محمية دبي الصحراوية
DUBAI DESERT CONSERVATION RESERVE

Emirates

Vegetation of the Dubai Desert Conservation Reserve: Initial Assessment and Baseline Data.

Husam El Alqamy, Conservation Officer
2004
Conservation Manager, Dubai Desert Conservation Reserve,
P. O. Box 7631, Dubai, UAE

Vegetation of Dubai Desert Conservation Reserve
Initial Assessment and Baseline Data

DDCR Floral Community

Introduction

Vegetation refers to the great diversity of plant species which occur in repeating assemblages over the face of the earth. Plants are significant part of any ecosystem. A general definition of community is any assemblage of populations of living organisms in a prescribed area or habitat. A more scientific definition of plant community was given by Mueller-Dombois and Ellenberg (1974); "A plant community can be understood as a combination of plants that are dependent on their environment and influence one another and modify their own environment".

Dubai Desert Conservation Reserve, DDCR, contains several floral species and topography elements. Although, these are not so numerous, different combinations of these floral and terrain elements could produce considerably complex patterns of habitats. The current document describes efforts to assess and quantify the vegetation cover and plant community in DDCR in a manner to provide baseline data that serve as the preliminary basis for temporal comparison provided that monitoring is a continuously ongoing activity in DDCR. These efforts mainly emphasise assessing the density, cover and diversity of the flora of DDCR and providing comparable indices or estimates in a quantitative manner for future monitoring and comparisons. In addition an attempt to map the vegetation of DDCR and to define an approximate lineage along different floral communities will be endeavoured. Multivariate analysis of field data combined along with GIS techniques is an obvious option to achieve this task.

The floral diversity of DDCR includes about 37 species, 6 of which are trees, 26 are shrubs and dwarf shrubs while the remaining 5 are grasses. The nomenclature of plant species used in this report is following Jongboled *et. al*. (2003). However, some species, especially shrubs are more abundant and more common than others. Tree species are considerably important since they represent a microhabitat and hot spot for diversity of floral and faunal elements around them. This study was conducted during the period of Jun 2004-Feb 2005.

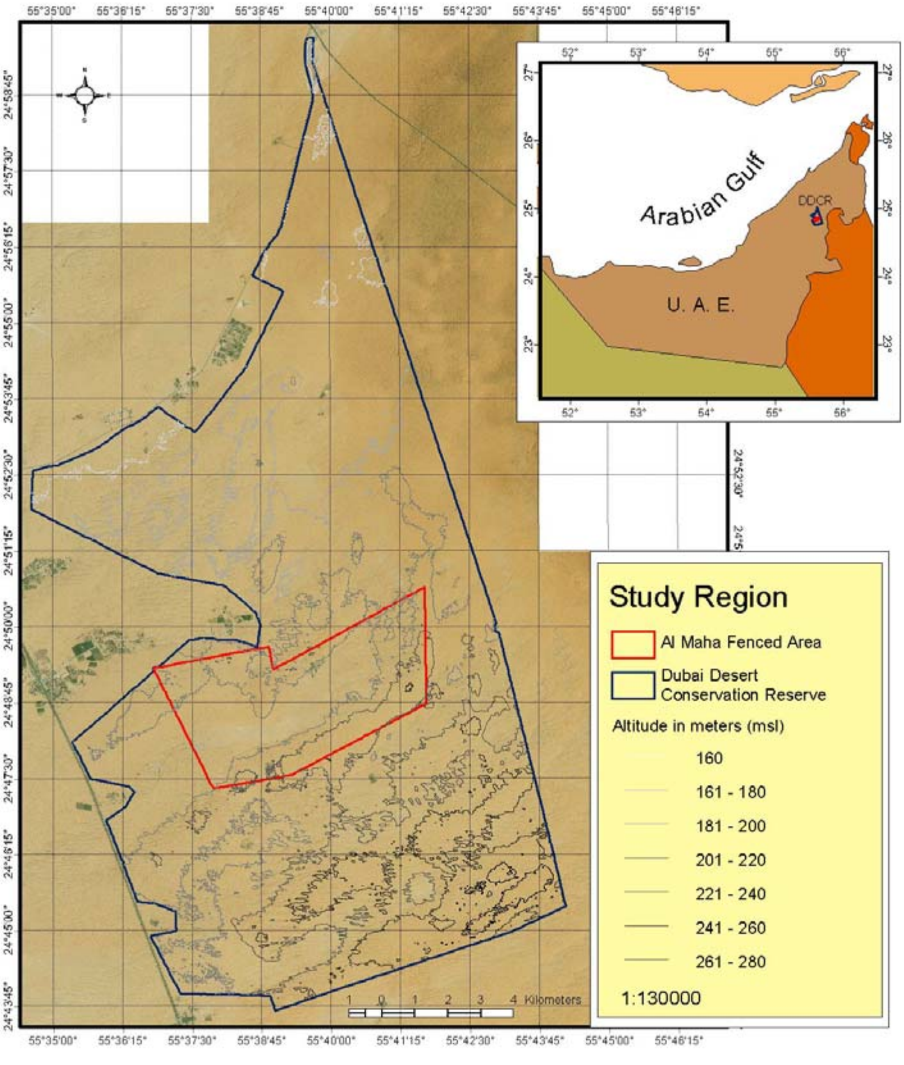
Study Region

Dubai Desert Conservation Reserve (DDCR) is a newly designated area set aside for conserving the natural flora, fauna and landscape of the desert ecosystem in Dubai. It encompasses about 225km² of sand dune desert and spans about 5% of the total area of Dubai. DDCR is a fenced area with a fence perimeter of about 85km. The reserve was declared in 2002 and the fence perimeter was finalized in late 2003. However, the area inside the main perimeter contains another core fenced area, the Al Maha Reserve (AMR), which surrounds the Al Maha Desert Resort & Spa. The AMR has been fenced since 1999. The AMR has been excluded from all grazing practices since 1999 and instead desert wild antelopes were introduced as free ranging animals. Wildlife in the AMR includes Arabian Oryx *Oryx leucoryx*, Scimitar horn Oryx *Oryx dammah*, and Mountain gazelle *Gazella gazella*. On the other hand the fence of DDCR still includes some farms in addition to free ranging livestock which is primarily camels. The numbers of camels counted in DDCR is 1209 which yields a density of 5.37 camels/km^2 (DDCR livestock survey 2004).

DDCR is mainly sand dunes desert ecosystem. The topography is simple where the landscape is dominated by low to medium high sand dunes. Gravel plains also occur amongst sand dunes. The altitude is not so variable where the maximum is 260m (msl) at the south and gradually sloping to the north to reach a minimum of 180m. Gravel Plains constitutes about 13.01% of the total area inside Al Maha Reserve measuring about 3.254 Km^2 and leaving a sum of 21.75Km^2 as Sand Dunes. Sand flats are also common lying among sand dunes. Map (1) shows a location map of DDCR illustrating the two fenced areas and the topography of the reserve. There is no record of the annual rainfall in the immediate area of DDCR; however there is some history of recordings in metrological stations in the vicinity. Records back to 12 years ago form Sharjah airport meteorological station reports an average annual rain fall of 50mm. Also a more extended record that dates back to 1967 is available from Dubai International Airport (station no. 41194 N25° 15' E55° 20') shows an average rainfall of 85mm over 40 years time (1967-2004). However variations in annual rainfall are considerable. Maximum of 229mm was recorded in 1997 while a minimum of 9.0mm was recorded in 1985. It should be held in mind that rain in desert landscapes is always localised and sporadic, in other words adjacent areas are not necessarily homogeneously receiving the same amount of rainfall every year but more or less follow the same pattern over time. Thus this figure should be used for DDCR with caution and as a guide only.

The presence of two fenced areas with considerable time difference of conservation measures being applied gives a special opportunity to compare the effects of conservation on the flora of the region. Although the primary purpose of the current work is to provide baseline data, about the status of the vegetation and the floral community in DDCR, such a unique opportunity to evaluate different land management regimes should not be missed. A hypothesis of a change being induced to the floral community structure according of different land use schemes is to be tested in the current study using the collected data.

Map (1) showing the location site of the Dubai Desert Conservation Reserve and the core fenced area of Al Maha Reserve and the topography as 20m slope increment contour lines



Methodology

The current study is aiming at providing baseline information about the status of the floral communities in DDCR. The scope of information provided will encompass two main themes. These are: 1) assessing species diversity and variability of the DDCR flora and 2) comparison of floral communities in different habitats; specifically comparing the communities of Gravel Plains against those of Sand Dunes, and against each other in different land-use schemes available. In addition some accounts of the distribution of individual species and species distribution patterns will be included.

The sampling is done using plot sampling approach. Sampling points are randomly selected over the 2 main habitats: Gravel Plains and Sand Dunes. Sampling strategy was a little bit different over the two different habitats. Randomly distributed points were generated separately for each of the individual Gravel Plains. Random sampling extension in ArcView was used to generate the random points in Gravel Plains. Each plain contained a varying number of points according to its surface area as to maintain a standard of 10% percent coverage.

For the Sand Dunes a different approach was adopted where a 500m grid was generated over the whole area, centeroids of grid units were generated and these formed the universal group out of which a partial group was selected to be sampled (see map 2) using a randomisation extension of ArcView. These appointed sampling points will serve as permanent sampling points to be sampled during the future monitoring rounds. Also a standard of 10% coverage was maintained.

In those appointed points circular plots were used for the sampling. Each circular plot involved sampling an area of 50m diameter. In this way each plot is equivalent to 7000m². In each plot several parameters were measured for each species, namely: density, relative density, frequency, relative frequency, abundance, relative abundance and importance value. Details for these quantities are described in Annex I. These parameters were used to assess the general condition of vegetation cover and to document the community structure quantitatively.

In addition diversity indices were used to quantitatively assess the diversity of plant communities in DDCR and to compare different habitats. Landscape ecologists have developed many quantitative values to account for spatial and temporal changes of species richness and diversity of ecosystems and also to compare between different habitats.

Field methods

In each of the Gravel Plains polygons 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 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. On arrival a 2 metre pole was fixed at the point and actual fix is recorded. 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 within 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 method of McAuliffe (1990). This method was preferred over conventional vegetation sampling methods (Muller–Dombois & Ellenberg, 1974) because its enhanced design oriented to the special properties of the desert vegetation. It has the advantages of 1) the time required per plot is less compared to time required per relevé in Braun-Blanquet sampling, 2)Log-series method provides more information by including rapid estimation densities 3)The survey of large areas allows inclusion of more rare species than is possible using standard quantitative technique.

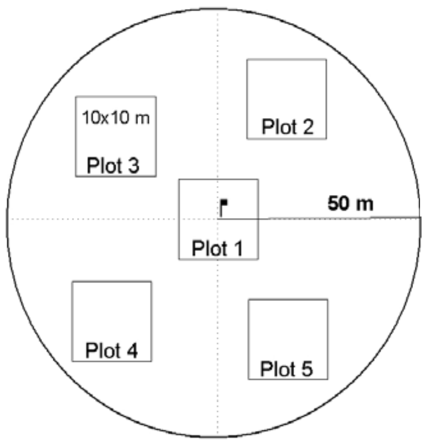
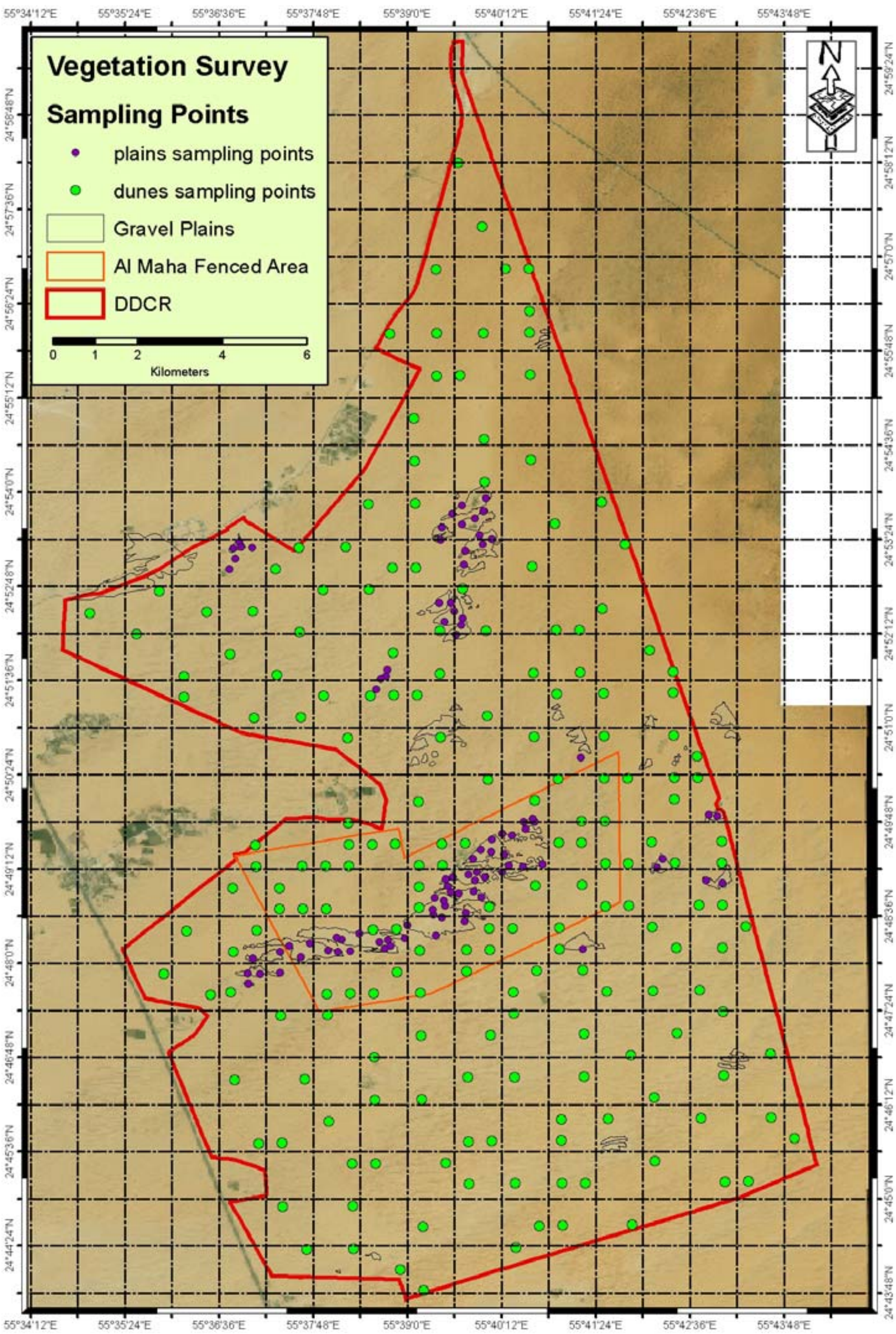


Fig (1)
In the Circular plot of 50 m diameter 5 plots of 10m x10m were sampled for floral species.

Map (2) Sampling point inside Dubai Desert Conservation Reserve



Data Analysis

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. Examples of *Type I* indices are Shannon-Wiener index and Birllouin 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.

