indices of Simpson, Shannon-Weiner and Brillouin were used to estimate the floral diversity and compare it with the previous data to check for the habitat diversity improvements; these results show the diversity estimates as point estimates. See Table 9 & 10

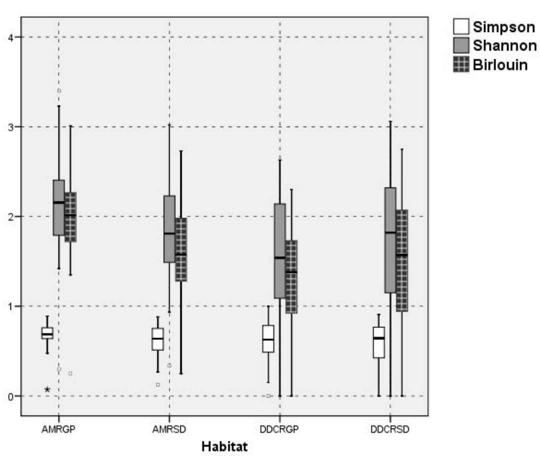
Index	AMRGP05	AMRGP08	AMRSD05	AMRSD08
Simpson	0.737	0.971	0.748	0.97
Shannon-Weiner	2.35	5.4	2.52	5.26
Brillouin	2.34	5.37	2.5	5.2

Table 9: Floral Diversity Estimates for Plant Community in AMR

Index	DDCRGP05	DDCRGP08	DDCRSD05	DDCRSD08
Simpson	0.831	0.953	0.542	0.985
Shannon-Weiner	3.04	4.75	2.05	6.67
Brillouin	2.91	4.68	2.04	6.62

Table 10: Floral Diversity Estimates for Plant Community in DDCR

The indices showing that there are changes in all habitats between the two surveys, all three indices have increased compared to the 2004 survey. It did not dramatically increased within the Simpson index because it is Type II index where it is most sensitive to the more abundant species; while it is nearly doubled or even tripled in Shannon-Weiner and Brillouin indices which are both consider to be type I indices most sensitive to rare species in the habitat. This is clear by seeing the species list and the number of new species recorded in this survey, most of which are annuals with low recorded number.



Boxplots used to identify and visualize heterogeneity, it is non-parametric method, and the space between the different parts of the box helps indicates the degree of dispersion and skewness in the data.

Figure 7: Diversity indices and their 95% confidence intervals

The boxplot illustrates that for the Simpson index, which is Type II, there is little differences between the four habitats. While for the Type I indices of Shannon-Weiner and Brillouin the AMR Gravel Plains habitat shows greater vegetation diversity when compared to the other three habitats.

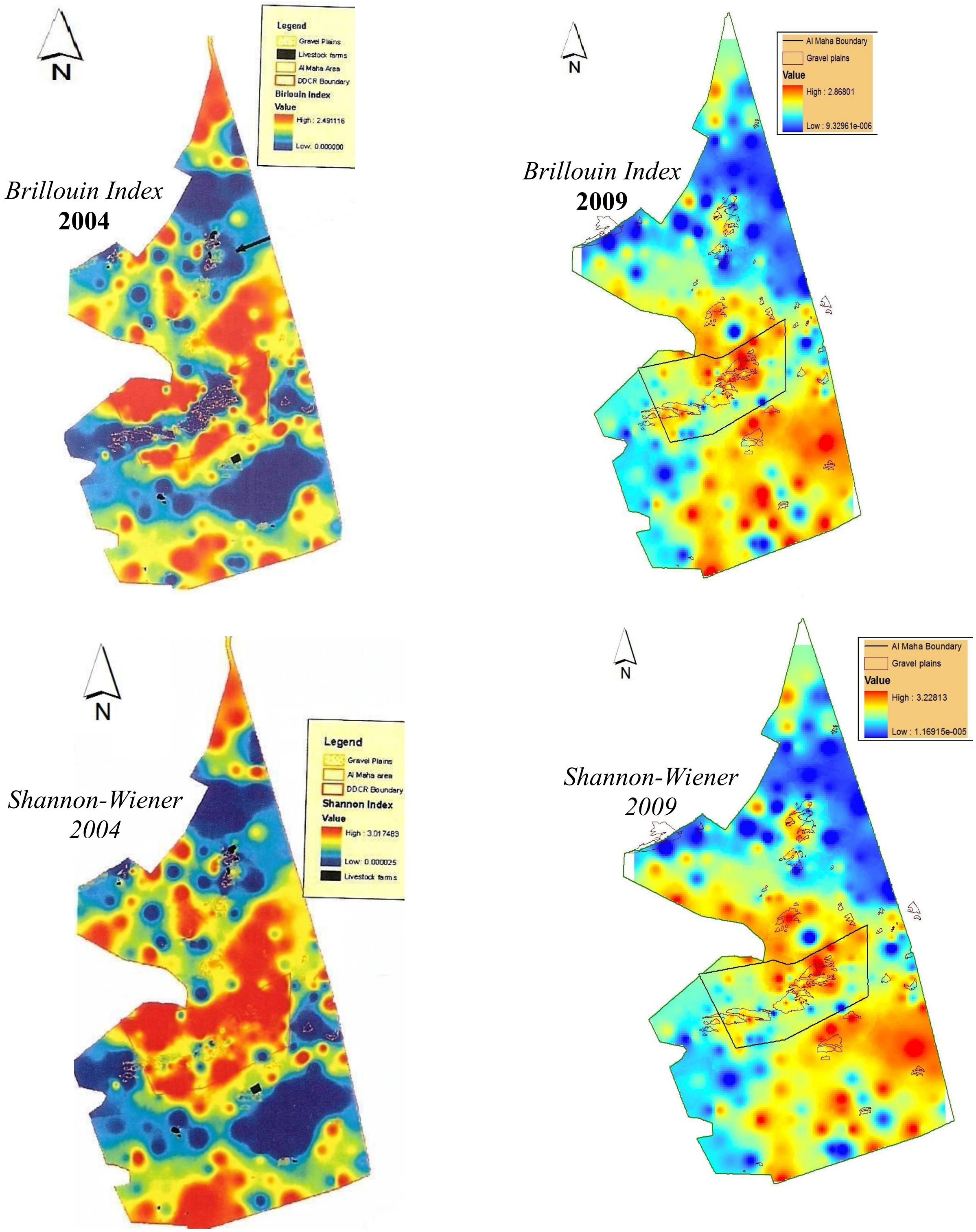
Al Maha Gravel Plain diversity increased over the AMR Sand Dunes compared to the previous survey.

On the other hand DDCR sand dunes diversity increased over the DDCR gravel plain comparing to the 2004 survey, this can be attributed to the effect of the free roaming camel herds and their negative impact on the floral diversity over the gravel plains. Alqamy, 2004 explained that there is a suggestion of a preference for the gravel plains as a grazing area by livestock and thus the plains flora is more heavily and adversely impacted when compared to the sand dunes habitat. In the case of the DDCR sand dunes; Since March 2007 the camel farms have been removed from the south range of the reserve allowing the habitat to recover and therefore increasing the diversity index for the DDCR sand dunes when compared to the DDCR gravel plains.

Predicted Floral Diversity in DDCR

The value of the diversity indices of individual plots over sand dunes and gravel plains were used to interpolate predicted diversity in un-sampled areas and to produce an overall picture of how diversity is changing over the entire DDCR. Kriging of the observed biodiversity values is used. This method uses the autocorrelation within the observed data to predict the parameter under investigation. The results showed that there is overall recovery in the southern range of the DDCR while in the AMR the diversity was reduced compared it to the 2004 survey. There are a lot of diversity hotspots distributed mainly in the south range indicate the recovery of vegetation, while in AMR there are some areas where the diversity affected from the local overgrazing of Oryx and gazelle. The area of the big camel farms shows a great deterioration in the vegetation diversity. See map (3) for the type (I) indices (Brillouin and Shannon-Wiener) and map (4) for the type (II) indices (Simpson).

Type (I) indices: more sensitive to changes in rare species in the community sampled



<u>Figure 8: Predicted floral diversity in the DDCR by Kriging, Type (I) indices (Brillouin and Shannon-Wiener)</u>

Type (II) indices: most sensitive to changes in more abundant species in the community sampled

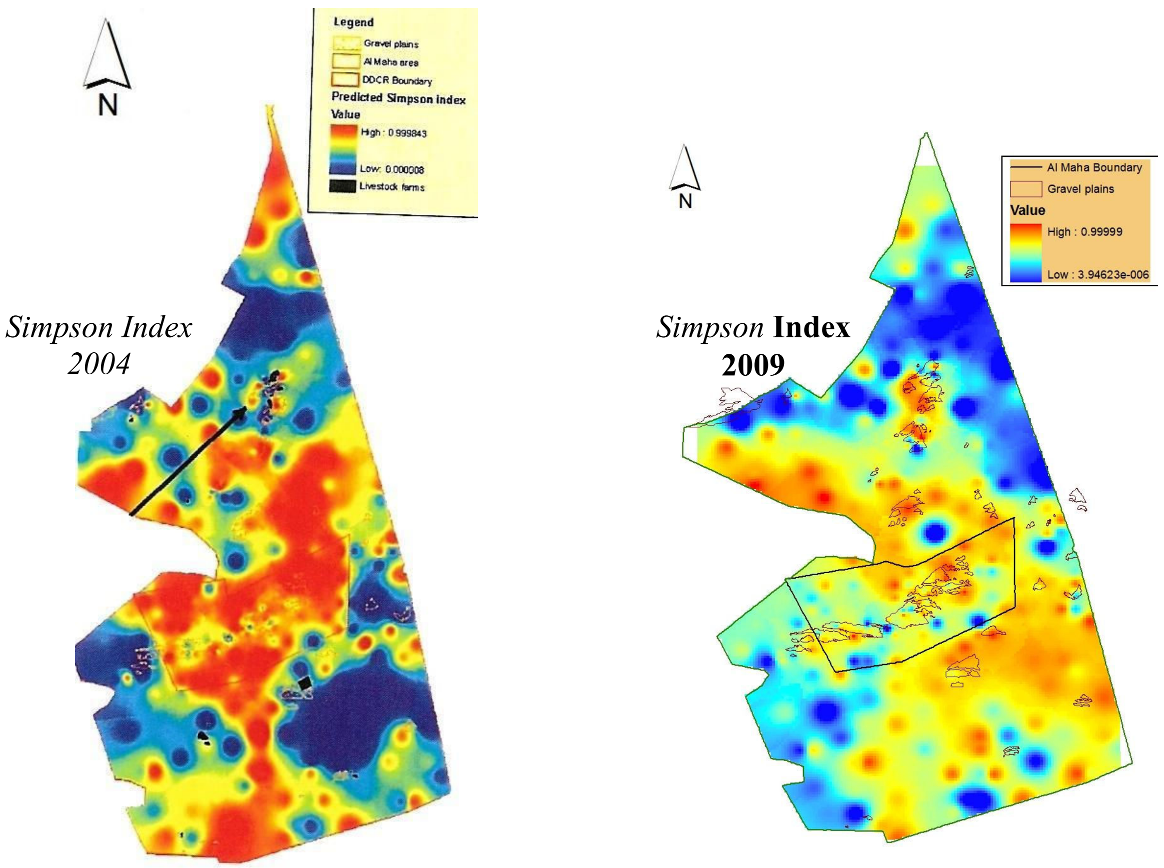


Figure 9: Predicted floral diversity in DDCR by Kriging, Type (II) indices (Simpson)

Key Finding

Comparing the key finding of the last survey with the recent survey result shows that:

- The south range showing higher diversity than the rest of the reserve, while in the AMR showing some deterioration in the vegetation diversity which indicates to the overgrazing from the wild animals (Oryx and Gazelle) inside the AMR.
- The Significant Important value Index of *Calotropis procera* within AMR Gravel Plains and Sand Dunes compared to DDCR Gravel Plains and

Sand Dunes showed that the SIVI of *C. procera* scored very high in the DDCR gravel Plains (67) while in AMR Gravel Plains scored only (7) the results giving the same indication of diversity degradation and direct result of overgrazing in DDCR Gravel Plains which indicates the effect of camel grazing. After removing all camel farms from the reserve it will give a very promising results in the next surveys.

1.3 Species Dispersion

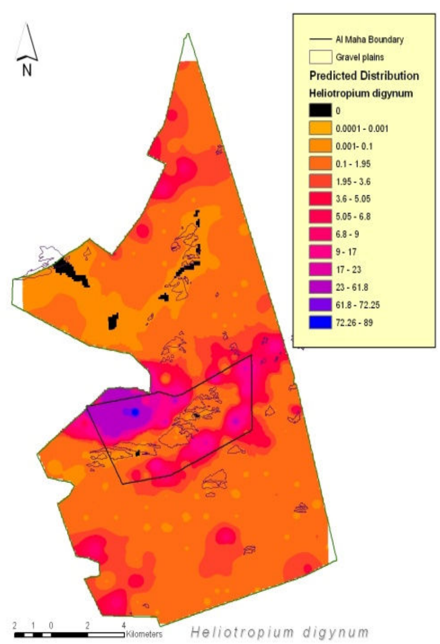
Kriging was used as the method to predict the spatial pattern of species involved in the study. The input was the abundance counts of samples over the study region of DDCR. The prediction was applied to selected species of the herbs and shrub vegetation layers.

Herb layer

Seven species were selected; *Heliotropium digynum*; *Fagonia indica*; *Moltkiopsis ciliate*; *Rhanterium epapposum*; *Dipterygium glaucum*; *Limeum arabicum*; *Cyperus conglomerates*. Most of these species are common in both Gravel Plains and Sand Dunes and were selected in the 2004 report.

1- ***Heliotropium digynum***

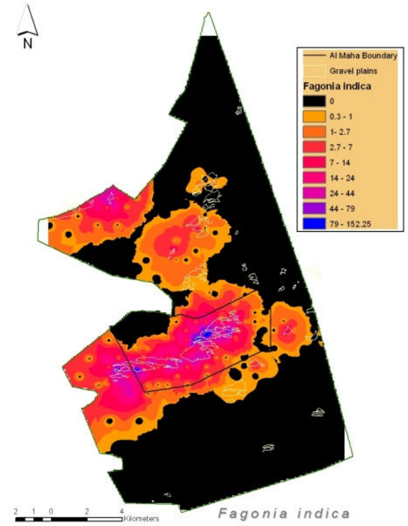
This herb shows a very good dispersed distribution over the sand dunes of both DDCR and AMR but still has restricted distribution over the Gravel plains. The map shows that the plants preferred habitat is sand dunes however there is an increase in the dispersed distribution over the gravel plains of AMR where many nucleus of the species high diversity have been developed. The plant seems to be least affected by grazing compared to other herbal species as it does occur in the lower



densities where other species are rare.

2- *Fagonia indica*

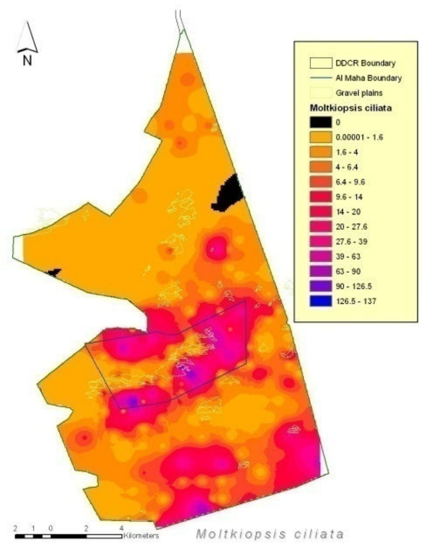
The species showed a great recovery and a very good dispersed distribution over all the gravel plains of AMR while in DDCR it showed a good recovery over some of the gravel plains Near Margham gate and near the Tawi Ruwayyan, the plant favored habitat is the Gravel Plains so it got a little to no dispersed distribution over the sand dunes of both AMR and DDCR.



F. indica is the pioneer species in the recently recovered gravel plains habitat.

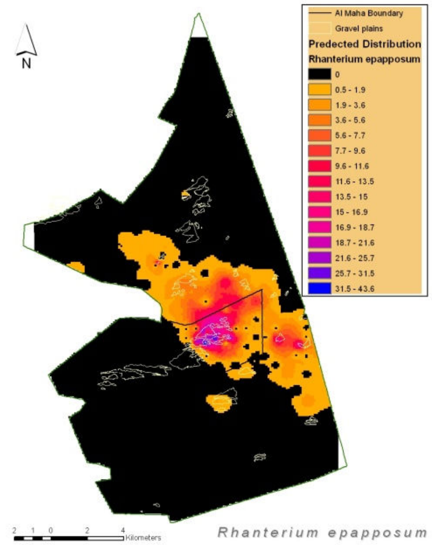
3- *Moltkiopsis ciliata*

The species shows a very good dispersed distribution better than previously recorded, the number of the hotspots increased widely over both AMR and DDCR and in both Gravel Plains and Sand Dunes habitats. There is only a small area of void distribution along the fence of Sharjah border.



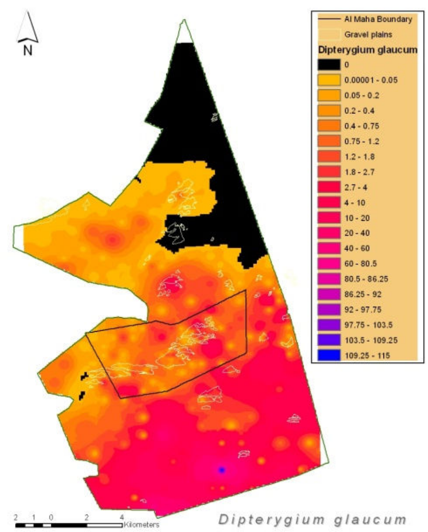
4- *Rhanterium epapposum*

The species still shows a remarkable trend in its dispersed distribution over the gravel plains in AMR and DDCR as it was mentioned in the previous report, the species was recorded on the gravel plains east of 55° 39.5’ and is still very abundant in this area and cannot be considered as rare. It was however rarely recorded to the west of this boundary.

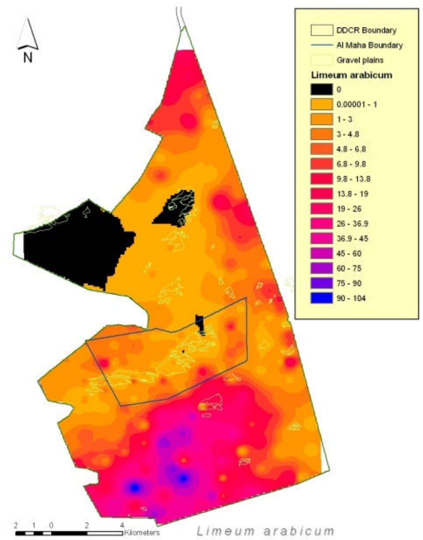


5- *Dipterygium glaucum*

The species showed a remarkable variation in the dispersed distribution over the AMR and DDCR habitats, the only area with void distribution is the area of the far north of the reserve and near the Tawi Ruwayyan; but the rest of the reserve shows a great recovery in the distribution. The southern range of the reserve showing the highest recovery sites; Al Maha Reserve showed a good dispersed distribution as well without any void areas compared to the previous report’s maps.

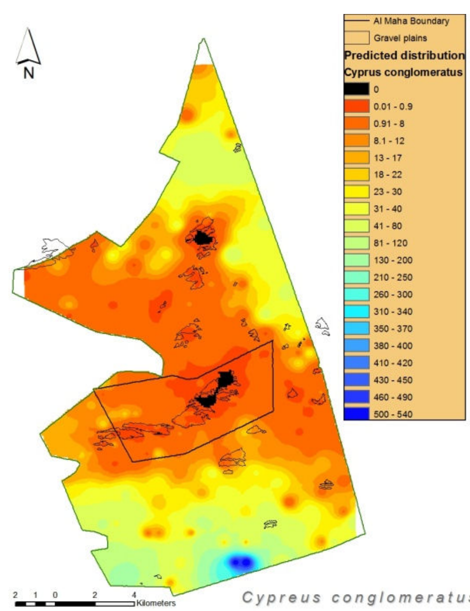


6- *Limeum arabicum*



The species developed very well in the south east range of the reserve and in the far north near Nazwa, this species mainly favors the sand dunes habitat and is rarely seen on the Gravel Plains. The plant is totally void in the area around the Tawi Ruwayyan and the area around Margham gate results that are due to the effects of overgrazing by livestock, mainly camels. In contrast to the previous survey results; the species showed considerable higher density in the southern range sand dunes compared to the dunes of the AMR, it is an indication that the southern range has recovered very well after the removal of the camel farms while in the AMR there is an effect of overgrazing pressure from the wild ungulates, Arabian Oryx and gazelle, redistributing herds will be a good managerial decision over the next year.

7- *Cyperus conglomerates*



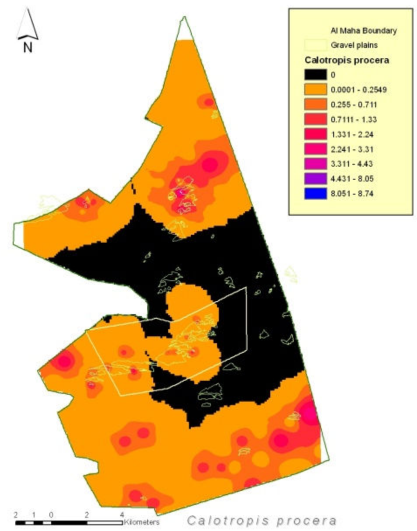
This species is still the most widespread and abundant species over the study areas, while it is void over the gravel plains in AMR and DDCR, the species is considered as sand dunes specialist and has never been recorded on the gravel plains. The species shows even dispersed distribution over the reserve dunes while in the southern range two new nucleus hotspots have formed.

Shrub layer

Three species were selected: *Calotropis procera*; *Haloxylon salicornicum*; *Leptadenia pyrotechnica*. These species are common in both Gravel Plains and Sand Dunes habitats. These species were selected to make the comparison with the previous surveys.

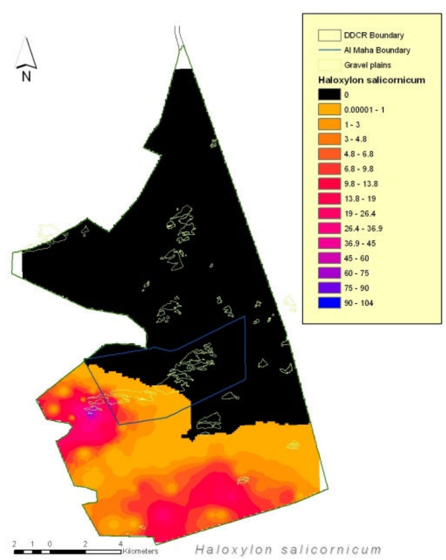
1- *Calotropis procera*

This species changed its pattern of relatively high abundance in the south eastern corner to a moderate abundance, this distribution is due to its relationship with other shrub species; the *C. procera* is a weak competitor and in areas where other species such as *Haloxylon salicornicum* and *Leptadenia pyrotechnica* are abundant the *C. procera* seems to be of a lower profile and is only thriving in areas where some adverse factors are affecting the habitat (e.g. Overgrazing).



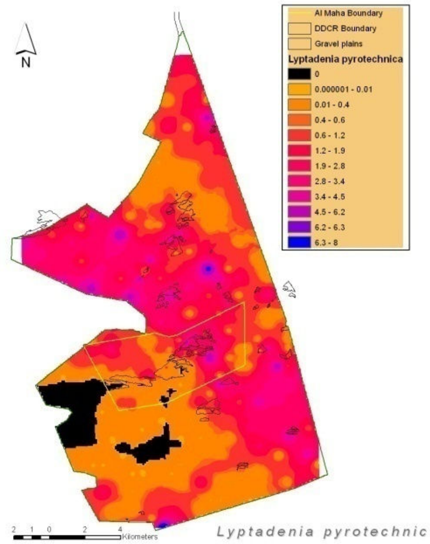
2- *Haloxylon salicornicum*

This species still have a very distinctive and discrete pattern of distribution as was recorded in the previous report; it is still restricted to the south western corner with little development to the south east and west of the reserve and not to be found any where else further to the north, investigation is required to rule out the effect of other factors such as soil compositions.



3- ***Leptadenia pyrotechnica***

This species showed a good overall improvement despite the void in dispersing distribution in the area around Al Maha Gate and the area around the Tawi Sohail. The area of high concentration is spread diagonally across the reserve as the effect of the livestock farms was significant in the distribution of the species. There is a great hope that in the coming years there will be a different positive distribution over the DDCR.