In addition to point estimates of diversity indices, variance and confidence intervals were also calculated. Variance and confidence intervals of Birllouin's and Simpson's indices were calculated as suggested by Heltshe and Forrester (1985) using Jackknife method (details of Jackknife re-sampling and variance estimation are described in Annex II). Zhal (1977) also calculated variance and confidence intervals of Shannon–Weiner index using Jackknife methods. Routledge (1980) confirmed that Jackknife estimation technique reduces the bias in diversity estimators when sampling is done using quadrates as well as providing an estimate for standard error.

The nature of spatial distributions of floral species were investigated for being either clustered, scattered or evenly spaced by fitting the data to negative binomial, Poisson or Binomial distributions respectively. Chi-Squared statistic was used to judge best fit (Kerbs, 1989). Results of distribution patterns are verified using another dispersion determination method which is Morisita's index of Dispersion (Morisita, 1959).

Clustering methods were used to determine the patterns underlying species distribution and how plant communities may delineate habitat types in the study region. Two Way Indicator Species Analysis (TWINSPAN, Hill 1979) was used for this purpose. The product of the TWINSPAN analysis is utilized to develop lineage approximation and spatial display of the detected cover-types. This is achieved by creating a grid of Thiessen polygons based on the actually sampled plots where cover-type attribute is assigned to the respective sample Thiessen polygon.

As mentioned earlier it is expected that there are differences to be encountered in the floral community structures between the two types of habitats (Sand Dunes and Gravel Plains). Also it is a variation between those communities who experienced longer conservation and protection (AMR) within the same habitat in comparison to those who are relatively less conserved or still subjected to the exploitation of grazing and recreational uses taking place in DDCR. Thus a hypothesis that a potential of four different communities are evolving under these varying conditions was postulated. These communities are:

1- Conserved plains inside AMR
2- Conserved dunes inside AMR
3- Exploited plains outside AMR and within DDCR
4- Exploited dunes outside AMR and within DDCR

To investigate the validity of this hypothesis, Discriminant Analysis Function (DAF) where adopted where individual properties of samples from each group were used into the analysis. Discriminant analysis is useful for situations where you want to build a predictive model of group membership based on observed properties of each category or group. Canonical functions were used to segregate members of the potential groups. The properties used in the analysis were total abundance, species richness and species diversity. Species richness was expressed as total number of species observed per plot while species diversity was expressed using the three diversity indices mentioned earlier collectively. Step-wise analysis was conducted to maximise the model fit and to obtain best group segregation possible. Statistical package SPSS 11.0.1 was used for applying the analysis and display of results.

Results and Findings

A total of 269 plots were sampled all over the DDCR and AMR. These total a cover of 1,883,000m² of sampling area. The sampling effort was split among the four habitats involved as specified in table (1). Sampling was done during the period Aug. 2004 to Jan. 2005.

Table (1) sampling effort in DDCR & Al Maha Reserve

Habitat	Sampling points	Sampled Area (m²)
AMR Gravel plains	52	364000
AMR Sand Dunes	46	322000
DDCR Gravel Plains	30	210000
DDCR Sand Dunes	141	987000

1.1 Community Structure

The community of DDCR was sampled with two different habitats in mind, the Gravel Plains and the Sand Dunes. Although two different sampling schemes were applied to ensure randomisation and coverage yet the results are comparable since the field methodology and data analysis is the same for both. Here below the results concerning these two habitats.

1.1.1 Gravel Plains (AMR)

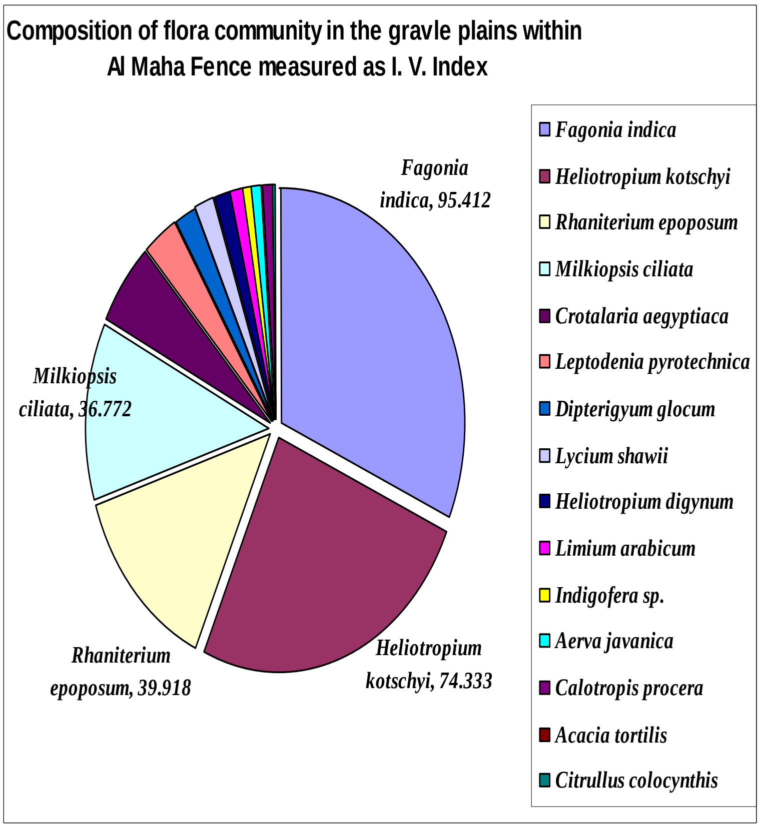
A total of 15 species were recorded on the Gravel Plains Table (2) lists the recorded species. All of the recorded species were perennials and no annuals were recorded in any of the sampling plots. The recorded species included 2 shrubs, 2 trees and 11 dwarf shrubs and herbs. Among all the species recorded *Fagonia indica* showed the highest IVI and thus considered as the dominant species around the Gravel Plains. *Heliotropium kotschyi* and *Rhaniterium epapposum* scored the second and third highest IVI scores respectively and thus are classified as co-dominant species. Interestingly *H. kotschyi* was totally absent during earlier times since it is not recorded at all in a survey done in the same area during 1999 (ref). *Moltkiopsis ciliata* is the fourth ranking species concerning the IVI but with a very narrow gab from *R. epapposum*. Looking at the values of frequency and abundance of the two top species we notice that *F. indica* is highest in abundance while *H. kotschyi* is highest in frequency which implies that *H. kotschyi* is more dispersed over the Gravel Plains compared to the more abundant but less dispersed *F. indica*.

Table (2) Plant species recorded around Gravel Plains inside AMR with various values of vegetation parameters used in computing IV index.

	Species	Freq.	R. Freq.	Abud.	R. Abud.	Density	R. Density	IVI
1	***Fagonia indica***	0.329	14.265	1414	40.574	0.048	40.574	95.412
2	***Heliotropium kotschyi***	0.502	21.765	916	26.284	0.031	26.284	74.333
3	***Rhaniterium epoposum***	0.329	14.265	447	12.826	0.015	12.826	39.918
4	***Moltkiopsis ciliate***	0.366	15.882	364	10.445	0.012	10.445	36.772
5	***Crotalaria aegyptiaca***	0.220	9.559	141	4.046	0.005	4.046	17.651
6	***Leptodenia pyrotechnica***	0.149	6.471	55	1.578	0.002	1.578	9.627
7	***Dipterigyum glocum***	0.088	3.824	32	0.918	0.001	0.918	5.660
8	***Lycium shawii***	0.078	3.382	28	0.803	0.001	0.803	4.989
9	***Heliotropium digynum***	0.054	2.353	22	0.631	0.001	0.631	3.615
10	***Limium arabicum***	0.054	2.353	18	0.516	0.001	0.516	3.386
11	***Indigofera sp.***	0.047	2.059	20	0.574	0.001	0.574	3.207
12	***Aerva javanica***	0.037	1.618	11	0.316	<0.001	0.316	2.249
13	***Calotropis procera***	0.037	1.618	11	0.316	<0.001	0.316	2.249
14	***Acacia tortilis***	0.007	0.294	3	0.086	<0.001	0.086	0.466
15	***Citrullus colocynthis***	0.007	0.294	3	0.086	<0.001	0.086	0.466

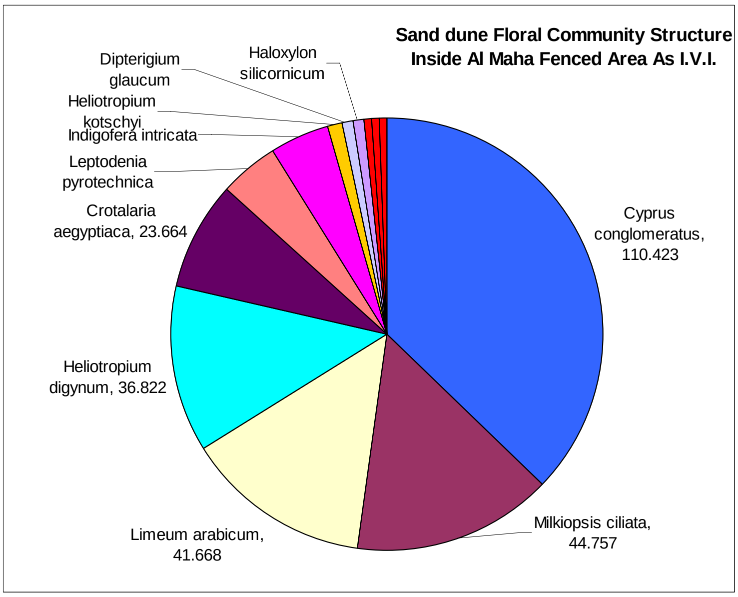
The Gravel Plain also contained some relatively rare species that scored very low IVI values. These are namely *Acacia tortilis* and *Citrullus colocynthis*. Both of the two species scored IVI of 0.466. Abundance and frequency where also very low; a total abundance of 3 for each of the 2 species shows very low overall occurrence of the species and also the low frequency of less than 1.0 % shows very limited distribution of the two species over the Gravel Plains. Figure (2) shows the relative proportions of the community structure evaluated as IVI values.

On the other hand, there were some very rare species that occurred on the gravel plains that showed very limited abundance and distribution that they failed to fall in the vicinity of any of the randomly selected sampling points. Prominent species that illustrate this case are *Ochradinus arabicus* and *Calligonum comosum*. Only one individual of the former and a handful of the latter were sighted during the sampling.



1.1.2 Sand Dunes (AMR)

A total of 17 species were recorded on the Sand Dunes inside AMR Table (2) lists the recorded species. Again the species list did not contain any annuals in any of the sampling plots. The recorded species included 4 shrubs and the rest were in the herbs layer. Among all the species recorded *Cyprus conglomeratus* showed the highest IVI and thus considered as the dominant species around the Sand Dunes. *Moltkiopsis ciliata* and *Limeum arabicum* scored the second and third highest IVI scores respectively and thus are classified as co-dominant species. On the other extreme of the scale, *Aerva javanica* was the least important species with the lowest IVI value. It scored only 0.436. Other species, such as, *Rhycosia minima* and *Calligonum sp.* where also very rare with IVI scores of less than 1.0. These were recorded in only 2 out of the 36 sampling plots. *Haloxylon silicornium* showed a restricted distribution where it was only found in the extreme south western corner of the fenced area and not anywhere else on the dunes.



Surprisingly *Rhaniterium epapposum* was recorded also on the Sand Dune habitat, however, it was scarcely recorded and very rare. Figure (3) shows the relative proportions of the community structure evaluated as IVI scores.

The rare species recorded should receive more monitoring effort especially regarding their presence in the soil as seeds. It may be critical for some of these species such as *R. minima* that they may *ex situ* conservation measures such as propagation or exclusion from wildlife herbivory.

Table (2) Plant species recorded around Sand dunes inside AMR with various values of vegetation parameters used in computing I.V. index.

Species	Abud.	Relative Abud.	Density /km²	Relative Density	Frequency	Relative Freq.	IV Index
Cyprus conglomeratus	1384	43.937	57,666.67	43.937	79.07	22.942	110.815
Limeum arabicum	419	13.302	17,458.33	13.302	60.00	17.409	44.012
Moltkiopsis ciliata	478	15.175	19,916.67	15.175	39.07	11.336	41.685
Heliotropium digynum	340	10.794	14,166.67	10.794	54.88	15.924	37.512
Crotalaria aegyptiaca	210	6.667	8,750.00	6.667	35.35	10.256	23.590
Indigofera intricata	136	4.317	5,666.67	4.317	19.53	5.668	14.303
Leptodenia pyrotechnica	80	2.540	3,333.33	2.540	27.91	8.097	13.177
Heliotropium kotschyi	28	0.889	1,166.67	0.889	3.72	1.080	2.857
Dipterigium glaucum	14	0.444	583.33	0.444	5.12	1.484	2.373
Panicum turgidum	13	0.413	541.67	0.413	4.19	1.215	2.040
Haloxylon silicornicum	16	0.508	666.67	0.508	2.79	0.810	1.826
Calotropis procera	9	0.286	375.00	0.286	4.19	1.215	1.786
Rhaniterium epapposum	10	0.317	416.67	0.317	3.26	0.945	1.580
Lycium shawii	5	0.159	208.33	0.159	2.33	0.675	0.992
Rhycosia minima	3	0.095	125.00	0.095	1.40	0.405	0.595
Calligonum sp.	3	0.095	125.00	0.095	0.93	0.270	0.460
Aerva javanica	2	0.063	83.33	0.063	0.93	0.270	0.397

1.1.3 Gravel Plains (DDCR)

A total of 15 species were recorded on the Gravel Plains in DDCR. This number is similar to that of AMR Gravel Plains but there are some considerable differences in community structure in terms of species composition and the densities of similar species in the two communities. Gravel Plains community in DDCR seems to be dominated by *Rhaniterium epoposum* and very highly deficient with *Heliotropium kotschyi* that dominated the Gravel Plains in AMR.

Table (3) Plant species recorded around Gravel Plains in DDCR area with various values of vegetation parameters used in computing I.V. index.

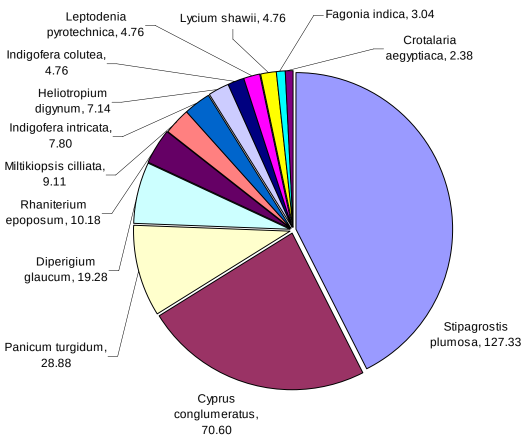
Species	Abud.	Relative Abud.	Density /km²	Relative Density	Frequency	Relative Freq.	IV Index
Rhaniterium epoposum	98	34.146	6,758.621	25.90412	48.00	27.586	87.637
Leptodenia pyrotechnica	29	10.105	2,000.000	7.665505	27.00	15.517	33.287
Acacia tortilis	38	13.240	2,620.690	10.04446	13.00	7.471	30.756
Lycium shawii	21	7.317	1,448.276	5.550883	21.00	12.069	24.937
Panicum turgidum	29	10.105	2,000.000	7.665505	10.00	5.747	23.517
Calotropis procera	19	6.620	1,310.345	5.022228	17.00	9.770	21.413
Indigofera intricate	22	7.666	1,517.241	5.815211	10.00	5.747	19.228
Haloxylon silicornium	7	2.439	482.759	1.850294	7.00	4.023	8.312
Heliotropium digynum	7	2.439	482.759	1.850294	6.00	3.448	7.738
Fagonia indica	5	1.742	344.828	1.321639	4.00	2.299	5.363
Limeum arabicum	5	1.742	344.828	1.321639	4.00	2.299	5.363
Citrullus colocynthis	4	1.394	275.862	1.057311	4.00	2.299	4.750
Acacia errynberghianum	1	0.348	68.966	0.264328	1.00	0.575	1.187
Heliotropium kotschyi	1	0.348	68.966	0.264328	1.00	0.575	1.187
Crotalaria retusa	1	0.348	68.966	0.264328	1.00	0.575	1.187

An interesting case was found in the DDCR part of the study region where a complete Gravel Plain was found to be fenced off and fitted with water sprinklers. This provided a unique case where it could be considered as a control case for Gravel Plains data. The plants here are provided with sufficient amount of moisture and are excluded from all exploitation conditions such as overgrazing and so on. The community analysis yielded the results shown in table (4) and Fig (4)

Table (4) Plant species recorded in an un-grazed fenced Gravel Plain inside DDCR with various values of vegetation parameters used in computing I.V. index.

Species	Abud.	Density	R. Den	Freq.	R. Freq.	R. Abud.	IVI
Stipagrostis plumosa	160	0.160	52.459	13	22.414	52.459	127.332
Cyprus conglomeratus	84	0.084	27.541	9	15.517	27.541	70.599
Panicum turgidum	23	0.023	7.541	8	13.793	7.541	28.875
Dipterigium glaucum	11	0.011	3.607	7	12.069	3.607	19.282
Rhaniterium epoposum	5	0.005	1.639	4	6.897	1.639	10.175
Moltkiopsis ciliata	6	0.006	1.967	3	5.172	1.967	9.107
Indigofera intricata	4	0.004	1.311	3	5.172	1.311	7.795
Heliotropium digynum	3	0.003	0.984	3	5.172	0.984	7.140
Indigofera colutea	2	0.002	0.656	2	3.448	0.656	4.760
Leptodenia pyrotechnica	2	0.002	0.656	2	3.448	0.656	4.760
Lycium shawii	2	0.002	0.656	2	3.448	0.656	4.760
Fagonia indica	2	0.002	0.656	1	1.724	0.656	3.036
Crotalaria aegyptiaca	1	0.001	0.328	1	1.724	0.328	2.380

Fig (4) Community structure for ungrazed Gravel plain as I.V.



The direct observation extracted from this small sample is first; the considerably higher proporion assumed by herbal species as both abundance and diversity compared to the grazed gravel plains and secondly dominance of the grass species in the community over other layers when the grazing is excluded, about 75% of the community is grasses. One of these grass species *Stipagrostis plumosa* is never recorded in anywhere else around the Gravel Plains that are subjected to livestock garzing, this suggests that this species is highly dependant on moisture availability and also being highly palatable as it is totally absent from all plains subjected to grazing.

The current findings of the community structure on Gravel Plains suggest a major change occurring compared to the findings reported by Böer (1997), On one hand he reported that Gravel Plains where dominated by *R. epapposum* and *L. pyrotechnica* as a co-dominant species. On the other hand the species list formulated for species recorded on the Gravel Plains in AMR included neither *F. indica* nor *H. kotschyi* which are the current dominant and co-dominant species respectively. Böer reported at the time of his survey in Dec. 1997 that the area was subjected to heavy livestock grazing evidently observed by large amounts of camel and goat/sheep tracks. It is suggested that the observed community change is due to either the exclusion of grazing activities from the area or that livestock is being replaced by wildlife herbivores that have different dietary requirements and that they are being partially fed with the provided rations.

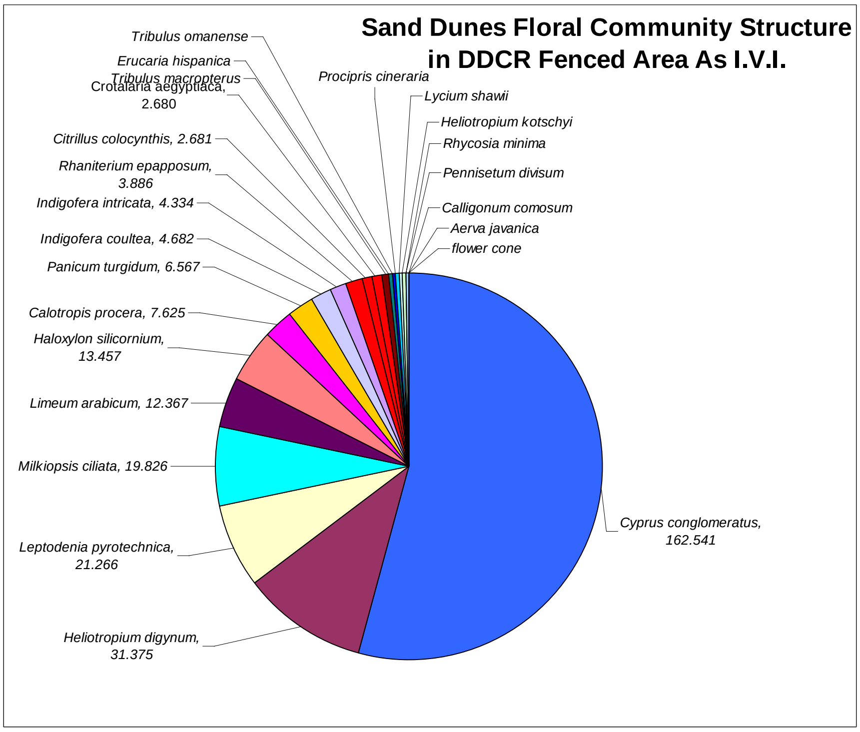
Böer also reported different community structure for the sand dune habitats. In his study he reported *Pennisetum divisum* as co-dominant species along with the *Cyprus conglomeratus* as the dominant species. However, currently *P. divisum* is totally absent from the dunes in AMR and very under represented on the DDCR dunes in the current survey. *Cyprus conglomeratus* is still the dominant species on the sand dunes habitat in Al Maha. It should be stated that Böer findings are considered here with high caution since the document contained no description of methods or any quantitative measures being applied, all results were empirically stated and in a crude way but yet providing the only comparison available.

1.1.4 Sand Dunes (DDCR)

A total of 24 species were recorded over the Sand Dunes in the perimeter of DDCR. Table (6) lists the recorded species and their sampling parameters.

Table (2) Plant species recorded around Sand Dunes inside DDCR Perimeter with various values of vegetation parameters used in computing IV index.

Species	Abud.	Relative Abud.	Density	Relative Density	Frequency	Relative Freq.	IV Index
Cyprus conglomeratus	3558	66.654	50,468.09	66.654	54.61	29.233	162.541
Heliotropium digynum	426	7.981	6,042.55	7.981	28.79	15.414	31.375
Leptodenia pyrotechnica	217	4.065	3,078.01	4.065	24.54	13.136	21.266
Moltkiopsis ciliata	288	5.395	4,085.11	5.395	16.88	9.036	19.826
Limeum arabicum	172	3.222	2,439.72	3.222	11.06	5.923	12.367
Haloxylon silicornium	193	3.616	2,737.59	3.616	11.63	6.226	13.457
Calotropis procera	88	1.649	1,248.23	1.649	8.09	4.328	7.625
Panicum turgidum	78	1.461	1,106.38	1.461	6.81	3.645	6.567
Indigofera coultea	52	0.974	737.59	0.974	5.11	2.733	4.682
Indigofera intricata	65	1.218	921.99	1.218	3.55	1.898	4.334
Rhaniterium epapposum	49	0.918	695.04	0.918	3.83	2.050	3.886
Citrullus colocynthis	29	0.543	411.35	0.543	2.98	1.595	2.681
Crotalaria aegyptiaca	31	0.581	439.72	0.581	2.84	1.519	2.680
Tribulus macropterus	31	0.581	439.72	0.581	1.70	0.911	2.073
Erucaria hispanica	13	0.244	184.40	0.244	0.57	0.304	0.791
Tribulus omanense	7	0.131	99.29	0.131	0.85	0.456	0.718
Prosopis cineraria	13	0.244	184.40	0.244	0.43	0.228	0.715
Lycium shawii	6	0.112	85.11	0.112	0.85	0.456	0.680
Heliotropium kotschyi	9	0.169	127.66	0.169	0.57	0.304	0.641
Rhycosia minima	9	0.169	127.66	0.169	0.57	0.304	0.641
Pennisetum divisum	1	0.019	14.18	0.019	0.14	0.076	0.113
Calligonum comosum	1	0.019	14.18	0.019	0.14	0.076	0.113
Cistanche tubulosa	1	0.019	14.18	0.019	0.14	0.076	0.113
Aerva javanica	1	0.019	14.18	0.019	0.14	0.076	0.113



Again *C. conglomeratus* is the dominant species with the highest IVI score. It is noticed that *C. conglomerates* have scored even higher IVI value on DDCR Sand Dunes if compared to that of it on AMR Sand Dunes. This is considered as an indication of higher levels of disturbance. *Heliotropium digynum* is the co-dominant species but with very big difference in IVI scores. A remarkable increase in the community proportion assumed by the shrub *Calotropis procera* is notice on the DDCR Sand Dunes compared to that on AMR Sand Dunes, a high IVI score of 7.6 of *Calotropis* is recorded over the DDCR Sand Dunes ranking as the seventh dominant species. It is also noticed that *Limeum arabicum* have retreated downward in the list where it scored much lower IVI compared to AMR Sand Dunes. On the other hand some rare species like *Rhycosia minima* have an increased IVI scores in DDCR Sand Dunes compared to AMR Sand Dunes, this could be attributed to the larger area on DDCR Sand Dunes causing higher sampling frequency (not abundance) for the species to cause the higher IVI score (the species had about the same density over the two Sand Dunes habitats 125 and 127 /km^2).

1.2 Floral Diversity and Species Richness

Generally, flora of this part of the UAE is devoid of endemic species and is of relatively low diversity in plant species compared to the northern mountains of Al Hajar. A total of 21 naturally occurring species were recorded inside AMR. Gravel Plains harboured 15 species while the dunes contained 17 species common species between the two overlapping habitat were found. However, species number gives very little about the diversity of any community. The indices of Simpson, Shannon-Weiner and Birllouin were used to estimate the floral diversity on the Gravel Plains within AMR and DDCR fenced areas. Table (3) shows the results for diversity estimates used as point estimates. The indices show relatively low diversity provided the area of the study region and the sample size.

Table (3) floral diversity estimates for plant community in AMR and DDCR

AMR

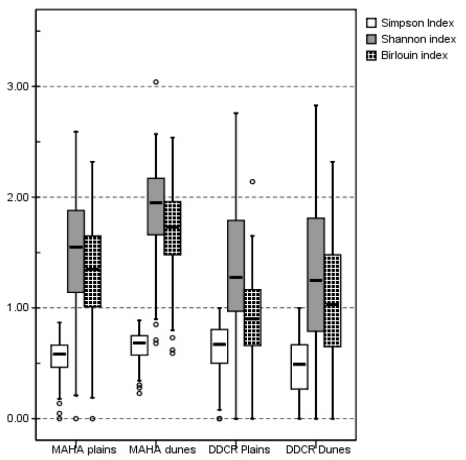
Index	Point estimate (Gravel Plains)	Point estimate (Sand Dunes)
Simpson	0.737	0.748
Shannon–Weiner	2.35	2.52
Birllouin	2.34	2.50

DDCR

Index	Point estimate (Gravel Plains)	Point estimate (Sand Dunes)
Simpson	0.831	0.542
Shannon–Weiner	3.04	2.05
Birllouin	2.91	2.04

However, as the purpose of this baseline study is to provide a comparable starting point about aspects of the vegetation and flora in the study region for future reference, point estimates of diversity are probably not enough. An estimate of variance for these point estimates and confidence intervals are more adequate for comparison in future assessments. In an approach to provide an estimate of variance and confidence intervals for these point estimate bootstrapping was applied. Jacknife re-sampling is proved as an effective way for providing estimates of variance for biodiversity indices (Zhal, 1977, Routledge, 1980 and Heltshe and Forrester, 1985). Figure (6) and Table 4a&b and shows the calculated values for the diversity indices and their variance estimates using Jacknife re-sampling for Gravel Plains and Sand Dunes inside AMR respectively.

Fig (6) diversity indices and their 95% confidence intervals



It is noticed that there are considerable differences in biodiversity amongst the four habitats sampled. Generally, Al Maha fenced area shows higher biodiversity over DDCR area. This could be a direct result of being fenced-off from livestock grazing and conserved for longer time duration compared to DDCR which still experience high stocking rates of free-ranging camels. The camel density in DDCR was estimated as 5.2 camels/km² (El Alaqamy, 2004). Floral communities of the dunes both in AMR and in DDCR are scoring higher diversity compared to the Gravel Plains in the two areas correspondingly. Though it should be emphasised that the difference in diversity between Sand Dunes and Gravel Plains, shown by the diversity indices, is less prominent in case of AMR habitat if compared for the same difference in DDCR area. This fact may suggest that there is some preference of the Gravel Plains as grazing ground favoured by the livestock and thus consuming the plains flora more heavily and thus adversely impacting it compared to the dunes.

The same conclusion is drawn after re-sampling the estimates, the new diversity indices are also reflecting medium to low diversity. However, the uncertainty around these estimates is low with relatively narrow confidence intervals, a matter that assures adequacy of the sample size used to account for the floral diversity in the Gravel Plains of AMR. However, it is easily seen that the Sand Dunes harbour slightly higher floral diversity compared to the Gravel Plains. This is a key result that should be drawn form this investigation.

The values of 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 DDCR geographical scale. Unfortunately, there is no explanatory data available yet to incorporate in a predictive model thus Kriging of the observed biodiversity values is used. This method is not the ideal choice since it doesn't include any of the ecological variables into the prediction; rather it only uses the autocorrelation within the observed data to predict the parameter under investigation. The result showed that AMR stands out as an Island of high diversity surrounded by the relatively much lower diversity areas of DDCR. Two hotspots of plant diversity are noticed in the far north and the far south of DDCR. It is also remarkable that livestock farms have a considerable impact over the diversity patterns in the DDCR where deep sinks of low diversity are usually observed having a livestock farm in the centre.