Complementarity

Complementarity is the process of covering the distinctness in species composition over a broad spectrum of environmental scales. (Colwell & Coddington, 1994) in the same reference they discussion that using the concept of complementarity when it is appropriate and informative allows us to understand the local floral differences as positive components of biodiversity. Using this new method to analyze the distinctness in species composition over the two deferent surveys and the different habitats showed that there is an obvious distinction between the two surveys.

1- Comparing accurate recorded species list of the **AMR Gravel Plains** during the 2004 and 2009 surveys showed that the total richness for both sites combined is: $S_{jk} = 32$

The number of species unique to either lists (equivalently, the number of mismatches between the two lists) is: $U_{jk} = 18$

Then the complementarity of the two lists is just: $\mathbf{C_{jk} = 0.56}$

2- Comparing accurate recorded species list of the **AMR Sand Dunes** during the 2004 and 2009 surveys showed that the total richness for both sites combined is: $S_{jk} = 31$

The number of species unique to either lists (equivalently, the number of mismatches between the two lists) is: $U_{jk} = 15$

Then the complementarity of the two lists is just: $\mathbf{C_{jk} = 0.48}$

3- Comparing accurate recorded species list of the **DDCR Gravel Plains** during the 2004 and 2009 surveys showed that the total richness for both sites combined is: $S_{jk} = 29$

The number of species unique to either lists (equivalently, the number of mismatches between the two lists) is: $U_{jk} = 16$

Then the complementarity of the two lists is just: $\mathbf{C_{jk} = 0.55}$

4- Comparing accurate recorded species list of the **DDCR Sand Dunes** during the 2004 and 2009 surveys showed that the total richness for both sites combined is: $S_{jk} = 40$

The number of species unique to either lists (equivalently, the number of mismatches between the two lists) is: U_{jk} = 22

Then the complementarity of the two lists is just: **C_{jk} = 0.55**

The complementarity is measured by C, varies from Zero (when the two lists are identical) to one (when the lists are completely distinct); or from 0 to 100%

From the above results it shows clearly that the two surveys are more distinct than being identical and that this is due to the good recovery of the southern range and the good conservational practice adopted by the reserve to manage the vegetation habitats. Furthermore it is quite promising for further recovery in the next few years as all the camel farms have been removed from the DDCR in December 2008 and this was the main threat or pressure affecting the flora habitat.

1.4 TWINSPAN

1.4.1 TWINSPAN Explained

TWINSPAN (**T**wo **W**ay **In**dicator **Sp**ecies **An**alysis) (Hill, 1979) implements a divisive classification method. This method is widely used in vegetation science by the mean of classifying the objects by hierarchical divisions and constructs an ordered two way table from the original species-by-site data table; it produces a tabular matrix arrangement that approximates the results of Phytosociological analysis tables.

TWINSPAN creates pseudospecies, each species is recorded into a set of dummy variables corresponding to relative abundance levels, and these classes are cumulative. In this study the cutting levels are 0%, 2%, 5%, 10% and 20% which mean a relative abundance of 5% at a site will fill the first and the second dummy pseudospecies vectors with “1” = (presence).

The main output of TWINSPAN is a two-way table of Species × Sites which provide the indicator values of the various species. Then a dendrograms can be easily drawn.

TWINSPAN is used in this study to outline the floral community in terms of species composition with the aid of dendrograms of quadrates clusters; the work done by PC-ORD Software ver. 4.25 packages.

1.4.2 Al Maha Gravel Plains and Dunes habitat

TWINSPAN used to classify the 98 AMR Gravel Plains and Sand Dunes sites into groups related to each other using Pseudo species cut levels of (0, 2, 5, 10 and 20), The maximum number of indicators per division was 5, the maximum levels of divisions used was 4, the minimum group size for each division was set at 5 and the maximum number of species in final table was set at 200.

1- **The first level of classification**

   The 98 sites were classified according to the following two indicator species, ***Fagonia indica*** and ***Arnebia hispidissima***, these species lead the division into two groups the negative group (*0) represented by 61 sites and the positive group (*1) represented with 37 sites.

2- **The second level of classification**

   Further explained the classification of the first level into:

   a- The negative group of the first level (61 sites) showed the classification into two groups according to one indicator species: ***Heliotropium kotschyi.***

      i- Negative group with a sign of (*00) - 42 sites.

      ii- Positive group with a sign of (*01) - 19 sites.

   b- The positive group of the first level (37 sites) showed the classification into two groups according to three different indicator species: ***Moltkiopsis ciliate***; ***Centropodia forsskaolii*** and ***Cyperus conglomerates***.

      i- Negative group with a sign of (*10) - 21 sites.

      ii- Positive group with a sign of (*11) - 16 sites.

3- **The third level of classification**

A- Worked on the group (*00) with 42 sites and the group (*01) with 19 sites:

a- Group (*00) with 42 sites classified according to the following indicator species: ***Arnebia hispidissima*** and ***Cyperus conglomerates***.

   i- Negative group with a sign of (*000) - 5 sites

   ii- Positive group with the sign of (*001) - 37 sites

b- Group (*01) with 19 sites classified according to the following indicator species: ***Stipagrostis plumosa*** and ***Fagonia indica***

   i- Negative group with a sign of (*010) - 11 sites.

   ii- Positive group with a sign of (*011) - 8 sites.

B- Worked on the group (*10) with 21 sites and the group (*11) with 16 sites:

a- Group (*10) with 21 sites were classified according to the following indicator species ***Tribulus macropterus***.

   i- Negative group wit a sign of (*100) - 2 sites.

   ii- Positive group with a sign of (*101) - 19sites.

b- Group (*11) with 16 sites classified according to the following indicator species: ***Heliotropium kotschyi***; ***Heliotropium digynum*** and ***Cyperus conglomerates***.

   i- Negative group with a sign of (*110) - 14 sites.

   ii- Positive group with a sign of (*111) - 2 sites.

4- **The fourth level of classification**

A- Worked on the group (*000) with 5 sites and the group (*001) with 37 sites:

a- Group (*000) with 5 sites classified according to the following indicator species: ***Arnebia hispidissima***

i- Negative group with a sign of (*0000) - 1 site (AMR-A habitat)

ii- Positive group with a sign of (*0001) - 4 sites (AMR-B habitat)

b- Group (*001) with 37 sites classified according to the following indicator species: ***Rhanterium epapposum***.

i- Negative group with a sign of (*0010) - 31 sites (AMR-C Habitat)

ii- Positive group with a sign of (*0011) - 6 sites (AMR-D Habitat)

B- Worked on the group (*010) with 11 sites and the group (*011) with 8 sites:

a- Group (*010) with 44 sites classified according to the following indicator species: ***Monsonia nevia***.

i- Negative group with a sign of (*0100) - 9 sites (AMR-E Habitat)

ii- Positive group with a sign of (*0101) - 2 sites (AMR-F Habitat)

b- Group (*011) with 8 sites classified according to the following indicator species: ***Limeum arabicum***.

i- Negative group with a sign of (*0110) - 6 sites (AMR-G Habitat)

ii- positive group with a sign of (*0111) - 2 sites (AMR-H Habitat)

C- Worked on the group (*100) with 2 sites and the group (*101) with 19 sites:

a- Group (*100) with 2 sites is too small for further classification (AMR-I habitat) b- Group (*101) with 19 sites classified according to the following indicator species: ***Crotalaria aegyptiaca***; ***Limeum arabicum*** and ***Leptadenia pyrotechnica***.

i- Negative group with a sign of (*1010) - 11 site (AMR-J Habitat)

ii- Positive group with a sign of (*1011) - 8 sites (AMR-K Habitat)

D- Worked on the group (*110) with 14 sites and the group (*111) with 2 sites

Group (*110) with 14 sites classified according to the following indicator species: ***Moltkiopsis ciliata***, ***Heliotropium digynum*** and ***Cyperus conglomerates***.

i- Negative group with a sign of (*1100) - 7 sites (AMR-L Habitat)

ii- Positive group with a sign of (*1101) - 7 sites (AMR-M Habitat)

Comments on AMR TWINSPAN result

- TWINSPAN program and analysis divided Al Maha gravel plains and sand dunes habitats into 13 habitat types according to the relation between the plant species and its abundance within the habitat types; it classified as follows (AMR-A; AMR-B; AMR-C; AMR-D; AMR-E; AMR-F; AMR-G; AMR-H; AMR-I; AMR-J; AMR-K; AMR-L; AMR-M)
- Out of 38 species recorded in AMR only 9 species were considered as indicator species for the habitat it represents; these species are as follows: *Arnebia hispidissima*; *Rhanterium epapposum*; *Monsonia nevia*; *Limeum arabicum*; *Crotalaria aegyptiaca*; *Leptadenia pyrotechnica*; *Moltkiopsis ciliata*; *Heliotropium digynum*; *Cyperus conglomeratus.*

- *Fagonia indica* established good communities over the gravel plains and was one of the early indicator species for gravel plains habitat recovery.

- *Arnebia hispidissima* growing very well on the gravel plains and in some flat sand dunes and is considered to be on of the important indicator species which lead the early classification of the habitat from the first level.

- *Monsonia nevia* an annual species considered to be as indicator for the habitat good regeneration and established very well on most of the gravel plains.

- There is a clearly distinctive amount of continuity and homogeneity in the structure and geographical spread of habitats

1.4.3 DDCR Gravel Plains and Dunes habitat

TWINSPAN was used to classify the 204 DDCR Gravel Plains and Sand Dunes sites into groups related to each other using Pseudo species cut levels of (0, 2, 5, 10 and 20), The maximum number of indicators per division was 5, the maximum levels of divisions used was 4 levels, the minimum group size for each division set at 5 and the maximum number of species in final table were set at 200.

1- **The first level of classification**

   The 204 sites were classified according to the following two indicators species (***Fagonia indica*** and ***Cyperus conglomerates***) these species lead divided the sites into two groups; the negative group (*0) represented by 173 sites and the positive group (*1) represented with 31 sites.

2- **The second level of classification**

   Classified the two groups from the first level:

   a- The negative group of the first level was classified into two groups according to five indicator species ***Cyperus conglomerates; Leptadenia pyrotechnica; Limeum arabicum; Centropodia forsskaolii*** and ***Stipagrostis plumose.***

      i- Negative group with a sign of (*00) - 122 sites.

ii- Positive group with a sign of (*01) - 51 sites.

b- The positive group of the first level was classified into two groups according to five indicator species ***Fagonia indica***; ***Haloxylon salicornicum***; ***Leptadenia pyrotechnica; Lycium shawii*** and ***Stipagrostis plumose***.

i- Negative group with a sign of (*10) - 18 sites.

ii- Positive group with a sign of (*11) - 13 sites.

3- **The third level of classification**

A- Classified the group (*00) with 122 sites and the group (*01) with 51 sites:

a- Group (*00) with 122 sites was classified according to the following indicator species: ***Centropodia forsskaolii***; ***Indigofera colutea***; ***Dipterygium glaucum***; ***Limeum arabicum*** and ***Haloxylon salicornicum***

i- Negative group with a sign of (*000) - 74 sites

ii- Positive group with the sign of (*001) - 48 sites

b- Group (*01) with 51 sites was classified according to the following indicator species: ***Tribulus pentandrus***; ***Cyperus conglomerates***; ***Lycium shawii*** and ***Moltkiopsis ciliate***

i- Negative group with a sign of (*010) - 44 sites

ii- Positive group with a sign of (*011) - 7 sites

B- Classified the group (*10) with 18 sites and the group (*11) with 13 sites

a- Group (*10) with 18 sites was classified according to the following indicator species: ***Stipagrostis plumose***.

i- Negative group with a sign of (*100) - 10 sites

ii- Positive group with a sign of (*101) - 8 sites

b- Group (*11) with 13 sites was classified according to the following indicator species: ***Fagonia indica***

i- Negative group with a sign of (*110) - 11 sites

ii- Positive group with a sign of (*111) - 2 sites

4- **The fourth level of classification**

E- Classified the group (*000) with 74 sites and the group (*001) with 48 sites:

c- Group (*000) with 74 sites was classified according to the following indicator species: ***Heliotropium digynum***; ***Moltkiopsis ciliate***; ***Centropodia forsskaolii*** and ***Leptadenia pyrotechnica***.

iii- Negative group with a sign of (*0000) - 53 sites (DDCR-N habitat)

iv- Positive group with a sign of (*0001) - 21 sites (DDCR-O habitat)

d- Group (*001) with 48 sites classified according to the following indicator species: ***Dipterygium glaucum***; ***Indigofera colutea*** and ***Haloxylon salicornicum***.

iii- Negative group with a sign of (*0010) - 45 sites (DDCR-P Habitat)

iv- Positive group with a sign of (*0011) - 3 sites (DDCR-Q Habitat)