Table (4) a. Jacknife re-sampled diversity indices and their variances for floral diversity on AMR Gravel Plains

Simpson		Shannon –Weiner		Birllouin	
Point estimate 0.531	SD 0.039	Point estimate 1.82	SD 0.189	Point estimate 1.50	SD 0.191
95% confidence intervals	0.443 - 0.618	1.40 – 2.25		1.07 – 1.93	

Table (4) b. Jacknife re-sampled diversity indices and their variances for floral diversity on AMR Sand Dunes

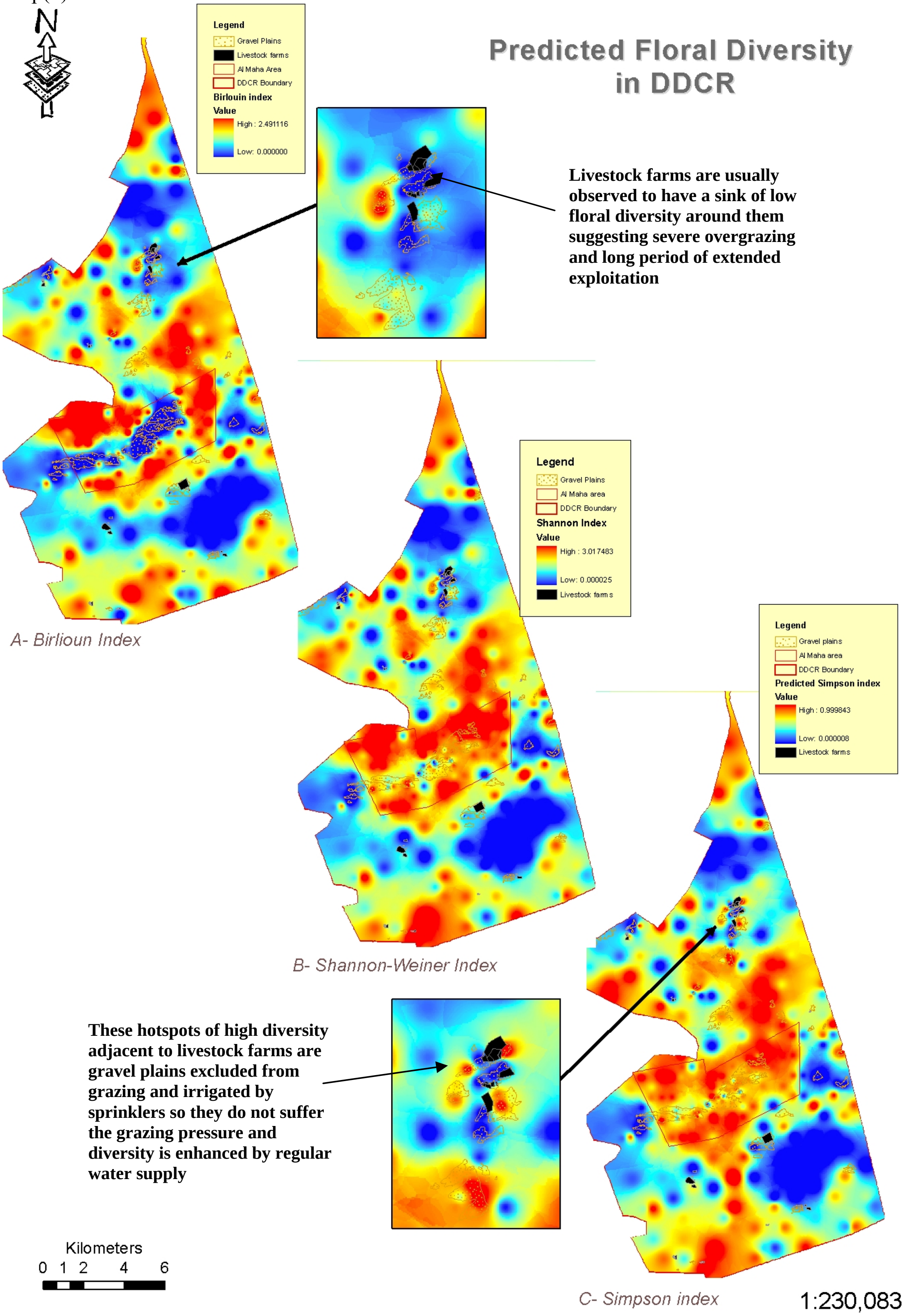
Simpson		Shannon -Weiner		Birllouin	
Point estimate 0.761	SD 0.006	Point estimate 2.57	SD 0.012	Point estimate 2.54	SD 0.009
95% confidence intervals	0.749 - 0.773	2.546 – 2.594		2.522 - 2.558	

Table (4) c. Jacknife re-sampled diversity indices and their variances for floral diversity on DDCR Sand Dunes

Simpson		Shannon -Weiner		Birllouin	
Point estimate 0.5471	SD 0.0004	Point estimate 2.07	SD 0.0016	Point estimate 2.03	SD 0.0009
95% confidence intervals	0.5464 - 0.5479	2.668 – 2.073		2.522 - 2.558	

Although the 3 diversity indices used agreed on that general pattern, Birllouin index seemed to emphasise the difference in diversity between the two habitats and maps show Gravel Plains as forming a distinctive corridor of low diversity surrounded by two high diversity banks of Sand Dunes in AMR. There were specially hot spots of floral diversity and all of them located on Sand Dunes and none of the Gravel Plains. On the other hand sinks of diversity showing highly converging contours were more common on the Gravel Plains. Diversity distributions predicted by Kriging are shown on maps (3 a, b, c).

Map(3)



Predicted Floral Diversity in DDCR
N
Legend
Gravel Plains
Livestock farms
Al Maha Area
DDCR Boundary
Birlouin index
Value
High : 2.491116
Low: 0.000000
Livestock farms are usually observed to have a sink of low floral diversity around them suggesting severe overgrazing and long period of extended exploitation
A- Birlioun Index
Legend
Gravel Plains
Al Maha area
DDCR Boundary
Shannon Index
Value
High : 3.017483
Low: 0.000025
Livestock farms
B- Shannon-Weiner Index
Legend
Gravel plains
Al Maha area
DDCR Boundary
Predicted Simpson index
Value
High : 0.999843
Low: 0.000008
Livestock farms
These hotspots of high diversity adjacent to livestock farms are gravel plains excluded from grazing and irrigated by sprinklers so they do not suffer the grazing pressure and diversity is enhanced by regular water supply
Kilometers
0 1 2 4 6
C- Simpson index
1:230,083

Key Findings

- First thing that comes to attention from the above results is that the flora of longer-conserved AMR is indeed showing higher diversity than that of the DDCR flora. The second observation is that Sand Dunes habitat is slightly more diverse compared to the Gravel Plains. Thus, it is suggested the activities taking place in DDCR and not in AMR are taking their toll on the floral structure of the reserve.

- Comparing the two IVI scores of the species *Calotropis procera* (AMR Sand Dunes 1.76 and DDCR Sand Dunes 7.63) in the communities of AMR Sand Dunes to that of DDCR Sand Dunes shows a four fold increase of the IVI score of the species in DDCR than it is in AMR. On the Gravel Plains this is of higher magnitude where the IVI of *C. procera* showed a score 10 fold higher in DDCR Gravel Plains compared to the score of AMR Gravel Plains (AMR Sand Dunes 2.249 and DDCR Sand Dunes 21.413). Higher IVI scores of *Calotropis procera* is know as an indication of diversity degradation and a direct result of overgrazing. Thus it is evident that the Gravel Plains are more targeted by grazing camels compared to Sand Dunes. Given the fact the minute surface area of the Gravel Plains in the study area compared to the vast area of Sand Dunes habitat, conserving the plains and designating them as off-reach area should be highly prioritised.

- Except for *Cyprus conglomeratus* all the palatable herbal species such as *Limeum arabicum, Moltkiopsis ciliate, Crotalaria aegyptiaca* and *Dipterigium glaucum* suffered a reduced IVI on DDCR Sand Dunes compared to their respective scores on AMR Sand Dunes. On the other side IVI scores for *Cyprus conglomeratus* experienced a two fold increase in DDCR when compare to its respective score in AMR Sand Dunes. It is documented that *Cyprus conglomeratus* is a species that benefits from disturbance (Ferguson et al., 1998) and that it has the capacity to colonise Sand Dunes habitat before any other species following events of overgrazing. A fact that adds more proof that DDCR is overgrazed and suffering from an ecological trauma that is induced by considerably high stocking rates of camels that are much beyond the carrying capacity of the pasture. Similar findings are reported by Gallacher & Hill (2004).

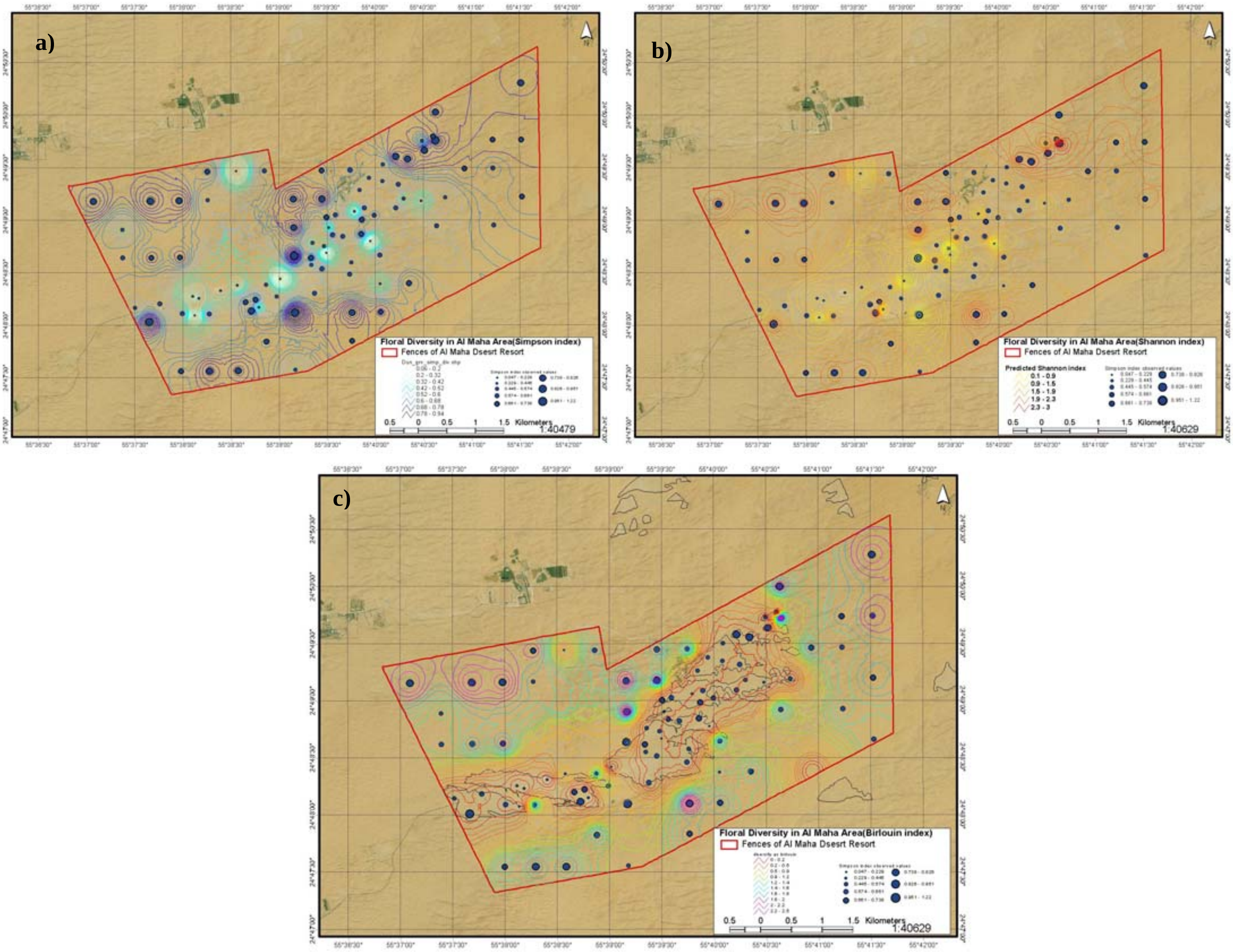
1.3 Density and Cover

Density and cover were determined using different approaches for Sand Dunes and Gravel Plains as the topography implied but again outcomes are still comparable. Estimates of cover were determined for each of the Gravel Plains individually and for the whole area of Gravel Plains collectively. On the other hand sampling plot served as the unit in case of Sand Dunes. Also cover was determined for each sampling plot and then collectively for the whole area of Sand Dunes inside AMR. This approach allowed for the spatial display of spatial heterogeneity in vegetation cover among sampling sites over the entire study region of AMR.

1.3.1 Gravel Plains

The total vegetation cover over the Gravel Plains in AMR was determined as 24,110m^2 which represents only 0.744% of the total area of the Gravel Plains. The amount of cover varied considerably over the entire AMR. The highest cover was recorded in the south western Gravel Plains with a gradual decrease of cover as we proceed towards the south eastern Gravel Plains. The highest cover percentage was recorded in south western Gravel Plains was 2.67% while the lowest was 0.42% in the eastern Gravel Plains. However, exceptionally high cover percentages were recorded in the small patches of the planted trees on the margins of the Gravel Plains that contributed to a higher overall cover percentage on the Gravel Plains. The highest cover percentage recorded in those marginal tree plains was 8.58% while the lowest was 1.56% and the average was 4.88 (S.D. 1.88).

Map (4) Predicted pattern of floral diversity over AMR using Kriging values of three diversity indices a) Simpson's, b) Shannon-Wiener and c) Birllouin's.



1.3.2 Sand Dunes

The total vegetation cover over the Sand Dunes in AMR was determined as 215,206m^2 which represent only 0.902% of the total Sand Dunes area. Cover on Sand Dunes also exhibited spatial variance where the Sand Dunes north to the Gravel Plains showed higher cover compared to the southern ones. The maximum cover percentage for a sampling plot was recorded in the north western corner of AMR scoring a cover of 4.328% while the lowest value was 0.0% where no cover recorded in sampling plots near the southern fence line. Average cover for all sampling plots on the Sand Dunes was 0.384% (S.D. 0.856). Thus it is obvious that the Sand Dunes are more heterogeneous and contain more spatial variation in cover distribution compare to Gravel Plains. Table (5) summarizes all cover findings for both Gravel Plains and Sand Dunes communities inside AMR.

Table (5) Summary of cover estimates for AMR

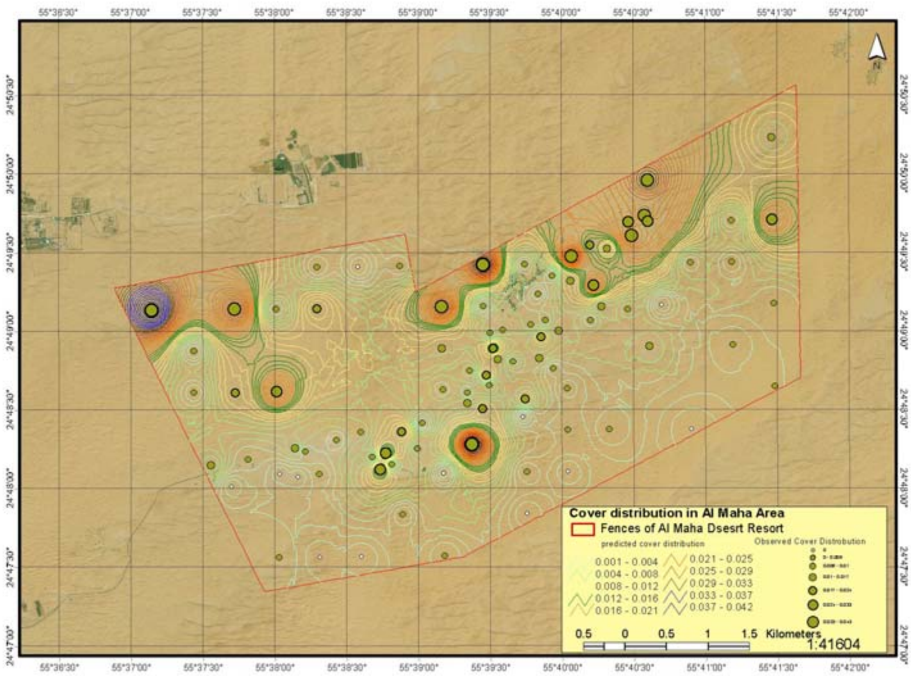
Cover	Sand Dunes		Gravel Plains	
Total cover	215206 m2	0.902%	24110m2	0.744%
Average cover	0.384%	SD 0.856	4.88%	SD 1.88
Max-Min	4.328%	0.0%	2.67%	0.42%

Table (6) Summary of density (km^{-1}) estimates for AMR

Cover	Sand Dunes		Gravel Plains	
Average density	153577.77	SD 127229.65	186042.55	SD 221901.07
Max-Min	840000.00	0.00	940000.0	20000.00

As a conclusion it could be stated that the vegetation cover has the tendency to be higher in the northern Sand Dunes of AMR and gradually decreasing towards the south passing from medium percentage cover in the Gravel Plains down to minimum of cover in the southern dunes. In conclusion Sand Dunes are more vegetated compared to the Gravel Plains as a whole. The spatial distribution of cover and the observed and predicted cover patterns over AMR are illustrated in map (4)

Map (5) illustrating spatial patterns of observed and predicted vegetation cover in Al Maha fenced area



1.4 Species Distribution

1.4.1 Species Dispersion

Kriging was used as the method to predict the spatial pattern of species involved in the study. Abundance counts of samples over the study region of DDCR were used as input. Prediction was applied to selected species of different vegetation layers as herb layer, shrub layer and trees. The spatial distribution of the grass *C. conglomeratus* was predicted separately since it is the most dispersed and abundant species in the community and it is expected to show significant indication about the status of the community in DDCR.

Herb Layer

Seven species selected for this layer namely *Heliotropium digynum*, *Dipterigyum glaucum*, *Moltkiopsis ciliata*, *Limeum arabicum*, *Heliotropium kotschyi*, *Rhanterium epopposum and Fagonia indica*. These species are either being restricted to Gravel Plains, restricted to Sand Dunes or being common to both.

1. ***Fagonia indica*** The species is of very limited distribution as it is confined to Gravel Plains in AMR with a very scant presence in Gravel Plains in DDCR. Only one sampling plot in DDCR showed positive record for the species. However this species showed higher affinity for occurring on the plains' periphery rather than being in the central areas.

2. ***Heliotropium digynum*** showed very a widely dispersed distribution over the Sand Dunes of both AMR and DDCR areas and restricted distribution over the Gravel Plains. The species showed higher density over the Sand Dunes compared to the Gravel Plains. The species seems to be least affected by grazing livestock compared to other herbal species as it is still occurs (at lower densities) where other species are absent. (See map (6.B)).

3. ***Moltkiopsis ciliata*** The species is shown to be widely spread in AMR with very high densities in some places. The gradient of the species seems to fade away when leaving AMR into the DDCR perimeter. Bands of void distribution are observed around camel farms. Map 5.A shows that camel farms are drawing two black bands north and south to AMR in the species distribution. (See map (6.C)).

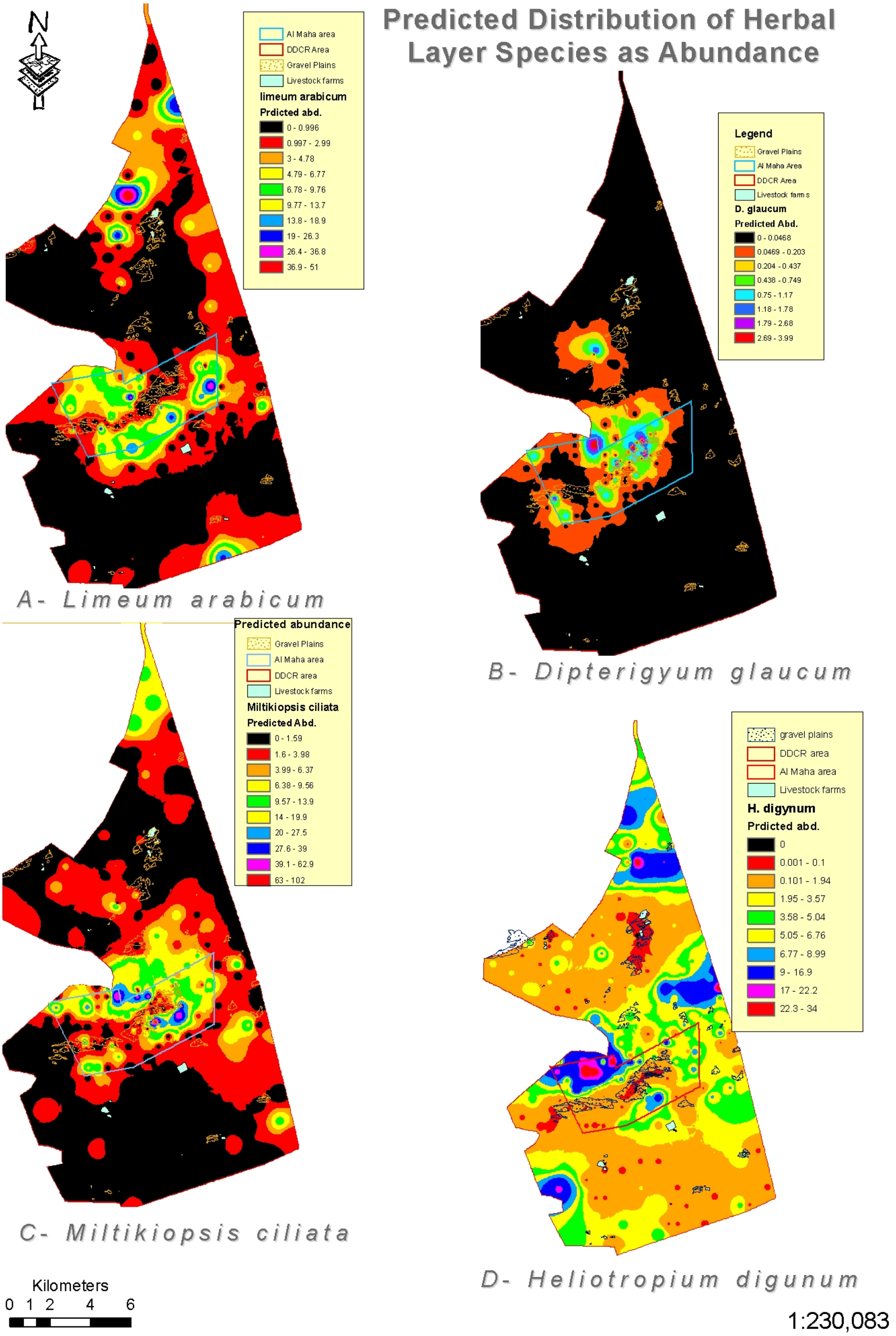
4. ***Rhanterium epopposum*** showed a remarkable trend in its spatial distribution over the Gravel Plains in AMR. The species was recorded only on Gravel Plains east to 55° 39.5' and never found anywhere on the west of this boundary. The species was very abundant where it was recorded and it cannot be considered as rare, yet showing restricted pattern of distribution. The species is woody and mostly dry thus it is highly unlikely to be influenced by the grazing wildlife ranging on the Gravel Plains (see map (6.i)).

5. ***Dipterigyum glaucum*** is expected to be highly palatable species for livestock. The detected pattern of distribution is highly limited to AMR and its immediate neighbourhood. The species presence in DDCR is very restricted to the areas adjacent to AMR fence and could be surely ruled out totally from all other areas sampled in DDCR. This again is pointing to the fact that the species is completely consumed by livestock in grazing areas while it still occurs only in areas excluded from livestock grazing. (See map (6.D)).

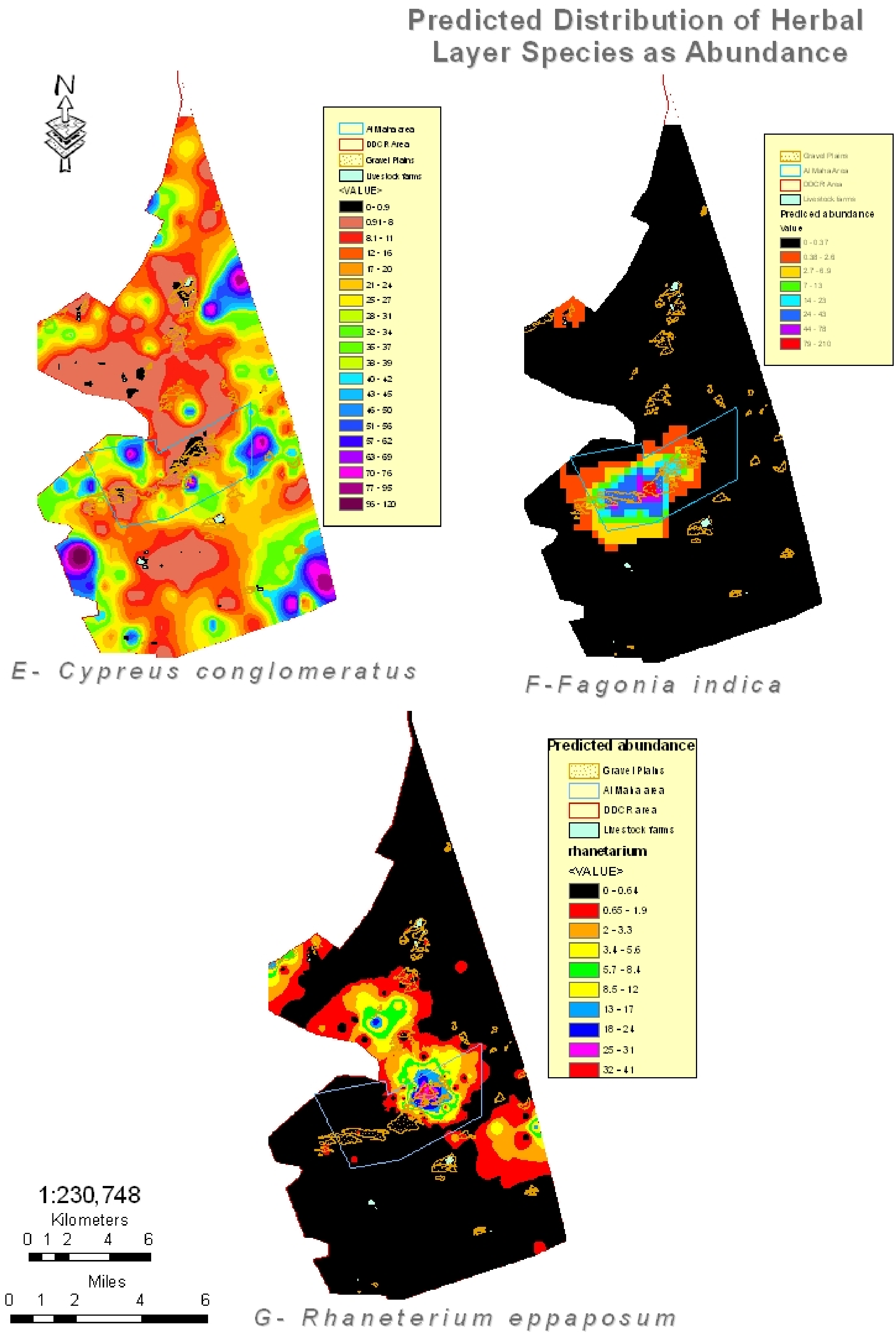
6. ***Limeum arabicum*** is seen to be a Sand Dunes species where it is hardly ever recorded on the plains either in AMR or in DDCR Area. The species showed considerably higher density in AMR Sand Dunes compared to its density over DDCR Sand Dunes. In DDCR the species was void in very large areas and the distribution is also believed to be controlled by the grazing livestock. The presence of camel farms is observed to be a limiting factor to the distribution of this species where higher concentration of the plant lie on the periphery of the DDCR area and in AMR and surrounded by wide areas of low densities found around the camel farms. Map 5.A shows that camel farms are drawing two black bands in the species distribution as it occurs only in areas excluded from livestock grazing. (See map 6.A).

7. ***Cyprus conglomeratus*** This is indeed the most widespread and most abundant species over the study region. The species is considered as a Sand Dunes species as it is never recorded on Gravel Plains, and was more abundant on sand flats rather than on less stable dunes. The species showed high concentrations around the periphery of the DDCR fence compared to central areas. Also the influence of livestock farms was very apparent in affecting the distribution of the species where the least abundance areas are always associated with livestock farms. (See map 6.E)

Map (6) Predicted distribution of some selected species of the herbal layer in DDCR



Map 6 (continued)



Shrub layer:

Four species have been selected for this layer namely *Calotropis procera*, *Leptodenia pyrotechnica*, *Haloxylon silicornicum and*, *Calligonum sp*. Representatives of these species were recorded on both Sand Dunes and Gravel Plains with the shrub *Calotropis procera* and *Calligonum sp*. being more restricted to the Sand Dunes habitat. These four species were selected as they show distributions that are indicative of habitat quality and of conservation implications.

8. ***Calotropis procera*** displays a pattern of relatively high abundance in the south eastern corner of the study region in addition to a patch in northern tip of DDCR. This distribution is indeed implying some relation with other shrub species. The pattern suggests that *Calotropis procera* is a weak competitor with other shrub species. In areas where other species such as *Haloxylon silicornicum* and *Leptodenia pyrotechnica* are abundant the *C. procera* seems to be of lower profile and is only thriving in areas where some other factor (such as overgrazing) is in action to reduce the abundance of these other shrub species. However, investigation is required to rule out the effect of other factors such as soil composition. (See map (7.A)).