F- Classified the group (*010) with 44 sites and the group (*011) with 7 sites:

c- Group (*010) with 44 sites was classified according to the following indicator species: ***Moltkiopsis ciliata***; ***Dipterygium glaucum***; ***Rhanterium epapposum*** and ***Centropodia forsskaolii.***

iii- Negative group with a sign of (*0100) - 22 sites (DDCR-R Habitat)

iv- Positive group with a sign of (*0101) - 22 sites (DDCR-S Habitat)

d- Group (*011) with 7 sites was classified according to the following indicator species: ***Acacia tortilis***.

iii- Negative group with a sign of (*0110) - 5 sites (DDCR-T Habitat)

iv- positive group with a sign of (*0111) - 2 sites (DDCR-U Habitat)

G- Classified the group (*100) with 10 sites and the group (*101) with 8 sites:

c- Group (*100) with 10 sites classified according to the following indicator species: ***Centropodia forsskaolii***.

i- Negative group with a sign of (*1000) - 3 sites (DDCR-V Habitat)

ii- Positive group with a sign of (*1001) - 7 sites (DDCR-W Habitat)

d- Group (*101) with 8 sites classified according to the following indicator species: ***Atractylis carduus***.

iii- Negative group with a sign of (*1010) - 1 site (DDCR-X Habitat)

iv- Positive group with a sign of (*1011) - 7 sites (DDCR-Y Habitat)

H- Classified the group (*110) with 11 sites and the group (*111) with 2 sites:

a- Group (*110) with 11 sites was classified according to the following indicator species: ***Monsonia nevia***.

iii- Negative group with a sign of (*1100) - 7 sites (DDCR-Z Habitat)

iv- Positive group with a sign of (*1101) - 4 sites (DDCR-Z2 Habitat)

b- Group (*111) with 2 sites was too small for further classification (DDCR-Z3 Habitat)

Comments on DDCR TWINSPAN result

- TWINSPAN program and analysis divided DDCR gravel plains and sand dunes habitats into 15 habitat types according to the relation between the plant species and its abundance within the habitat types; it classified as follows (DDCR-N; DDCR-O; DDCR-P; DDCR-Q; DDCR-R; DDCR-S; DDCR-T; DDCR-U; DDCR-V; DDCR-W; DDCR-X; DDCR-Y; DDCR-Z; DDCR-Z2; DDCR-Z3)
- Out of 36 species recorded in AMR only 11 species were considered as indicator species for habitat it represents; these species are as follows: *Rhanterium epapposum*; *Monsonia nevia*; *Leptadenia pyrotechnica*; *Moltkiopsis ciliata*; *Cyperus conglomeratus; Heliotropium digynum; Centropodia forsskaolii; Dipterygium glaucum; Indigofera colutea; Haloxylon salicornicum; Acacia tortilis; Atractylis carduus.*

- The first classification is very clear and accurate for distinguishing the main two habitat types of Sand Dunes with ***Cyperus conglomerates*** as the indicator species and most dominant species of the sand dunes habitat while ***Fagonia indica*** is the indicator and the most dominant species in the gravel plains habitat.
- *Acacia tortilis*; *Atractylis carduus; Lycium shawii* and *Tamarix aphylla* are indicators for the gravel plains.
- *Fagonia indica* established good communities over the gravel plains and was one of the early indicator species for gravel plains habitat recovery.

- *Cyperus conglomeratus* growing very well on the sand dunes and considered to be the most important indicator species which lead to the early classification of the habitat from the first level.

- There is a clearly distinctive amount of continuity and homogeneity in the structure and geographical spread of the habitats

See annex IV for TWINSPAN results and dendrograms

1.4.4 Thiessen Polygons

It is a polygon whose boundaries define the area that is closest to each point relative to all other points. Thiessen polygons are generated from a set of points. They are mathematically defined by the perpendicular bisectors of the lines between all points. A tin structure (ArcGIS software product used for surface representation, modeling and display) is used to create Thiessen polygons.

In order to clearly display the distribution of the plant communities spatially over the studied area Thiessen polygons were adopted with the aid of the habitat classification of TWINSPAN which will enable the spatial display of the final results.

See Figure 10 for more clarification.

Comments on Thiessen Polygons

Thiessen polygons clearly showed the habitat classification as follows:

- The area of Nazwa (North) has been classified as a single group of habitat (s) according to its uniqueness in vegetation types and its geological feature of being the only mountain habitat of Al Hajar mountain range within DDCR; while also being the least disturbed habitat being away from the safari companies and other old camel farms activities.
- Beneath Nazwa there is distinguish gathered polygons together forming a strip which shows an area previously used by a safari operator for desert driving activities. The area still shows the effect on the type of vegetation by this activity and hence its classification.
- The southern range of the DDCR shows a very diverse habitat classification and the only explanation for this is that it is an indication of habitat recovery and that during this pioneer stage there are more plant communities. This will be the case until a climax stage is reached where there will be more homogeneity of vegetation types and indicator species.
- The area of the Al Maha gravel plains has shown homogeneity in their structure and geographical spread due to the long term conservation of the AMR.

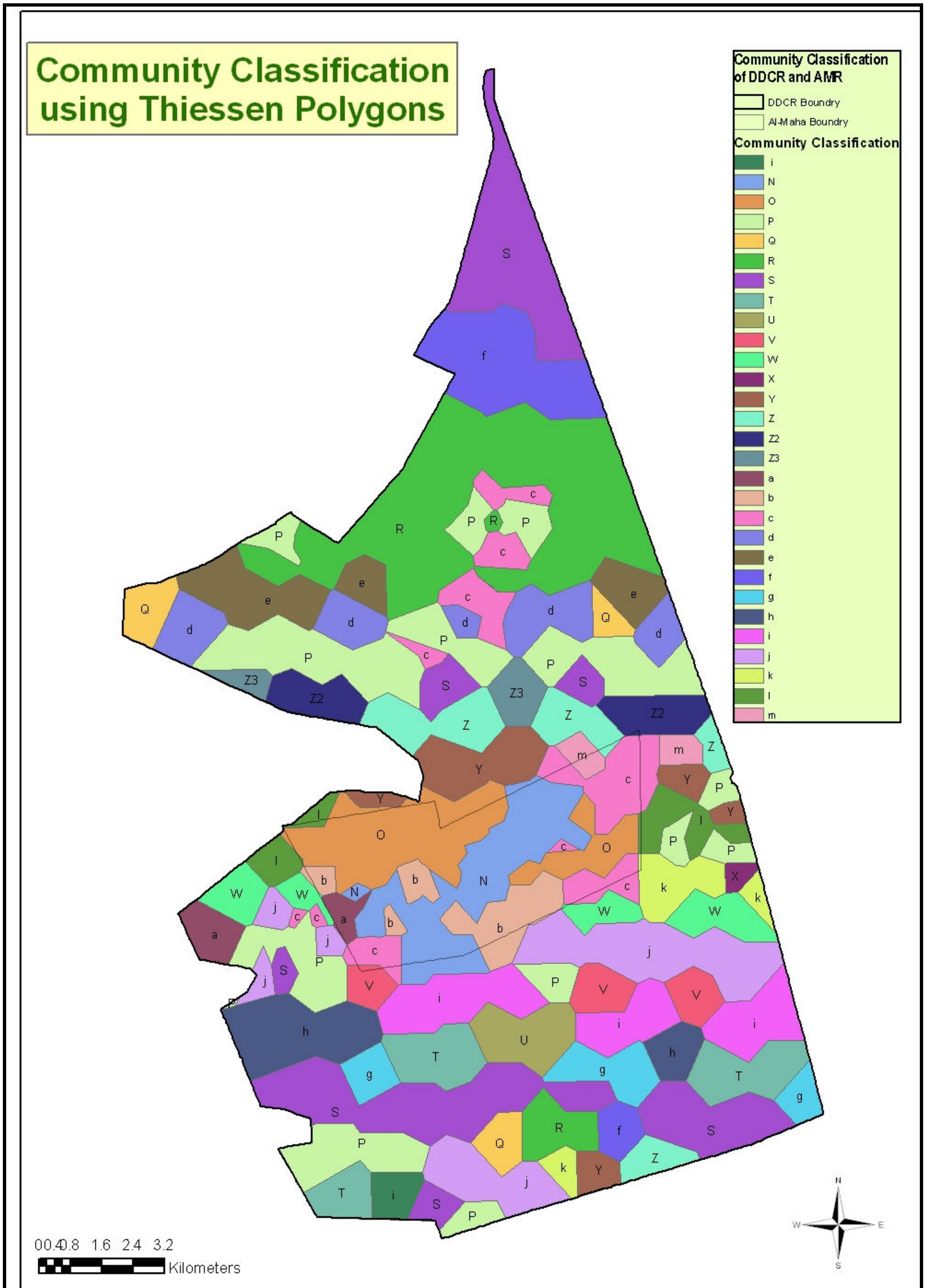


Figure 10: The spatial extent and distribution of floral communities as delineated by TWINSPAN and Thiessen Polygons based on sampling grids

1.5 *Discriminant Function Analysis*

Discriminant function analysis is used to determine which variables discriminate between two or more naturally occurring groups. If discriminant function analysis is effective for a set of data, the classification table of correct and incorrect estimates will yield a high percentage correct.

The analysis was done using Abundance of each species; species richness (calculated for each of sampling plot individually); cover estimate and diversity (expressed as Brillouin, Simpson and Shannon indices).

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.55	177.011	18	0
2 through 3	0.869	41.392	10	0
3	0.982	5.44	4	0.245

Table 10: Significance of Discriminant Function through various habitat

The *p* values for the three function are all significant (0.05> sig.) which indicates that the four habitat vary according to (Cover, Diversity indices, Abundance and Richness).

	Function		
	1	2	3
Species Richness	0.709*	0.332	-0.298
Brillouin Index	0.431*	0.214	-0.167
Shannon Index	0.319*	0.122	-0.207
Simpson Index	0.220*	-0.116	-0.183
Cover	-0.065	0.760*	0.282
Abundance	0.652	0.147	0.697*

*. Largest absolute correlation between each variable and any discriminant function

Table 11: Structure Matrix

From the table 11 the structure matrix shows that all selected parameters are giving strong correlation with the three functions; function 1 shows strong correlation with Simpson index, Brillouin index; Shannon index and Richness of the species; while function 2 is showing correlation with the cover of the species and Function 3 shows correlation with Abundance.

The result of the Discriminant functions become very clear when present it with the scatter plots of samples. It showed that the used functions clearly separate the samples of AMR and DDCR Plains from AMR and DDCR Dunes. The two habitats showed more uniform and more homogeneous cluster of points compared to the old survey. Nearly the four habitats types are lying mainly along the positive axe of function two (Cover) and Function one (Species richness and Diversity indices).

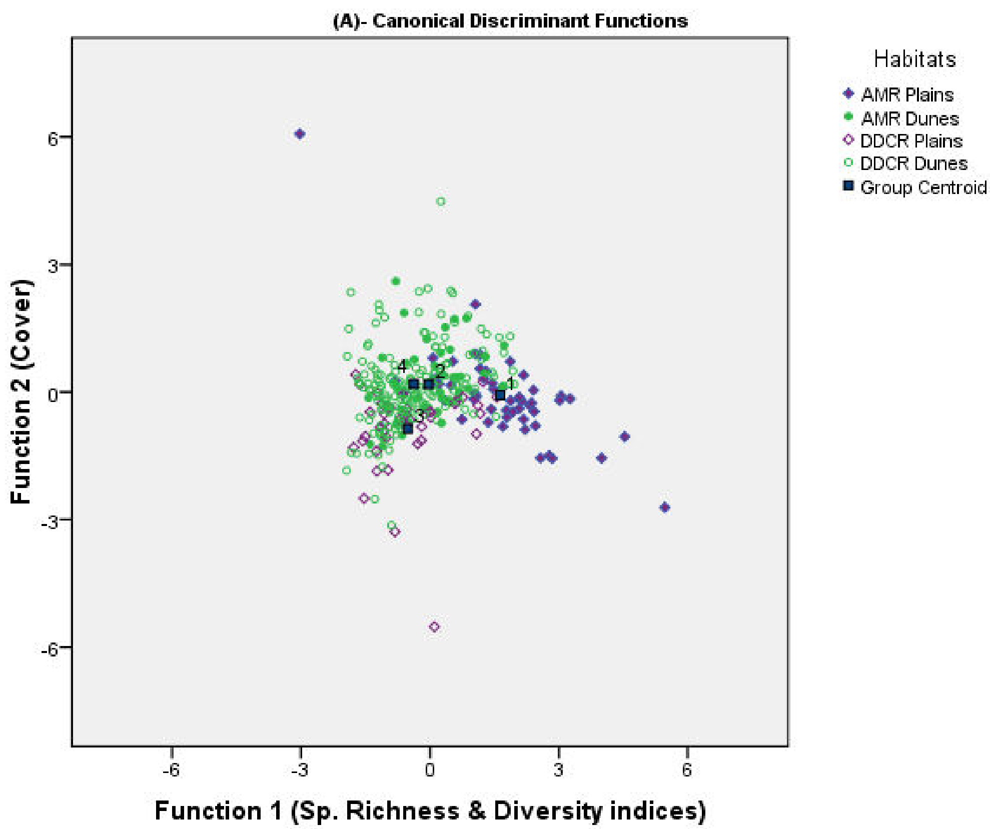


Figure 11: Scatter plot of Discriminant Functions for DDCR and AMR habitats

Habitats	Function		
	1	2	3
AMR Gravel Plains	**1.633**	-0.075	0.0457
AMR Sand Dunes	-0.040	**0.183**	-0.311
DDCR Gravel Plains	-0.520	**-0.866**	-0.012
DDCR Sand Dunes	-0.379	**0.190**	0.076

Un-standardized canonical discriminant functions evaluated at group means

Table 12: Functions at Group Centroids

Except for DDCR Gravel Plains the groups centroids show mainly positive results which leads to a conclusion that the habitats are in a steady process of regeneration and restoration, AMR Gravel Plains showed a positive centroid with function 1 (Cover) which give an indication how the cover restored in Al Maha Gravel Plains but the diversity is still low; AMR Sand Dunes and DDCR Sand Dunes showed positive centroid result with function 2 of species richness and Diversity Indices which still illustrates the same trend of habitat regeneration. The DDCR Gravel Plains are showing negative centroid with function two and this is obviously due to the negative effect of overgrazing that has been taking place in DDCR Gravel Plains until recently.

The following scatter plots will work on the habitats as pairs. (AMR and DDCR Sand Dunes)

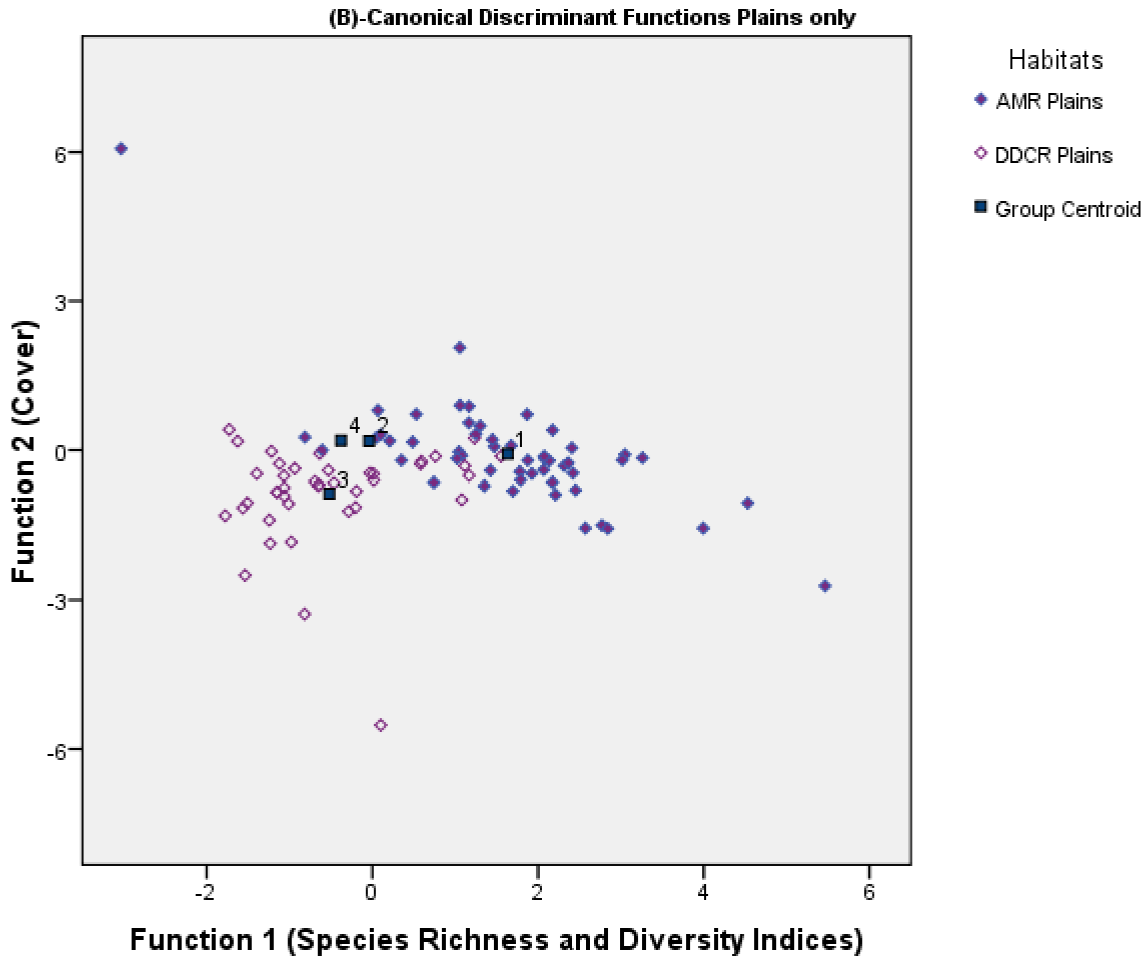


Figure 12: Scatter plot of Discriminant Functions for AMR and DDCR Gravel Plains

The above scatter plot shows that most of the AMR gravel plains sites lie on the positive side of the species richness and diversity indices which means it has mostly recovered with regards to the species richness and diversity indices while the cover still shows only minimum recovery. In the case of DDCR gravel plains most sites are laying on the negative axes of the cover and the diversity indices. The study suggests that in the following years there will be an obvious regeneration and habitat restoration after removal of all camel farms from DDCR in all means of cover; species richness and diversity indices.

Group centroid scores showed that there is a gap between the AMR Gravel Plains which scored higher than the DDCR Gravel Plains in all the parameters studied, which still explains the damage caused by over-grazing.

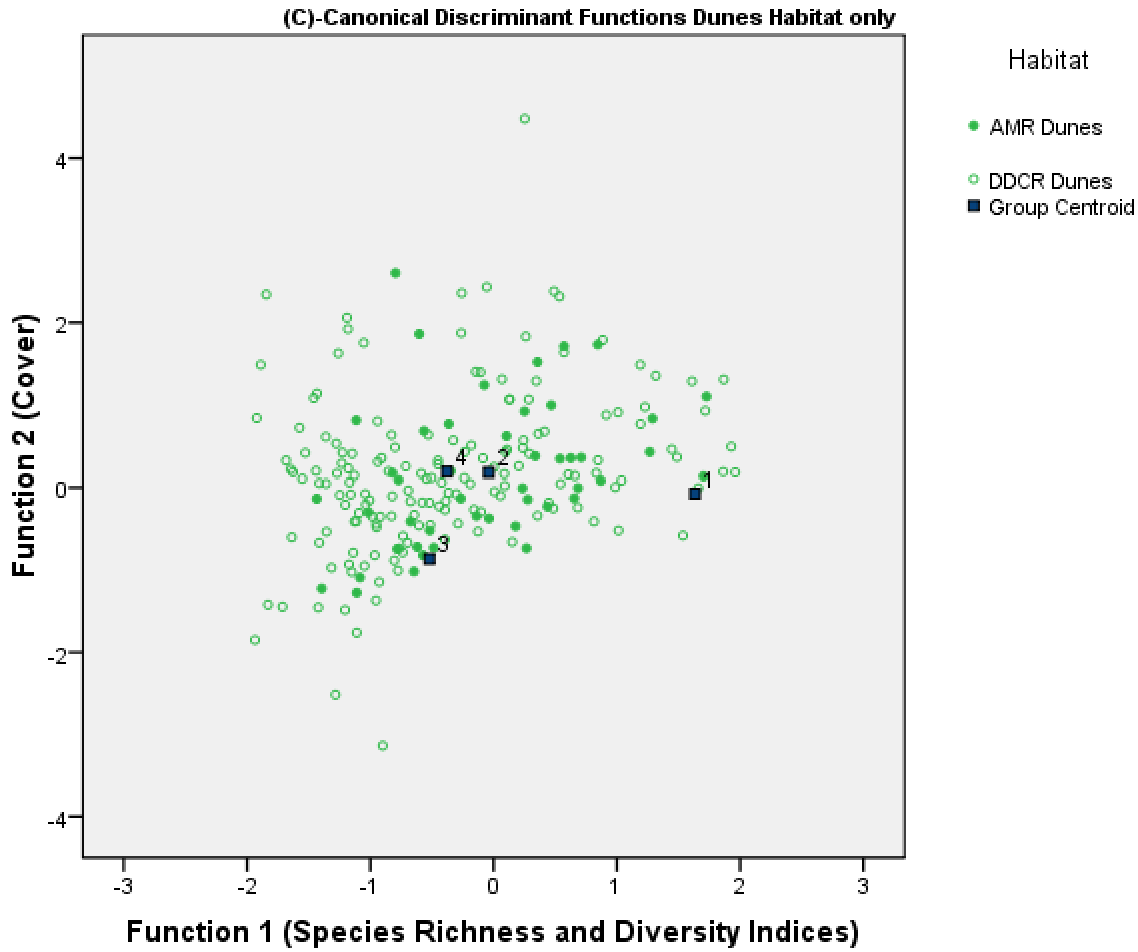


Figure 13: Scatter plot of Discriminant Functions for AMR and DDCR Sand Dunes

The dunes habitats show a greater recovery pattern where the group centroids are closer to each other and there is a normal homogeneous distribution around it. Plots from both AMR and DDCR affected by the parameters of Cover, Species Richness and Diversity indices); group centroid scores showed that both AMR and DDCR Dunes Habitats are very close both in cover and diversity indices along with the species richness.

This study concludes that the invasive activities like overgrazing which had occurred over the last number of years caused a great deal of damage and degradation to the habitat and the associated vegetation, while it is expected that in the years to come there will be positive changes to the vegetation of the DDCR since the removal of the camel in December 2008.

1.6 Summary and Conclusions

There are two main habitat types in Dubai Desert Conservation Reserve, Gravel Plains and Sand Dune habitats. The area doesn't show any endemism or species with any particular value; However the DDCR is still a good representation of the Dubai inland desert ecosystem. In comparing the number of species recorded between this survey and the previous one it shows an incredible increase of 22 Species with 46 species recorded as naturally occurring throughout the study area the number of species recorded in the gravel plains habitat was 36 while the number of species recorded in the sand dunes habitat was 41. From these figures it show that the floral diversity is considered to be medium comparing it to the previous survey. Biodiversity indices showed values of 1.00 for Simpson index and 4.0 – 7.0 for Shannon-Weiner.

Still the land use and the management regimes are different in the various parts of the reserve (Desert Safaris; Camel Farms and Resort). Fortunately; his highness Sheikh Mohamed Al Maktoum's decree of removing all the camel farms located within the DDCR premises since four months back of the date of this report. The areas of these camel farms have been practicing sever overgrazing and continuous stocking rates for long time. While in the time of collecting the data for this report there wasn't enough time for the affected areas to be recovered, but it is expected to be promising in the future surveys.

In contrast to the previous survey report; the DDCR (mainly in the southern range) showed better habitat quality when compared to AMR, it is attributed to the removal of the southern range's camel farms since March 2007 which has give the vegetation and the habitat a good chance to recover. On the other hand the AMR has shown signs of grazing pressure from the indigenous desert ungulates (Oryx and Gazelle) and a re-distribution of the herds is recommended.

The high values of *Cyprus conglomeratus* especially in the southern parts where there were some plots with no other vegetation except the Dune Grass; this result indicates that the area was previously overgrazed and the habitat was degraded; C. *conglomeratus,* as a pioneer species, reflects the high capacity of re-colonization in the areas that were previously heavily disturbed and are the first stage of habitat recovery.