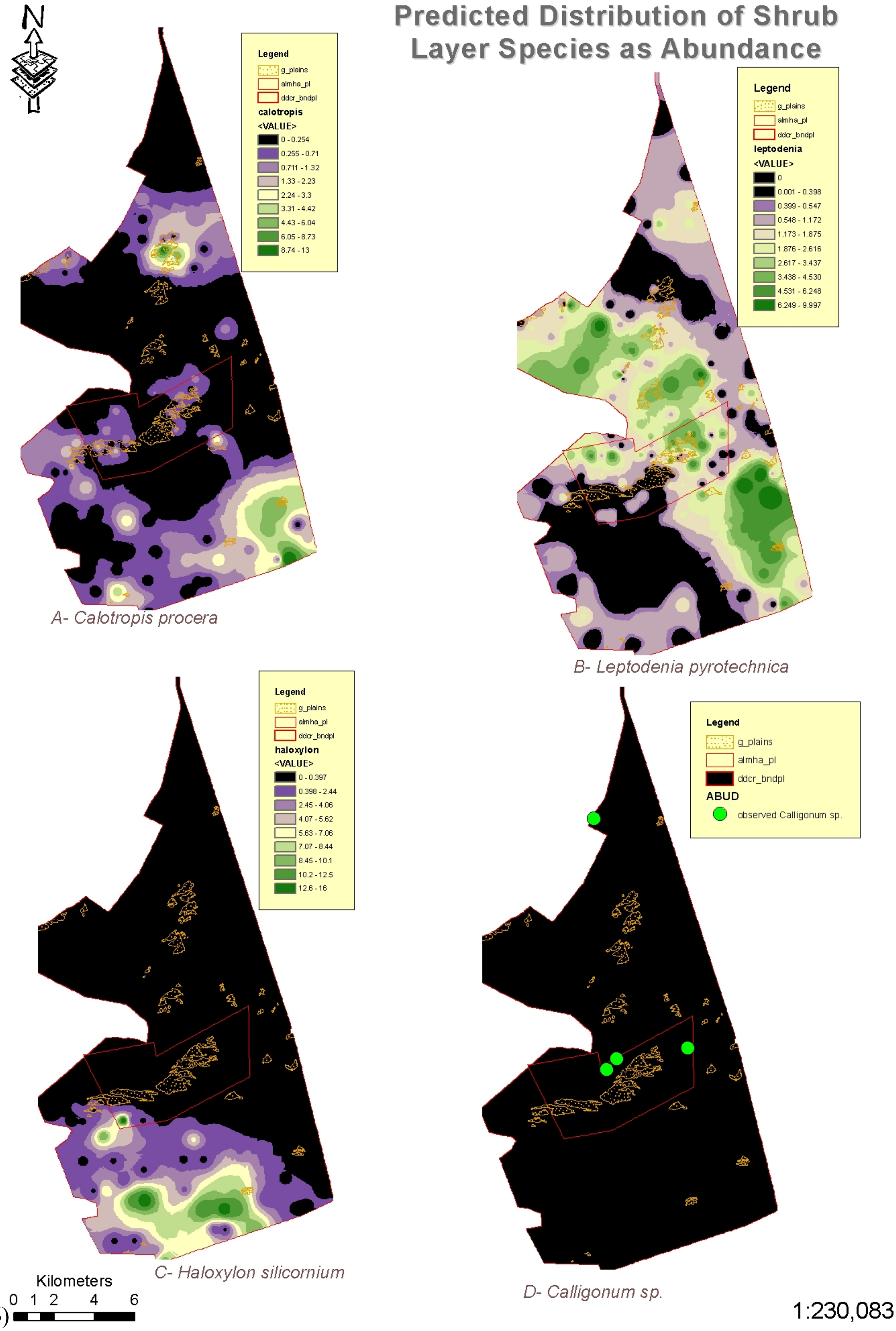
9. ***Haloxylon silicornicum*** This species has shown very distinctive and discrete pattern of distribution. It was found to be restricted to the south western corner of DDCR spreading in a north-east direction as just to touch at the southern border of AMR and not to be found any where else further to the north or east. (See map (7.C)).

10. ***Leptodenia pyrotechnica*** The species was found to have a high concentration that occupies a central area in DDCR and across the AMR. The high concentration area is spreading diagonally in a north west – south east direction. It seems that the livestock farms are again playing an influential rule in shaping the distribution of this species as areas void of the species above and below the diagonal pattern are occupied by those farms and are their direct spatial vicinity (See map (7.B)).

11. ***Calligonum sp.*** This shrub species is very rare and poorly represented in the study region. Few individuals were spotted on opportunistic basis. The species is a strong candidate for *ex situ* conservation and propagation. (See map (7.D)).

Map (7)

Predicted Distribution of Shrub Layer Species as Abundance



A- *Calotropis procera*

B- *Leptodenia pyrotechnica*

C- *Haloxylon silicornium*

D- *Calligonum sp.*

(6)

1.4.2 Species Spatial Patterns

The count data of species comprising the floral community of the study region were used to determine the spatial distribution pattern of each species. Plot Counts of each species where fitted to three different distributions namely Poisson, binomial and negative binomial to determine their mode of distribution (scattered, even or clustered respectively). Chi-squared (χ^2) statistic was used to choose between distributions as indication of best fit. However this type of analysis requires the species to be abundantly available and recorded in a considerable number of plots, thus it is conducted only for the most abundant species of the community, in other words it requires the species to score at least 6 presence counts over all the plots in order to give comparable results. Therefore, only 10 species were incorporated in this process. In addition Morisita's index was also used for the same purpose and as a complementary to indicate the extents of dispersion variation among these species.

All floral species involved showed clustered distributions that are not surprising in desert ecosystem. However scattered distribution is also expected but none of the species seems to assume the scattered distribution pattern. Morista's index for *L. Pyrotechnica* was slightly higher than one which indicates that the distribution of the species is probably clustered with high affinity in being scattered random distribution.

M. ciliata showed the highest clustering affinity, scoring the highest value of 2.9106. This species was indeed found over the entire study region where it was recorded in both Sand Dunes and Gravel Plains constituting a high proportion of the community as reflected by its IVI in both habitats (section 1.1). *F. indica*, *R. epapposum* and *H. kotschyi* showed similar medium dispersion affinities.

Table (7) patterns of distributions for floral species over gravel plains in AMR as fitted to different probability distributions

Species	Distribution	Morisita's Index of Dispersion
Leptodenia pyrotechnica	Negative binomial (clustered)	1.0866
Heliotropium kotschyi	Negative binomial (clustered)	1.2081
Fagonia indica	Negative binomial (clustered)	1.2089
Rhanitareum epapposum	Negative binomial (clustered)	1.5679
Indigofera intricata	Negative binomial (clustered)	1.6368
Cyprus conglemeratus	Negative binomial (clustered)	1.6726
Crotalaria aegyptiaca	Negative binomial (clustered)	1.6780
Limeum arabicum	Negative binomial (clustered)	1.8036
Heliotropium digynum	Negative binomial (clustered)	1.9137
Moltkiopsis ciliata	Negative binomial (clustered)	2.9106

1.5 TWINSPAN Community Analysis

Two Way Indicator Species Analysis (Hill, 1979) was used to analyse the floral community in terms of species composition. Dendrograms of both species and quadrates clustering are produced. Figure (5a and 5b) shows these dendrograms.

1.5.1 Plains Community

1.5.1a AMR Gravel Plains

Clustering of sampling sites on Gravel Plains of AMR suggests the following:

- There are two main habitat type defined by indicator floral species
    - Habitat (MHA-PLN-A) that is dominated by *Rhanterium epopposum*, *Leptodenia pyrotechnica* and possibly *Aerva javanica.*
    - Habitat (MHA-PLN-B) that is dominated by *Fagonia indica* and *Heliotropium kotschyi*. These appear to be co-dominant, though *H. kotschyi* has a broader range.

- The sampling sites cluster in the following groups
    - Habitat (MHA-PLN-A) type: 33, 34, 35, 39, 40, 42, 46, 47, 48 & 49
    - Mixture but mostly A (MHA-PLN-Ab) type: 29, 31, 32, 36, 37, 38, 41 & 43
    - Mixture A & B (MHA-PLN-AB) type: 27, 28, 30, 50 & 51.
    - Habitat (MHA-PLN-B) type:1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 44, 45 & 52.

1.5.1b DDCR Gravel Plains

Clustering of sampling sites on Gravel plains of DDCR area suggests the following:

- There are 3 detectable main habitat types defined by indicator floral species
    - Habitat (DDCR-PLN1). This is dominated by *Calotropis procera* and vague presence of the shrub *Leptodenia pyrotechnica* but with remarkably high deficiency in all other herbal or shrub species. This type of community structure is noticed to be closely associated with Gravel Plains occupied by camel farms running intensive stocking.

    - Habitat (DDCR-PLN3). This is dominated by *Rhanterium epopposum* and *Moltkiopsis ciliata*. The shrub layer in this community is represented by *Leptodenia pyrotechnica* mainly.

    - Habitat (DDCR-PLN4). This is much like (DDCR-PLN3) as being dominated by *Rhanterium epopposum* and *Moltkiopsis ciliata* but with considerably higher concentration of the former. In addition the shrub layer is much poorly represented and instead the Tree layer is well represented by *Acacia tortilis*.

- The DDCR plains sampling sites cluster in the following groups
    - Habitat (DDCR-PLN1) : samples 5, 6, 7, 23, 24, 25 & 30
    - Habitat (DDCR-PLN3) : samples 28, 29, 1, 19, 26, 8, 11, 12,13, 14, 15, 16, 17, 9 &10
    - Habitat (DDCR-PLN4) :samples 18, 22, 27, 2, 3, 4, 21 & 20

1.5.2 Sand Dunes Community

1.5.2a AMR Sand Dunes

Clustering of sampling sites on Sand Dunes in AMR suggests the following:

- There are two main habitat types over the Sand Dunes and each of them is showing some further division into two sub-sections. These habitats are described as
    - Habitat (C1). This is dominated by *Limeum arabicum* and the grass *Cyprus conglemeratus*. In addition in this habitat there is a considerable presence *of Heliotropium digynum.*
    - Habitat (C2). It is also dominated by *Limeum arabicum* and the grass *Cyprus conglemeratus* but with the *H. digynum* being replaced by two other herbal species namely: *Indigofera intricata* and *Moltkiopsis ciliata.*
    - Habitat (D1). This is dominated by *Limeum arabicum* and the grass *Cyprus conglemeratus*. An addition to this habitat type is the presence of considerable amounts of *Moltkiopsis ciliate* and diminished account for any other herbal species.
    - Habitat (D2) On the contrary to the previous communities on AMR Sand Dunes where *Limeum arabicum* and the grass *Cyprus conglemeratus* are abundant, it is not the case for this cover type. Instead these species are replaced by a remarkably higher presence of *Crotalaria aegyptiaca*. In addition *Moltkiopsis ciliata* is the second defining species for this habitat.

- The sampling sites cluster in the following groups
  - Habitat (C1) type: 574, 540, 575, 609, 636, 543, 582, 477, 475, 706, 546, 580, 604, 603, 617, & 605
  - Habitat (C2) type: 509, 715, 676, 649, 474 & 748
  - Habitat (D1) type: 670, 642, 672, 545, 705, 671, 683, 512, 612, 668, 749, 815 & 579
  - Habitat (D2) type: 709, 707, 675, 779, 746, 647, 714, 710 & 473

1.5.2b DDCR Sand Dunes

Clustering of sampling sites on Sand Dunes in DDCR area suggests the following:

- There are two main habitat types over the Sand Dunes and each of them is showing some further division into two sub-sections. These habitats are described as
  - Habitat (E1): This cover-type is remarkably characterised by the dominance of the shrub *Haloxylon silicornicum* which is the main feature for this cover-type. Along with that, other herbal species are also represented especially *Cyprus conglemeratus, Heliotropium digynum* and *Moltkiopsis ciliate.* The shrub layer of this cover-type comprises *Calotropis procera* mainly with very scant presence of *Leptodenia pyrotechnica* that could be considered as negligible. This cover-type is referred to as the Haloxylon range due to its uniqueness in having this shrub. The distribution of this cover-type is observed to be limited to the southern parts of DDCR where it forms a recognisable continuous habitat. In the north the cover-type exists as fragmented scattered representative areas.
  - Habitat (E2). This is the major cover-type of the DDCR Sand Dunes where it covers most of the area in DDCR. The community of this cover-type is of the highest diversity over the dunes. However, this cover-type is further characterised by the extreme dominance of the herbs *Cyprus conglemeratus* and *Heliotropium digynum* in the herbal layer and the shrub *Leptadenia pyrotechnica.* The cover-type shows room for further division, where 2 sub-divisions are noticed
    - E2a: Lower diversity where very few species of the herbal layer are absent. Relatively low proportions of *C. conglemeratus* and *H. digynum,* instead, these species seem to be replaced by high presence of *Panicum turgidum* and *Crotalaria aegyptiaca*. The shrub layer is still represented by L. *pyrotechnica.*
    - E2b: Higher diversity where most of the herbal species of the dunes are represented. Extreme dominance of *C. conglemeratus* and H. *digynum* over the herbal species while *L. pyrotechnica* dominates the shrub layer.

  - Habitat (E3). Is specially characterised by the unique presence of the herb *Rhanterium epopposum* which is not recorded in any of the other cover-types over the DDCR Sand Dunes. This cover-type contains few other herbal species such as *Heliotropium digynum* and *Moltkiopsis ciliata* and noteworthy the absence of *Cyprus conglemeratus.* The shrub layer is represented by few shrubs of *Leptodenia pyrotechnic.* This cover-type is not of widespread over the area of DDCR dunes where it is observed to occur in areas more adjacent to the Sand Dunes of AMR.
  - Habitat (E4). Is very limited in its occurrence and distribution where a very poor community is recorded comprising only one herbal species *Moltkiopsis ciliata* and only one shrub species *Lycium shawii.* This degraded community is showing direct spatial relevance to the locations of livestock farms providing further evidence on the degrading impact of this activity over the ecological value of DDCR as a natural reserve.

Although TWINSPAN provides a good reliable grouping of various samples into distinctive communities, yet it doesn't provide a clear display of these communities spatially over the study region. To provide this output of displaying the spatial extents of these various communities another solution was adopted. The actual sampling points were used to create a grid of Thiessen polygons. Attributes representing the various community structures estimated by TWINSPAN were assigned to their respective Thiessen polygon, thus enabling the spatial display of results from TWINSPAN analysis.

The sizes and shapes of each Thiessen polygon were determined by the proximity and location of adjacent sample points. Thiessen polygons define individual areas of influence around each point in such a way that the polygon boundaries are equidistant from neighbouring points, and each location within a polygon is closer to its contained point than to any other point (Maggio and Long 1991). Each cover type classification is correct at the point where it was measured, but classification certainty decreases with distance from that point. The Thiessen polygons are therefore not necessarily representative of the true spatial extent of vegetation types, particularly in areas where sample points are widely spaced but yet provide the best approximation for these extents provided the current sampling coverage. Table (8) shows the estimated areas of each cover-type detected in the study region while Map (8) displays the spatial extents and distribution of these floral communities as delineated by TWINSPAN and Thiessen polygons based on the sampling grid.