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Appendices

Annex 1 (Vegetation Parameters)

In each stand several parameters were assessed as follows:

1- Density of species (i) = $\frac{total\ number\ of\ individuals\ of\ species\ (i)\ in\ all\ sampled\ plots}{area\ of\ sampled\ plots}$

2- Relative density of the species (i) = $\frac{total\ number\ of\ individuals\ of\ species\ (i)}{total\ number\ of\ individuals} \times 100$

3- Frequency = $\frac{total\ number\ of\ plots\ in\ which\ species\ (i)\ occurs}{total\ number\ of\ plots\ sampled} \times 100$

4- Relative frequency = $\frac{Frequency\ of\ species(i)\ in\ plot\ (x)}{total\ frequencies\ of\ all\ species\ in\ plot(x)} \times 100$

5- Abundance = $\frac{total\ number\ of i\ ndividuals\ of\ species\ (i)}{total\ number\ of\ plots\ in\ which\ species(i)\ occured}$

6- Relative Abundance = $\frac{Abundance\ of\ species(i)\ in\ plot\ (x)}{total\ abundance\ of\ all\ species\ in\ plot(x)} \times 100$

7- Relative cover = $\frac{Total\ \mathrm{cov}\ er\ of\ species(i)\ in\ all\ plots}{Total\ \mathrm{cov}\ er\ ofall\ species\ in\ allplots} \times 100$

Significant Important Value Index (S.I.V.I.) = the sum of all the four relative values recorded for each species which show the overview picture of the ecological importance and to measure the dominance and the co-dominance species per each stand. (Shukla and Chandle, 1996)

Annex II Vegetation Parameters (Tables)

D= Density; F= Frequency; A= Abundance; C= Cover; RD= Relative Density; RF= Relative Frequency; RA= Relative Abundance; RC= Relative Cover, SIVI= Significant Important Value Index; IVI= Important Value Index.

1- Vegetation parameters of plant species recorded around the gravel plains in AMR

	Species	D	F	A	C	RD	RF	RA	RC	SIVI	IVI
1	*Aerva javanica*	0.5	30.0	1	0.3078	2.41	5.96	4.31	3.94	16.62	12.68
2	*Arnebia hispidissima*	11.4	65.7	14	0.2128	20.74	12.93	20.31	3.61	57.59	53.98
3	*Atractylis carduus*	0.5	30.5	1	0.0057	1.56	5.45	2.70	0.09	9.80	9.71
4	*Bassia muricata*	0.3	26.7	1	0.0522	1.48	6.21	3.58	0.40	11.68	11.27
5	*Calotropis procera*	0.2	20.0	1	2.4252	0.81	4.08	2.06	35.44	42.39	6.94
6	*Centropodia forsskaolii*	1.0	40.8	2	0.0065	4.82	7.71	5.69	0.09	18.31	18.22
7	*Chrozophora oblongfolia*	0.6	33.8	2	0.3959	2.22	6.10	3.54	2.33	14.19	11.86
8	*Citrullus colocynthis*	0.2	20.0	1	0.0079	0.12	2.63	0.53	0.21	3.49	3.28
9	*Crotalaria aegyptiaca*	0.2	20.0	1	3.2554	0.89	4.42	2.80	15.94	24.05	8.12
10	*Dipterygium glaucum*	0.4	30.5	1	0.5232	1.81	6.50	2.72	5.59	16.62	11.03
11	*Eremobium aegyptiacum*	11.7	60.0	20	0.1515	7.22	8.63	10.54	4.00	30.39	26.39
12	*Fagonia indica*	6.9	74.0	8	0.5955	20.84	15.45	16.40	8.93	61.62	52.69
13	*Fagonia Sp.*	0.6	20.0	3	0.0603	2.33	4.55	8.13	0.48	15.49	15.00
14	*Farsetia linearis*	0.7	34.1	2	0.0059	2.04	6.52	3.68	0.09	12.32	12.24
15	*Haloxylon salicornicum*	3.1	53.3	4	0.1068	2.45	7.92	3.48	2.77	16.62	13.85
16	*Heliotropium digynum*	0.2	24.4	1	0.0701	1.54	5.18	3.38	0.46	10.56	10.10
17	*Heliotropium kotschyi*	8.7	89.2	9	13.7495	23.72	19.47	17.77	65.78	126.74	60.96
18	*Indigofera intricata*	0.5	30.6	1	0.0023	1.64	5.76	3.19	0.02	10.61	10.59
19	*Leptadenia pyrotechnica*	0.6	36.3	2	11.1639	3.31	8.10	4.74	59.66	75.81	16.15
20	*Limeum arabicum*	0.2	20.0	1	0.0156	0.88	4.50	2.91	0.08	8.37	8.29
21	*Lycium shawii*	0.3	25.0	1	2.3315	1.30	4.90	3.12	11.79	21.10	9.32
22	*Moltkiopsis ciliata*	3.0	44.8	5	0.0322	10.64	9.21	10.99	0.92	31.76	30.84
23	*Monsonia nevia*	10.5	51.3	18	0.0458	23.18	9.85	31.36	0.57	64.95	64.39
24	*Neurada procumbens*	0.4	30.0	1	0.0018	1.23	5.87	2.42	0.03	9.55	9.52
25	*Panicum turgidum*	0.2	20.0	1	0.0359	0.69	5.90	2.62	0.22	9.44	9.22
26	*Pennisetum divisum*	0.4	28.0	1	0.5196	1.77	4.73	3.14	5.98	15.62	9.64
28	*Polycarpaea repens*	0.6	24.4	3	0.0009	1.87	4.82	4.16	0.01	10.87	10.86
27	*Rhanterium epapposum*	3.9	82.1	5	3.3749	19.30	17.36	12.99	23.66	73.31	49.65
29	*Sisymbrium erysimoides*	0.2	20.0	1	0.0011	1.41	4.35	3.91	0.01	9.67	9.67
30	*Stipagrostis plumosa*	2.0	61.7	3	0.0264	6.94	12.54	6.57	0.31	26.35	26.04
31	*Tribulus omanense*	0.3	20.0	2	0.0064	1.16	4.34	3.69	0.08	9.27	9.20
32	*Tribulus pentandrus*	0.6	36.3	1	0.0066	1.67	6.99	2.93	0.11	11.69	11.58

2- Vegetation parameters of plant species recorded around the Sand Dunes in AMR

	Species List	D	F	A	C	RD	RF	RA	RC	SIVI	IVI
1	***Aerva javanica***	0.2	20.0	1	0.9165	3.57	5.88	6.90	2.66	19.01	16.35
2	***Arnebia hispidissima***	1.5	37.5	3	0.1158	8.17	7.91	10.61	0.49	27.18	26.70
3	***Atractylis carduus***	0.3	20.0	2	0.0029	2.28	4.67	5.59	0.01	12.55	12.54
4	***Bassia muricata***	1.1	38.6	2	0.3048	6.80	11.21	9.15	1.48	28.64	27.16
5	***Calligonum comosum***	0.2	20.0	1	0.0227	2.33	7.14	6.67	1.01	17.14	16.14
6	***Calotropis procera***	0.2	20.0	1	9.1883	1.85	5.71	5.22	33.12	45.91	12.78
7	***Centropodia forsskaolii***	1.1	40.0	3	0.0242	6.34	9.66	9.86	0.15	26.00	25.86
8	***Chrozophora oblongfolia***	0.6	33.3	2	0.6606	4.21	7.47	5.99	2.09	19.76	17.67
9	***Crotalaria aegyptiaca***	1.1	40.0	2	5.2306	6.82	9.85	8.31	16.78	41.77	24.99
10	***Cyperus conglomeratus***	1.3	50.3	3	0.2705	19.04	19.81	17.85	5.98	62.68	56.70
11	***Dipterygium glaucum***	0.5	37.6	1	1.4762	4.61	10.82	6.57	9.93	31.94	22.00
12	***Fagonia indica***	0.5	23.3	2	0.1573	3.09	6.48	7.14	0.50	17.22	16.72
13	***Farsetia linearis***	0.2	20.0	1	0.0064	1.49	7.69	5.68	0.01	14.88	14.87
14	***Haloxylon salicornicum***	0.8	36.7	2	3.6116	5.28	11.50	9.08	21.46	47.31	25.85
15	***Heliotropium digynum***	3.5	66.8	4	5.9569	25.44	21.59	21.28	27.08	95.39	68.31
16	***Heliotropium kotschyi***	7.0	66.0	8	10.5608	43.23	20.60	30.46	41.76	136.06	94.29
17	***Indigofera colutea***	0.6	25.0	3	0.0054	3.27	4.66	9.11	0.05	17.09	17.04
18	***Indigofera intricata***	0.4	20.0	2	0.0025	1.41	3.99	4.73	0.01	10.14	10.13
19	***Leptadenia pyrotechnica***	0.4	31.3	1	15.3028	3.10	9.07	4.93	45.60	62.70	17.10
20	***Limeum arabicum***	0.9	44.3	2	2.2165	9.31	15.41	11.11	21.24	57.08	35.84
21	***Lycium shawii***	0.2	20.0	1	1.9367	1.49	7.69	5.68	3.65	18.52	14.87
22	***Moltkiopsis ciliata***	6.6	69.1	8	0.9176	36.83	19.87	31.36	6.09	94.14	88.06
23	***Neurada procumbens***	3.4	44.6	5	1.4272	19.16	13.78	18.52	4.87	56.33	51.46
24	***Panicum turgidum***	0.2	20.0	1	0.0755	2.08	3.85	5.08	1.50	12.52	11.01
25	***Polygala erioptera***	0.6	20.0	3	0.0038	6.25	3.85	15.25	0.07	25.43	25.35
26	***Rhanterium epapposum***	1.3	40.0	3	2.8267	8.77	9.46	12.23	10.36	40.83	30.46
27	***Salvadora persica***	0.2	20.0	1	1.3279	1.35	5.00	3.61	3.11	13.07	9.97
28	***Stipagrostis plumosa***	0.6	33.3	2	0.0515	3.85	8.27	6.95	0.27	19.34	19.07
29	***Tribulus macropterus***	0.4	24.0	2	0.0939	2.31	6.34	5.74	1.29	15.68	14.39
30	***Tribulus pentandrus***	0.5	34.0	1	0.0275	4.36	9.43	7.00	0.27	21.06	20.78

3- Vegetation parameters of plant species recorded around the gravel plains in DDCR

	Species List	D	F	A	C	RD	RF	RA	RC	SIVI
1	*Acacia tortilis*	0.8	48	1	9.2246	11.44	20.80	11.88	45.13	89.24
2	*Arnebia hispidissima*	3.6	33	7	0.1226	11.92	8.45	16.90	1.77	39.04
3	*Atractylis carduus*	0.2	20	1	0.0062	1.02	5.05	3.29	0.05	9.41
4	*Calotropis procera*	0.3	26	1	1.7653	5.75	14.43	8.55	37.78	66.51
5	*Centropodia forsskaolii*	2.3	45	4	0.0100	32.62	23.69	28.10	7.17	91.59
6	*Citrullus colocynthis*	0.3	33	1	0.2061	10.44	18.89	10.60	30.01	69.93
7	*Crotalaria aegyptiaca*	0.8	40	2	0.4780	20.00	22.22	16.00	5.12	63.34
8	*Dipterygium glaucum*	0.9	40	2	0.3639	8.84	14.58	14.61	23.41	61.44
9	*Fagonia indica*	4.1	65	5	0.3206	40.08	32.75	34.29	17.61	124.72
10	*Farsetia linearis*	0.7	40	2	0.0863	3.44	9.76	5.87	0.60	19.67
11	*Haloxylon salicornicum*	6.9	89	7	5.4432	33.24	32.47	28.62	58.63	152.96
12	*Heliotropium digynum*	0.3	27	1	0.0520	7.07	8.89	12.32	0.82	29.11
13	*Heliotropium kotschyi*	1.2	48	2	0.0441	5.69	14.76	6.25	2.64	29.34
14	*Indigofera colutea*	1.0	50	2	0.0299	6.95	13.38	8.12	1.90	30.35
15	*Indigofera intricata*	0.2	20	1	0.0008	6.58	14.76	11.75	2.80	35.89
16	*Leptadenia pyrotechnica*	0.3	28	1	4.3136	11.50	17.00	13.53	67.27	109.30
17	*Lycium shawii*	0.3	27	1	1.4256	18.33	21.25	18.68	28.33	86.59
18	*Monsonia nevia*	2.3	34	6	0.0052	21.33	12.72	28.57	0.73	63.35
19	*Moltkiopsis ciliata*	0.8	30	2	0.0100	4.85	10.57	8.32	0.70	24.44
20	*Panicum turgidum*	0.2	20	1	0.0050	1.23	4.55	3.16	0.04	8.98
21	*Pennisetum divisum*	1.2	40	3	1.4667	30.00	22.22	24.00	15.71	91.94
22	*Polycarpaea repens*	0.9	29	3	0.0010	15.20	13.86	17.38	0.57	47.02
23	*Rhanterium epapposum*	1.6	60	2	0.1944	13.82	19.41	12.35	19.52	65.10
24	*Stipagrostis plumosa*	3.3	45	5	0.0571	24.93	18.11	25.61	6.30	74.95
25	*Tamarix aphylla*	0.2	20	1	7.0714	6.25	12.50	16.00	15.77	50.52
26	*Tribulus omanense*	0.2	20	1	0.0020	0.75	6.25	2.21	0.03	9.24
27	*Tribulus pentandrus*	1.0	42	2	0.0221	18.50	20.62	16.50	5.63	61.26

4- Vegetation parameters of plant species recorded around the Sand Dunes in DDCR

	Species List	D	F	A	C	RD	RF	RA	RC	SIVI
1	***Arnebia hispidissima***	0.4	27	2	0.0297	1.74	4.81	3.20	0.14	9.90
2	***Calotropis procera***	0.3	26	1	5.8635	4.65	11.48	6.59	26.95	49.67
3	***Centaurea pseudosinaica***	0.9	33	2	0.2453	8.72	8.92	9.01	0.83	27.48
4	***Centropodia forsskaolii***	3.5	43	7	0.0306	22.17	13.04	23.66	0.31	59.19
5	***Chrozophora oblongfolia***	1.1	53	2	0.5307	7.54	17.35	10.31	0.83	36.04
6	***Citrullus colocynthis***	0.3	25	1	11.7733	1.91	10.29	5.80	29.12	47.12
7	***Crotalaria aegyptiaca***	0.4	26	2	0.9209	3.28	7.93	5.88	1.27	18.36
8	***Cyperus conglomeratus***	6.8	70	8	10.1686	46.08	32.68	36.81	33.78	149.35
9	***Dipterygium glaucum***	1.7	45	3	1.4375	8.58	12.46	8.64	8.13	37.80
10	***Eremobium aegyptiacum***	34.0	90	38	1.3305	76.94	42.36	67.95	18.12	205.37
11	***Monsonia nevia***	0.6	23	2	0.0051	9.85	9.11	13.19	0.06	32.21
12	***Fagonia indica***	0.5	20	2	0.4067	6.61	5.56	10.52	6.12	28.81
13	***Farsetia linearis***	0.2	20	1	0.0003	1.39	3.57	2.75	0.00	7.71
14	***Haloxylon salicornicum***	2.0	61	3	15.5680	10.00	16.05	8.84	31.20	66.08
15	***Heliotropium digynum***	0.6	36	2	0.1185	6.61	13.16	8.17	1.05	29.00
16	***Heliotropium kotschyi***	0.5	35	1	0.1821	8.64	15.86	12.04	2.68	39.23
17	***Indigofera colutea***	2.4	33.6	6.0	0.1	9.5	9.2	14.4	0.6	33.6
18	***Indigofera intricata***	0.6	35	1	0.0215	2.33	8.19	3.55	0.10	14.17
19	***Leptadenia pyrotechnica***	0.5	44	1	11.4287	8.35	17.39	8.33	67.98	102.05
20	***Limeum arabicum***	2.9	59	4	7.2021	17.17	20.54	15.93	27.74	81.37
21	***Moltkiopsis ciliata***	1.9	34	5	0.1127	12.58	10.60	16.29	0.43	39.89
22	***Neurada procumbens***	0.6	26	2	0.0062	3.23	6.86	7.13	0.07	17.30
23	***Ogastemma pusillum***	0.7	25	3	0.0021	7.83	8.37	13.78	0.03	30.01
24	***Panicum turgidum***	0.4	26	2	0.2300	2.88	6.77	6.22	2.00	17.86
25	***Pennisetum divisum***	0.5	30	1	0.9981	4.63	10.44	7.05	5.08	27.20
26	***Plantago boissieri***	3.8	40	10	0.0166	7.48	11.11	11.66	0.04	30.29
27	***Polycarpaea repens***	0.5	20	3	0.0043	6.48	5.61	9.15	0.07	21.30
28	***Prosopis cineraria***	0.4	20	2	0.0039	6.90	16.67	18.18	0.04	41.79
29	***Rhanterium epapposum***	0.8	47	1	0.3483	10.91	14.41	9.51	3.54	38.37
30	***Silene villosa***	0.2	20	1	0.0001	0.39	5.56	1.23	0.00	7.18
31	***Stipagrostis plumosa***	1.1	33	3	0.0288	9.81	11.46	13.17	0.42	34.87
32	***Tribulus macropterus***	0.2	20	1	0.0328	3.90	7.56	7.16	0.11	18.73
33	***Tribulus omanense***	0.2	20	1	0.0079	1.15	3.85	3.88	0.07	8.94
34	***Tribulus pentandrus***	0.4	28	1	0.0145	4.49	8.70	6.94	0.17	20.29

Annex III (Diversity Index)

Shannon's index *H'*= $-\sum_{i=1}^{S} p_i \ln p_i$

Where p_i is the proportion of individuals in species (*i*) and (*S*) the total number of species in the sample

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Brillouin index *HB* = $\dfrac{\ln N! - \sum_{i=1}^{S} \ln n_i!}{N}$

Where n_i is the number of individuals in species (*i*), N is the total number of individuals in the sample and (*S*) the total number of species

Simpson's index =1- λ $\lambda = \sum_{iI=1}^{S} \dfrac{n_i(n_i - 1)}{N(N-1)}$

Where n_i is the number of individuals in species (*i*), N is the total number of individuals in the sample

Annex IV: results of TWINSPAN and its dendrograms

1- [TWINSPAN OF Al-Maha Gravel Plains and Sand Dunes]

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16 Far  lin   -21-3332342--22------1--1-----1-11-------------1---------------------------------------------1----  0000
37 Tri  oma   --1----2------------------------------------------------------------------------------------------  0000
 9 Cit  col   ---------------------------------------1----------------------------------------------------------  00010
13 Ere  aeg   --------------------------------------25----------------------------------------------------------  00010
15 Fag  sp    -----------------------------2--------------------------------------------------------------------  00010
34 Sis  ery   ----------------------------------1---------------------------------------------------------------  00010
19 Hel  kot   31--2554-554455555555555555555555555555555555-------1----------1------------1--------2---------52  00011
26 Mon  nev   5-33-55-4545---55555----455-43-455255555------4---2-----------------------------------------------  00011
 6 Cal  pro   --------------1-----------------------1--111-2------1--------------------------------------1------  00100
 2 Arn  his   24--244555531555555524555543435535243255--1--3551452231--22-54-2---4------------------------------  00101
 3 Atr  car   3---2---1-------2111----42--1--1-11---12---1-2--3-2--1--------------------------------------------  00101
27 Neu  pro   -----2312--1---111122-12122-111--321-----------------------42-------------------------------------  00101
28 Pan  tur   -------------------11-1-----------------1-----------------1---------------------------------------  00101
14 Fag  ind   25555555555545533334255555355454555-13135111231-5454--22224---------------------------------------  0011
31 Pol  rep   -----4--1------1------------------2-11----------1---11--------------------------------------------  0011
 8 Chr  obl   1----2-21----------1---2----2-12--2-3------2-32-3--------------2----------------------------------  010
20 Ind  int   -----------------------1-----------2---------------------3--2------------1------------------------  010
35 Sti  plu   451333355433534322242-22312232532434221----23--5324-33213322-2-1---32231---1-------1--------1-----  010
38 Tri  pen   -2-22211-1---3--111-1-22112-1-12-22-2-3511-2--112-2-2---2232--2212-----------1-1-----1-1----------  010
21 Ind  col   21-2-2123------------1--------1------1----1-----123--1-2--132--------------------------------------  01100
29 Pen  div   -------11---------------------------------------2-2----2------------------------------------------  01101
30 Pol  eri   ----------------------------------------------------------2---------------------------------------  01101
32 Rha  epa   55534-343-----5-------------------------------554444543554--24----------------------2-------------  01101
33 Sal  per   ------------------------------------------------------1-------------------------------------------  01101
 1 Aer  jav   1--1---3--------------------------------------------21-2------1-----------------------------------  0111
24 Lyc  sha   ----2---1------------------12------------------112------12-----------------------------------1----  0111
 7 Cen  for   2-----4--1----1-----1--1-2-----1-222-131--2-23333441333343134233-3-1322315333--1----------------2-  10
12 Dip  gla   -----1-------------11--1--1----211--1211222212222-1-32412-223-233-221--2---12-------11111----1--2-  10
22 Lep  pyr   223222--1-----------------------------------13-2222-2223122112131122--2211-1-1-----1-------111--2-  10
17 Hal  sal   -----------------------------------1---35-----2----------------33-----------------2---1-------2---  1100
 5 Cal  com   ----------------------------------------------------------------------------1---------------------  11010
10 Cro  aeg   1-1----------1-----------------------------1------------------11-1-323532-------------------------  11010
36 Tri  mac   ---------------------------------------------------------------22------1--------------------------  11010
11 Cyp  con   -----------------------------------------2-222----------------23--1-2-22243322323122244-3444255433  11011
18 Hel  dig   ------------------------------1--1-11-----212----1-1-1-12-4544123--55555555444343445121323555511-1  11011
23 Lim  ara   -------1-------------------1-------------21123------------1---2-22-2222243312223343423222432-2-21  11011
 4 Bas  mur   ---------------------1---------------------11-2--------1----54---41131--2-2---1-----2------------1  111
25 Mol  cil   ----2-4-32-----122-1-1541543223112-425-2-35-1-5-35443355-54555355555434555554544455522--12-1------  111

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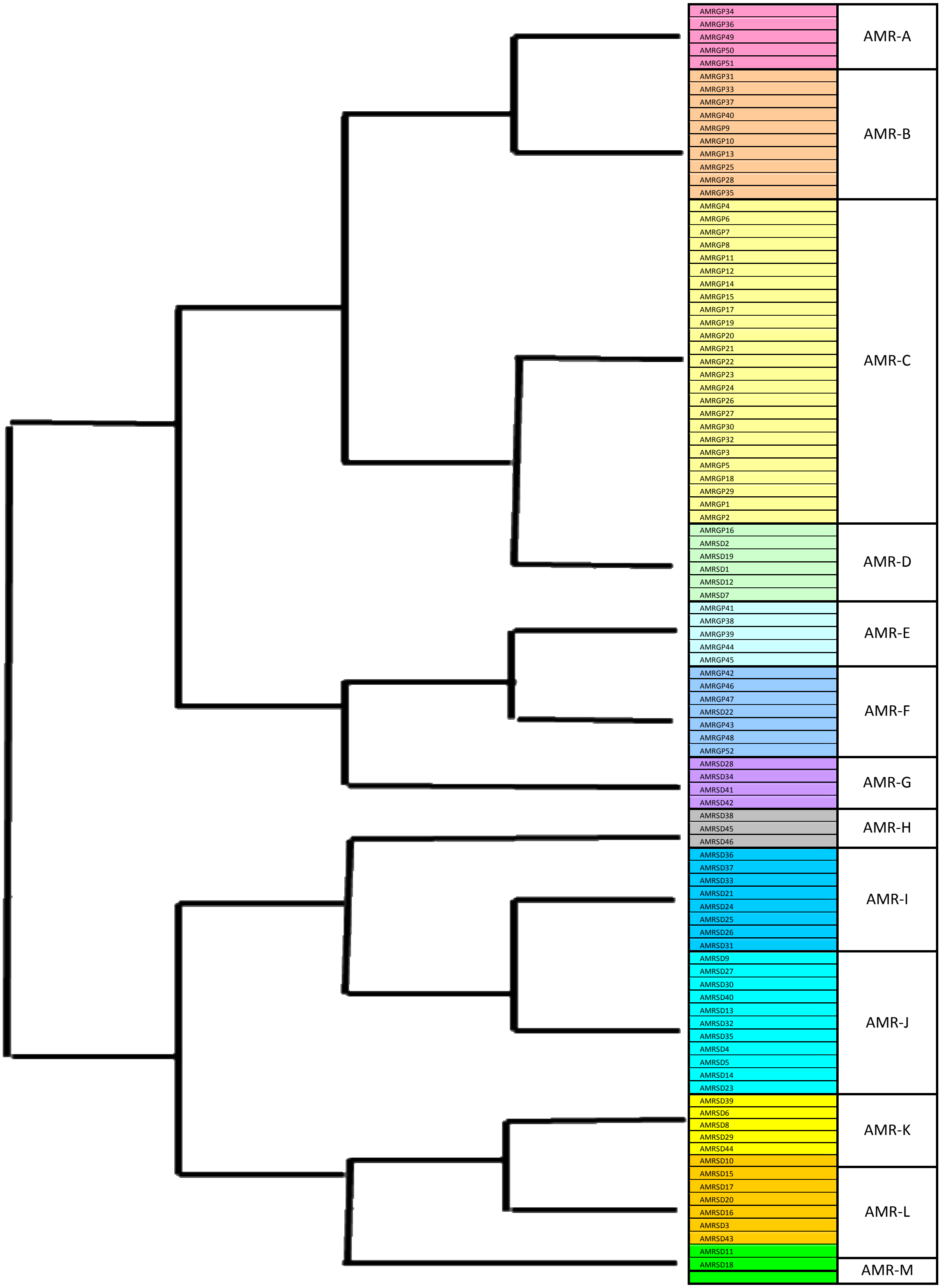