Table (8) Proportions of different cover-types over study region of AMR and DDCR

Habitat/Cover-type	Surface Area (Km^2)		Study Region
E1	38.06	(19.59%)*	**DDCR Sand Dunes (86.22%) ****
E2a	26.65	(13.74%)*	
E2b	106.03	(54.64%)*	
E3	10.46	(5.39%)*	
E4	1.57	(0.81%)*	
No Vegetation	12.04	(6.21%)*	
C1	1.99	(8.34%)*	**AMR Sand Dunes (10.60%) ****
C2	9.23	(38.68%)*	
D1	7.13	(29.88%)*	
D2	5.51	(23.09%)*	
DDCR-PLN1	0.358	(7.41%)*	**DDCR Gravel Plains (2.45%) ****
DDCR-PLN3	1.1	(22.77%)*	
DDCR-PLN4	1.83	(37.89%)*	
No Vegetation	1.76	(36.44%)*	
MHA-PLN-A	0.44		**AMR Gravel Plains (1.44%) ****
MHA-PLN-B	2.16		
MHA-PLN-AB	0.14		
MHA-PLN-Ab	0.51		

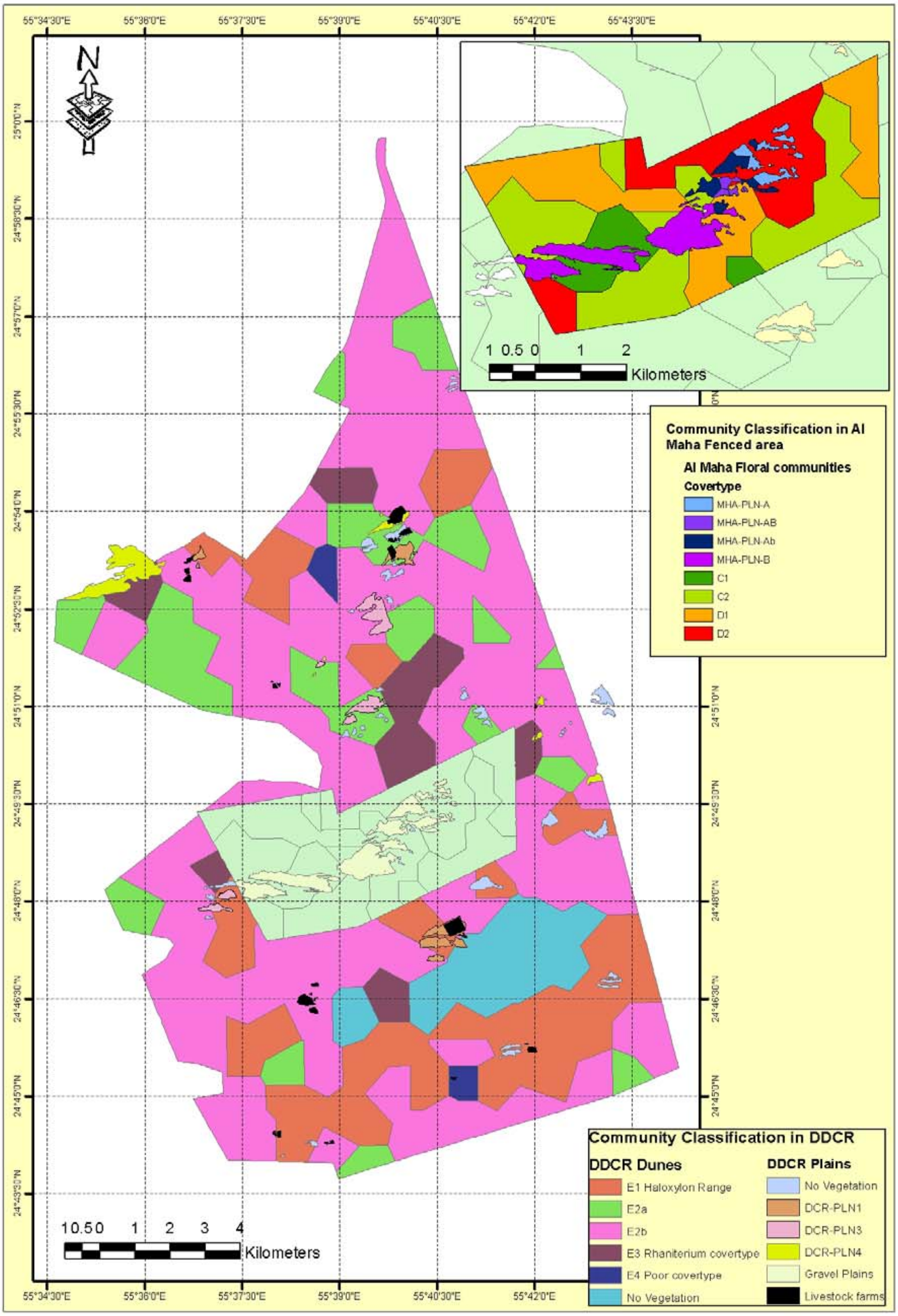
*Percentage expressed as proportion to the specific study region
** Percentage expressed to all area of DDCR.

Comments on TWINSPAN Results

- It is clearly recognised that the relatively long-conserved AMR shows distinctive distribution of habitats and these show higher amounts of continuity and homogeneity in their structure and geographical spread while, on the other hand, fragmentation is clearly evident in case of the relatively less-conserved area of DDCR. Habitats and communities in DDCR are fragmented and are of larger number of categories which suggests being subjected to heterogeneous array of compromising factors that creates scattered pieces of landscape that varies in their parameters and attributes accordingly.
- The analysis showed that a considerable area of the less-conserved DDCR dunes showed a drastic extreme of being totally void of vegetation and forming a big gap in the landscape of DDCR Sand Dunes. Rehabilitation is crucial priority for this area as to restore landscape continuity and to upgrade the status of fauna in DDCR ecosystem.

- In the DDCR region where overgrazing is taking place, TWINSPAN analysis gives more evidence that suggests a livestock grazing preference for the Gravel Plains compared to Sand Dunes. It is noticed that grazing have rendered 36% of the Gravel Plains into barren grounds while only 6% of the Sand Dunes are recorded as areas void of vegetation. This might be due to either easier travelling on Gravel Plains or that the flora of the Gravel Plains contains more palatable species. This fact also suggests that gravel plains are more vulnerable habitats and are much more susceptible to habitat deterioration if compared to the Sand Dunes.
- Sampling scale is noticed to be too big to detect some obviously unique communities, an example of these in the Ghaf forests. These are indeed unique communities with high concentrations of Ghaf trees and specially associated shrub and herbal species. Future monitoring should consider stratifying and allocating more sampling efforts and denser sampling grid in these areas to be able to pick these as unique communities.
- *Rhanterium epapposum* and *Leptadenia pyrotechnica* are clearly aggregated and also appear to be highly co-existent. This raises the question about the nature of such relation, whether they assist each other's survival somehow, or whether there is a soil type or wildlife influence that enhances their co-existence.
- *Fagonia indica* is probably aggregated, but less so, co-exists with *Heliotropium kotschyi*. It was observed during sampling that *F. indica* in Gravel Plains is more found in highly aggregated manner in the marginal areas between Gravel Plains and their surrounding Sand Dunes.
- *Dipterygium glaucum*, *Lycium shawii*, *Limeum arabicum*, *Calotropis procera*, *Crotalaria aegyptiaca* and *Moltkiopsis ciliata* appear to be randomly distributed without any distinctive pattern. Thus neither of these species is significant as an indicator species.
- Although the shrub *Leptadenia pyrotechnica* is far more abundant in the dunes compared to the case of it on the Gravel Plains, the analysis failed to give it any role in defining the major habitat types on the dune. This may be explained by the fact that in terms of abundance the shrub is not a match for the most abundant species on the dunes such as *L. arabicum, C. conglemeratus, H. digynum* and *M. ciliata* that were picked up by TWINSPAN as habitat defining specie. It should be noted that *L. pyrotechnica* is a significant species in the community of the sand dunes as indicated by its relatively high IVI (See section1.1.2).
- On the dunes habitat type C2 was the most dominant type which represented about 39.13% of the sampled habitats and was noticed to be found in all corners of the AMR.
- Habitat type D2 was really interesting since it was found only in the vicinity of some Gravel Plains in the eastern part of AMR. Knowing that *C. conglemeratus* and *L. arabicum* are highly palatable species and that these areas are known to be preferred grazing grounds of all desert antelopes in the AMR it could be suggested that this type of community structure is simply dictated by the wildlife herbivory.

Map (8): The approximated lineage of different habitats and floral communities in DDCR as estimated using the TWINSPAN clusters attributes being assigned to corresponding Thiessen polygons generated based on the sampling points grid.



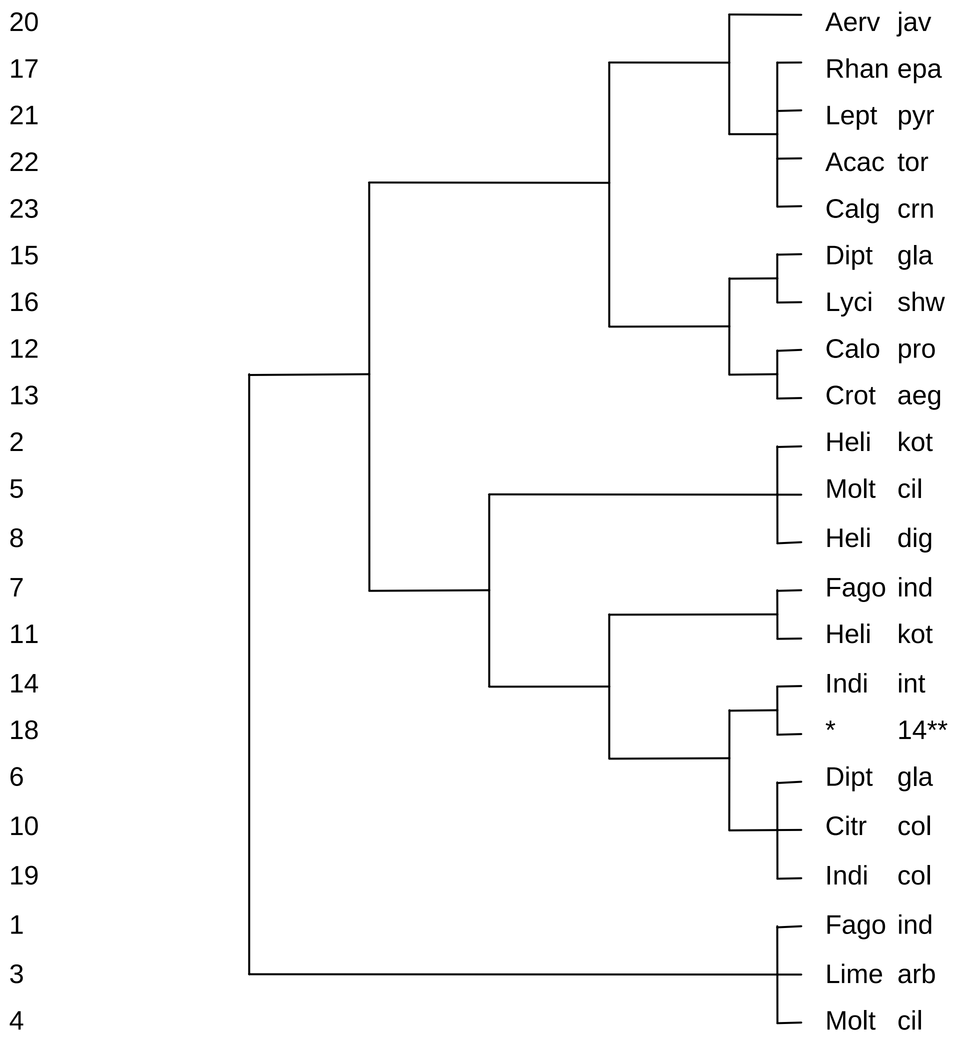
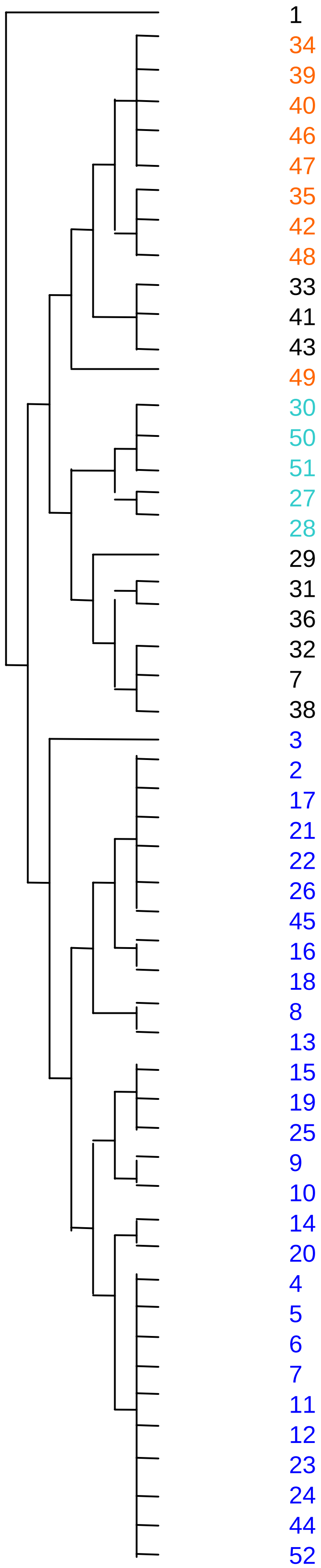


Fig (7a) Dendrogram showing clustering of species on Gravel Plains in AMR




```
                  43443344434423333333552212    112245112 1 1 1222411
                   9528490673139278160017840456712344259590832712656831

   20 AERV JAV0  -------12----221------1-----------------------1-----  0000
   17 RHAN EPA0  243345544532445555544551----------------------------  0001
   21 LEPT PYR0  22111322322-2-222222-13-----------------------------  0001
   22 ACAC TOR0  2------1--------------------------------------------  0001
   23 CALG CRN0  4-------------------2-------------------------------  0001
   15 DIPT GLA0  ---1--1--22----2---2211--------11-1---3----------2--  0010
   16 LYCI SHW0  1--11221-1-1-1-21-----2-------2-----12-1---11-11----  0010
    9 LIME ARB0  -22--22-----1-----------1-1--------1-1-1--------111-  0011
   12 CALO PRO0  --1--111--1----------11---12-------1----------------  0011
   13 CROT AEG0  -143124342423--1---1-------213-2--2221212--------1--  0011
    2 HELI KOT6  --------------------------------------------------22  010
    5 MOLT CIL0  254511212233-----3-21--2-1-12122122524444123331525--  010
    8 HELI DIG0  1-11-2------------1---2---------------2-22--------2-  010
    7 FAGO IND0  ------------23132255555225545355545555321---------2-  0110
   11 HELI KOT0  -----11--134-2--11443225555555545443-35534-2243323--  0110
   14 INDI INT0  -------1-------------1------21------1-322--1---1----  01110
   18 *    14**  ---------------------------------3------------------  01110
    6 DIPT GLA6  --------------------------------------------------2-  01111
   10 CITR COL0  ------------------------1----------------------2---  01111
   19 INDI COL0  ---------------------------------------------1-------  01111
    1 FAGO IND4  ---------------------------------------------------4  1
    3 LIME ARB6  ---------------------------------------------------1  1
    4 MOLT CIL6  ---------------------------------------------------3  1

                 0000000000000000000000000000000000000000000000000001
                 00000000000000000000000111111111111111111111111111
                  0000000000011111111110000000000000000000000000001
                   01111111111000000111110000000000000000001111111111
                    000000001110111110001100000000000000111110011111111
                  00011111    00011     00111111111100011  00000011
```