2- AMR TWINSPAN - Dendrogram

2-a [TWINSPAN of DDCR]

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 9 Cro  aeg        ----1---------------------------------------------------------------211-23--2--------------3-211   000
15 Hal  sal        -542--------------11----1----1---2----3-----------------2---------3---------1-1---21-----------245354   000
27 Pan  tur        --------------------------------2-----------------------2----------------1-22-------1-----------   000
21 Lim  ara        --2----2---3-1-313-13232222223--34221352124--44221442452555124123232 3-22-23345343525555545344554445   00100
10 Cyp  con        4445534525454555555545554445255255553555455455555555553555244355555 33-3-5453245423554535523444555555   001010
 7 Chr  obl        -32---------------------------------------------------------------------------------------------   001011
12 Ere  aeg        55----------------------------------------------------------------------------------------------   001011
29 Pla  boi        -4----------------------------------------------------------------------------------------------   001011
31 Pro  cin        ---2--------------------------------------------------------------------------------------------   001011
33 Sil  vil        -1----------------------------------------------------------------------------------------------   001011
11 Dip  gla        ----------------1111-1--1-1------2----4-----------------2--------211-23-1----213-3253131232222155-32   0011
18 Ind  col        ------1-------11214-1-231----5----------------------1-----1------------2-1-445555243425-343334555-4   0011
25 Neu  pro        -----------------1------1--1----------------------------------------------1-----31-332--3---32--   0011
36 Tri  mac        -------------------------------------------------------------------------------------1-----------   0011
 6 Cen  pse        -2----------------------------------------------------------------------------------------------   0100
 8 Cit  col        ----------1-----------2----------1--------------------------------------------------------------   0100
26 Oga  pus        ------------------------------------------------------------1-----1----4------------------------   0100
35 Tam  aph        ------------------------------------------------------------------------------------------------   0100
 5 Cen  for        --------------2-----1---2-----------------------------1-2-----2--1-111-14424435254554343334 55-55555   0101
16 Hel  dig        --------------3--21-------11------21--321---111-223111213-233-233--23332131-21124-2---------11-1131-   011
23 Mol  cil        ----------------5-131---1---1---------12-2-----------32-----1--3254-1-43123124--22212121-1--321534-4   011
28 Pen  div        ------------------12--------------2--1--1-----1--1------2-1----212--2----21--2-------------1-----21-   011
 4 Cal  pro        ----------1-2----1121-1---2---------------------------------------------------------------------1   100
 2 Arn  his        ---------------------------------------------------------------------------2--------2---1---   1010
37 Tri  oma        -----------------------------------------------------------------------1--------------------   1010
22 Lyc  sha        ------------------------------------------------------------------------------------------------   10110
24 Mon  nev        ----------------------------------------------------------------1----------2-1--------------   10110
30 Pol  rep        ------------------------------------------------------------------------------------1-------   10110
 1 Aca  tor        ------------------------------------------------------------------------------------------------   101110
 3 Atr  car        ------------------------------------------------------------------------------------------------   101110
13 Fag  ind        ------------------------------------------------------------------------------------1-----------   101110
14 Far  lin        ------------------------------------------------------------------------------------------------   101110
17 Hel  kot        -------------------------2--------------------------------------------------1-------------------------   101111
19 Ind  int        ---------------------------------------------------------------------------3----------------   110
38 Tri  pen        -2---------------1--1------------1--1--------------------1-------111----23-2-----2232-211-1121------   110
20 Lep  pyr        ------------1-----1--------------22-1----1-1-1-1-1--212---11--11--------1-2---221-------1212-2-3--1-   111
32 Rha  epa        -------------------------------------------------------------------1--------------------------   111
34 Sti  plu        -2---13------2---1-4-------2----2---1-212-------1----1-12-----------2-1-----1---2-2-3-11-1--21-25435   111

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 9 Cro  aeg    ----------------2--------------------1--------------------------------2-----------------------------  000
15 Hal  sal    34444443454-----1------------------------------------------------------------------------------55444  000
27 Pan  tur    ----------------2-----------------------------------------------------------------1-----------------  000
21 Lim  ara    552445553-321---41--34-----------2-2224224-------1---2---2------------------------------------------  00100
10 Cyp  con    5544445543-325532332223442324354532243533522----1-2--1-2-1--1-------------------2-------------------  001010
 7 Chr  obl    ---------3------------------------------------------------------------------------------------------  001011
12 Ere  aeg    ----------------------------------------------------------------------------------------------------  001011
29 Pla  boi    ----------------------------------------------------------------------------------------------------  001011
31 Pro  cin    ----------------------------------------------------------------------------------------------------  001011
33 Sil  vil    ----------------------------------------------------------------------------------------------------  001011
11 Dip  gla    355445342-------3233------2-1------142312--13----3233-1-32---1-----1--------------------------------  0011
18 Ind  col    23-22245--------1-----------1----1---1------3----------11-------------------------2-----------------  0011
25 Neu  pro    -----------------------1--------------------------------1-------------------------------------------  0011
36 Tri  mac    ------------------------------------------------------------1---------------------------------------  0011
 6 Cen  pse    --------------------------------------------------14------------------------------------------------  0100
 8 Cit  col    -----1--------------------------------------------------------2-21----------------------------------  0100
26 Oga  pus    ---------------------------2-------------2-----------2-32-------------------------------------------  0100
35 Tam  aph    -------------------------------------------------------------------1--------------------------------  0100
 5 Cen  for    35-22555133-543555212324--532-2345434443223455452453552434511233333-22--------2521-----2--2-------3-  0101
16 Hel  dig    12222-2-----12221--322-1--------21-1-1--14-21--1111------2---------------2----------------------2---  011
23 Mol  cil    22-44-554--45345353443--3-1------12-2--1-1-33---2243-421--2----2------------------351-------1-2-1-21  011
28 Pen  div    --------------342121--------1-11----2---------1---1--------221--------3---------1-------------------  011
 4 Cal  pro    -11--1---------1--2------------1-1----------------------------121---11-------1---------------21-2--1  100
 2 Arn  his    -2----------------------------------2-------------1-----------------------------------------------51  1010
37 Tri  oma    ---------------------------------------------------------------------------------------------------1  1010
22 Lyc  sha    --------------------------------------------------------------222-----2122121211---1----------------  10110
24 Mon  nev    ---------------------------1-----1--------------313-3--2-----1------------2--22-2---2--3----------34  10110
30 Pol  rep    ---------------------------------------2------------------4---------3------31-2--------2-----2----1-  10110
 1 Aca  tor    -------------------------------------------------------------------2--1-----------1------34---------  101110
 3 Atr  car    ----------------------------------------------------------------------------------1-------------1---  101110
13 Fag  ind    ---------------------------------------3----------------1----------------13242-2--1-4543422255555555  101110
14 Far  lin    ------------------------------------1---------------------------------------------22----------------  101110
17 Hel  kot    ---------22-----------------------------------------------2------------------1--------------------53  101111
19 Ind  int    -----1-------1---------------------------------------2------------1-1--------------------1----------  110
38 Tri  pen    1-2222-1--------2-----12-----11--11131---111---1--1-11-2--1122222124233--1----1---442-23--3-----1---  110
20 Lep  pyr    -2----1----11222221221123122222323222232223213331223221321-222111---1-211222112-2221112--1---12-----  111
32 Rha  epa    --------------------2-----1---------2-111---1-2--2--324-34---1-----------1--------42--344-----------  111
34 Sti  plu    114----1---23-1433---113--222-2432-22-22323215321553422222-1122222--------2-1-2-11553345545-4---1-2-  111

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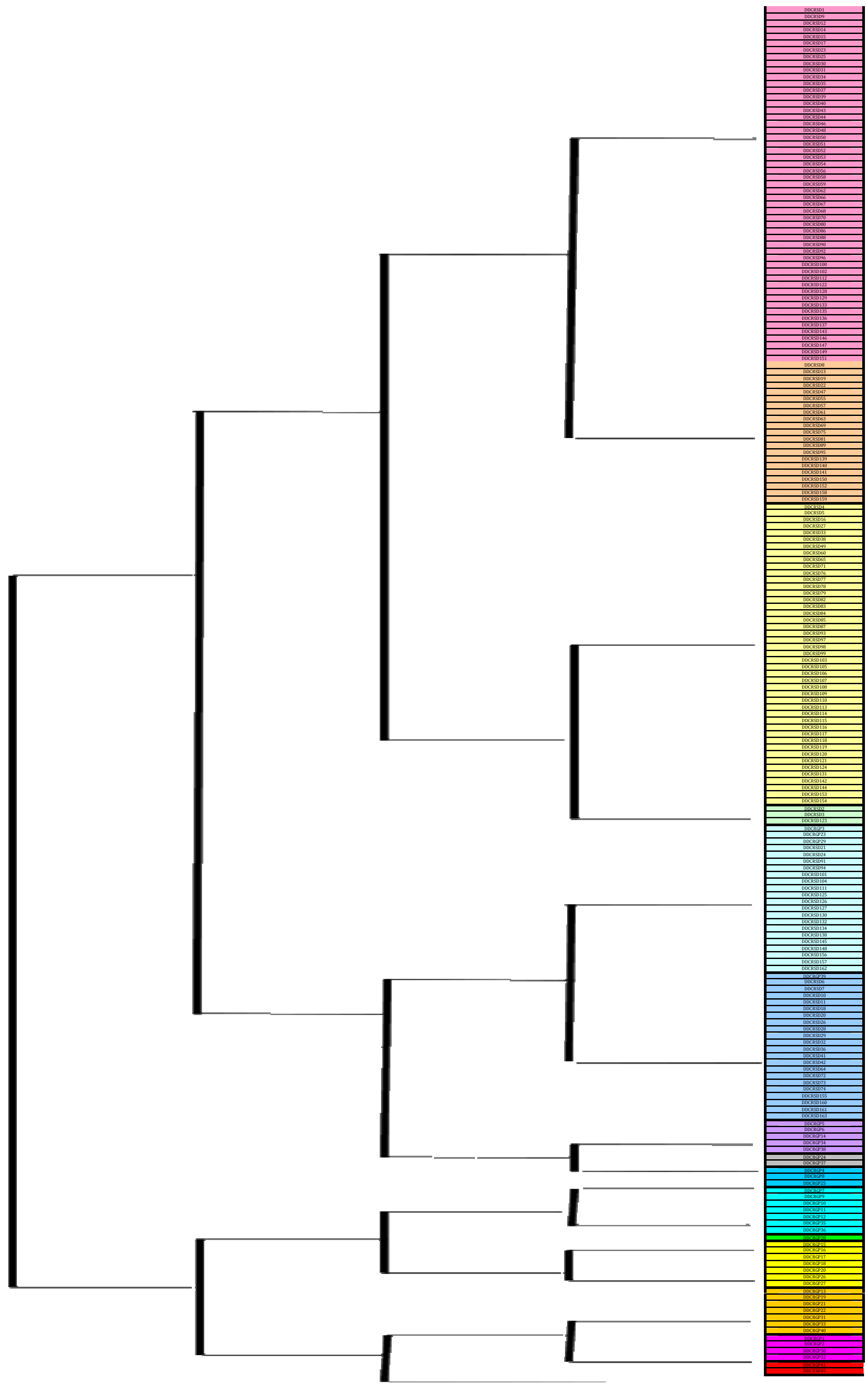

DDCR TWINSPAN DENDROGRAM