TWINSPAN clustering for Gravel Plains in Al Maha area

Fig (7 b)
Above: TWINSPAN output showing clustering of sampling sites and species of AMR Gravel Plains
Left: Dendrogram showing clustering of sampling sites on Gravel Plains according to habitat types
Below: TWINSPAN output showing clustering of sampling sites and species of DDCR Gravel Plains

```
                  222322 12 1111111 1122   22
                 567345089196812345679082723410

    6 CALO PRO4  1111-1------1-------------1---  0000
    9 FAGO IND6  111---------------------------  0000
   17 HALX SAL5  ---1112-1---------------------  0000
   18 HELI KOT6  ---1--------------------------  0000
    1 INDI INT6  --111-1--112------------------  0001
    7 LEPT PYR4  111-------1111111111--1---1---  001
    3 RHAN EPA6  ----1-11111111-12111--2222222-  0100
    4 PANI TUR6  1--------1------------21-22---  0100
   10 MOLT CIL6  ----1--22-111---------111-----  0100
    5 HELI DIG6  ----------1---------------11---  01010
    8 LIME ARB6  -----------1--------------11--  01010
   14 LEPT PYR5  ----------------------------1-  01010
   15 ACAC TOR6  ----------------------1-------  01011
   16 LEPT PYR6  ----------------------1-------  01011
   19 ACAC ERE1  -----------------------1------  01011
    2 LYCI SHW5  -------1-1111111111-11--1-----  011
   11 CITR COL6  -----------1---------1--------  011
   12 ACAC TOR1  ----------21----------1-1-----  011
   13 ACAC TOR3  -----------------------------2  1

                 000000000000000000000000000001
                 0000000111111111111111111111
                 0001111000000000000000011111111
                        00111111111111110001111
                          0001111111111111
                             0000000011
```

TWINSPAN clustering for Gravel Plains in DDCR area

E1 E2b E2a E2c E3 E4

```
              111  11 111111111111111                                        111              1111111111111111111 1111              1   11    1    11  1    11  11
              334559058222234400111332345782 112233444455555666677788889999999000  1222333456670001111222333445555 801334445111233444456666677795 216  385122235891157824117 24
              14256804802575135646769638024462629243456127895789013356902346791393815675682502524813581341780513687272234672589007017931346468171939025919018400750449099377 88

  1 HALX SAL5 --------4344435432344224-------------------------------------------1------------------313-1-311-----------------------------------3-------------------------------    00000
 11 CITR COL6 2-12------212-21--1----1-----------------------1-------------22------1-------------------2------1---------------1-------1-----------1---1-----------------------    00000
 20 PROS CIN1 --------5-----------------------------------------------------------------------2-------------------------------------------------------------------------------    00000
 33 HALX SAL4 --4-------------------------------------------------------------------------------------------------------------------------------------------------------------    00000
 13 CALO PRO6 -----------------------2------1-----------------------2-------------------------------------------------------------------------------------------------------    00001
 10 CALO PRO4 42242222--221-12-----11--1--------------------1--1------------------2----1---11----------212-1-2-1--4222333231--------------------------1-----------------------    0001
 12 TRIB OMN6 -----------------2-----------------------------------------------------------------------------1---1--------------1---2---------------------1-----------------------    0001
 22 RHYN MIN6 -------------2--------------------------------------------------------------------------------1---1---------2--2-------2-------------------------------------------    0001
  7 LIME ARB6 ------------------1-----3--2-22-----2232--25-33-23-1111311-21-2---411--111-11-2-----------1--1------2-----------------2----------------155----------------------    00100
 15 PENN DIV6 ------------------------------1---------------------------------------------------------------------------------------------------------------------------------    001010
 18 LEPT PYR6 ---------------------------------1------------------------------------------------------------------------------------------------------------------------------    001010
 23 ERUC HIS6 --------------------------------------1-------------------------------------4---------------------------------------------------------------------------------    001010
 25 CALG COM5 ---------------------------------------1------------------------------------------------------------------------------------------------------------------------    001010
 27 HELI DIG0 ------------------------------------------------2--------------------------------------------------------2------------------------------------------------------    001010
 28 CYPR CON4 ---------------------------5------------------------------------------------------------------------------------------------------------------------------------    001010
 30 CALO PRO5 -----------------------------------------------------1------------------------------------------------------------------------------------------------------    001010
 31 AERV JAV6 -------------------------------------------------------1----------------------------------------------------------------------------------------------------    001010
 21 HELI KOT6 -----------------------------------------------------------------------------------------------------------------3-------------1----------------------------    001011
 26 HELI KOT0 -----------------------------------------------------------------------------------------------------------------------1--------------------------------------    001011
 14 INDI COL6 ------------------------43222-1----1111-11--1--------1--------------2-------1-1----2-21--211-1-1--------2-2---1-2-------------------------------1---------------    0011
  8 CYPR CON6 ----42345453545333332---454-45555452555554555555555445555555555545555355555535555555544555555555355525545555554-3253353225533234335-----53------1-5-24-------------    010
  9 PANI TUR6 -11--------------------1--43---321---1--1--1-22112-------11-12-----2--------------------------------1------1-3--1-1----1212-1----1-22-------------1--------2---    010
 17 CROT AEG6 ------------------------------------------------------------------------1------------------------------------1--2---2-----------------------------1---------------    010
  2 HELI DIG6 --1-1--1-12-2-2-212--22143253-2--2--23-21--21232-44322----222121222----12--1221--212-13-22-11--1-2----1-1-1-2-22221432542222232432233413-----1-222-33-13333212--    011
  6 HALX SAL6 -----4---------------------------------------------------------3-2--------------------------------------------------------------34---------2-------------    011
 24 CROT AEG5 -------------------------23-----------1-----------------------------------------------------------------------111--1--2-1----------------------2---------    011
  3 INDI INT6 ----------------1-------------------------------------------------------211--1--------1---------2---21--------------------------1-2--45---------2-1------11---    10
  4 LEPT PYR4 -2--------1-2-2---1---------1--21----11----1---2-1-1-----1--11----11111-21-121111122221-21-2---11111322233323322222112222211222212111-----1-132222233333244223--    110
  5 MOLT CIL6 ----1--1----------11211---2---1------2----------131-1-------2-------2--23---221-42121211--24-214-2----21111-1--31224443-3322-41-432111----4---433443122222222411    110
 29 CALG CRN6 -5-------------------------------------------------------------------------------------------------------------------------------5-------------------------4--    110
 32 TRIB MAC6 -----------------12------------------------------------------------------------------23--2----1--1-------------------------------------------------4-----------    110
 16 RHAN EPA6 --------------------------------------------------------------------------------2-------------------1-2------2------------------------------33-322442131--3-------    111
 19 LYCI SHW5 ----------------------------------------------------------------------------------1---1-----------------------------------------------1-------------------11-----11    111

              0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000001111111111111111111111
              0000000000000000000000001111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111110000000000000000000011
              0000111111111111111111110000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000111000000001111111111111
                  00001111111111111111000000000000000000000000000000000000000000000000000000000000000000000000001111111111111111111111111   00000111000111111111
                      00000000111111110000000000000000000000000000000000000000000111111111111111111111111111111111111111111100000000000000000000000011   00111      000000001
                      011111110000000100000111111111111111111111111111111111111100000000000000000000000000000000000111111111000000000000000000001111                000000011
```

1.6 Habitat Categorisation and Effect of Conservation vs. Exploitation

As stated in the introduction and the methodology sections a hypothesis of habitat change and differentiation due to 1) different durations of conservation and 2) various land management regimes in various parts of the study region is investigated. It is expected that variable degrees of conservation and anthropogenic and livestock exploitation over the spatial range of the study region have lead to a corresponding change in the community structure of the flora communities accordingly. Discriminant analysis of characteristics extracted from the sampling process has yielded results supporting this initial hypothesis.

Step-wise Discriminant Analysis was done using abundance, diversity (expressed as Birlouin index) and species richness (calculated for each of the sampling plots individually) as independent variables. For Sand Dunes plots abundance was used as: the total abundance – abundance of *Cyprus conglomeratus.* This was done because *C. conglomeratus* is found everywhere on the dunes and seems to blur the picture when total abundance is to be used as discriminant factor. Analysis showed that species richness is not adding significantly to variance among the groups and thus eliminated from further processing leaving only total abundance and biodiversity as the independent variables.

Table (9) Significance of Discriminant function to account for group separation for various habitats

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.642	110.737	6	**.000**
2	.926	19.327	2	**.000**

From table (9) it is found that *p* values for the 3 functions are significant (0.05>sig) and are meaningfully segregating the plots of the four habitats. This indicates that the four habitats vary on the three facets: total abundance, diversity and species richness. However, it is required to know how much does each of these variables influence or contribute to habitats segregation, thus standardised coefficients and structure matrix is investigated.

Table(10) Structure Matrix of DFA showing correlation values of each parameter to canonical functions

	Function	
	1	2
Abundance - *Cyprus*	**.797***	-.604
Species Richness(a)	.573*	.480
Birlouin index	.623	**.782***

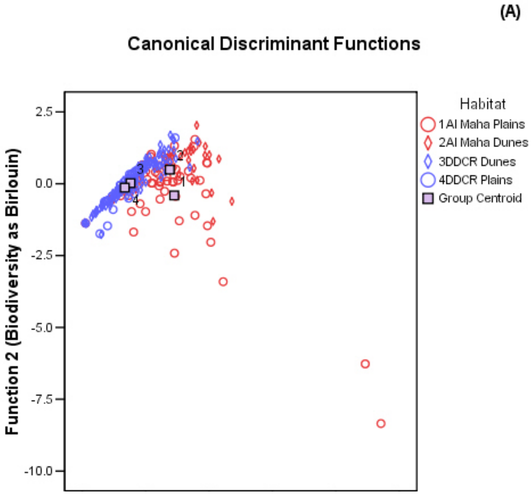
Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any Discriminant function

Structure matrix in table (10) shows that all selected parameters showed strong correlation (>0.4) with Functions 1 and 2. It is also evident that there is strong correlation between Function 1 and abundance while Function 2 is closely correlated to species richness. Hence, Function 1 could be representing Abundance while Function 2 representing biodiversity expressed as Birlouin Index.

Table (11) Standardised Canonical Discriminant Function Coefficients

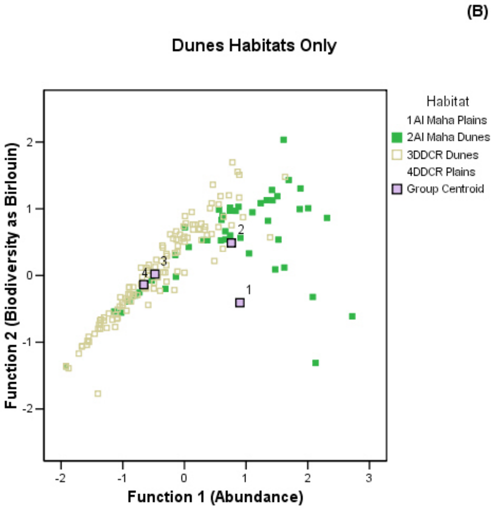
	Function	
	1	2
Biodiversity (Birlouin index)	.604	.797
Abundance	.782	-.624

Using these findings and looking at the scatter plots of samples show that the abundance separates the samples of AMR plots (red circles and diamonds) from those from DDCR plots (Blue circles and diamonds). These plots are supposed to represent a uniform, more homogeneous cluster of points as they are expected to belong to the same Dune-Plains habitat and they are very close to each other geographically, but in reality they segregate into different groups as an indication of different management schemes. Samples from these 4 areas are supposed to be similar in terms of species diversity, richness and abundance; however they seem to be very different with the group belonging to AMR lying mainly on the positive side of Abundance axis and those from the DDCR lying mainly on the negative end of the axis.



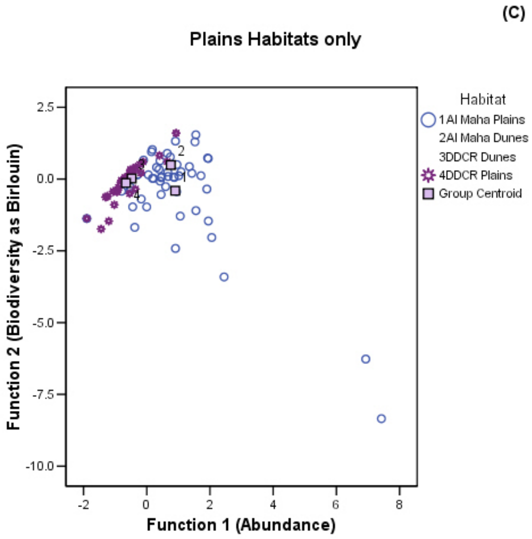
Habitat	Function	
	1	2
AMR Gravel Plains	.899	-.408
AMR Sand Dunes	.761	.488
DDCR Sand Dunes	-.478	.021
DDCR Gravel Plains	-.659	-.136

Table (12) Functions at Group Centroids
Un-standardised Canonical Discriminant functions evaluated at group means



The segregation among floral community of supposedly same habitats is more obviously illustrated when treated as pairs. When plotting results for only Sand Dunes plots from both regions it is clearly shown the flora of DDCR Sand Dunes is indeed unique to that of AMR Sand Dunes. Plots from AMR Sand Dunes show normal homogeneous distribution around the group centroid, on the other hand those of DDCR Sand Dunes exhibits a very obvious pattern affected by both parameters: abundance and diversity. Group centroids scores showed that AMR Sand Dunes habitat is higher to DDCR Sand Dunes habitat both in total abundance and diversity (see table 12) but the magnitude is much higher in case of the abundance. This finding is again emphasising the damage inflected by the overgrazing taking place currently in DDCR wider perimeter.

Thus it could be concluded that the invasive activities like grazing, off-road driving and others that are occurring in DDCR and excluded from AMR have resulted in the degradation of the habitat quality and floral community as results of samples from DDCR Sand Dunes and Gravel Plains are consistently plotting at the negative side from the Canonical Discriminant axis. On the other hand, while in AMR where conservation is the main theme the samples showed different case where they consistently plotted on the positive side of the Canonical Discriminant axis. **Thus it is proved that, the detrimental activities taking place in DDCR are degrading the habitat quality by affecting it on two main facets: decreased flora total abundance and reducing the biodiversity of the floral communities. This is resulting in general habitat fragmentation and vegetation loss.**



1.7 Exotic and Introduced Species

AMR contains some man-made habitats divided into two categories: 1) landscaping around the tourist facility and 2) assemblages of trees that were planted during the period of 1999-2002 for purposes of habitat upgrading. The landscaping around Emirates Al Maha Desert Resort & Spa facilities is a mixture of exotic species typically those used for urban landscaping. Plant fences and grass grounds are not uncommon and ornamental shrubs are also abundant. However, some indigenous species of trees are used in the process such as *Ziziphus spina-cristi*, *Acacia nilotica* and *Prosopis cineraria*. Other exotic tree species are also abundant around the resort such as *Pithacellubium dulce* and the Neem tree.

The trees assemblages are situated mostly on the fringes of the main Gravel plains in AMR. These trees were part of a landscape rehabilitation programme to increase the quality of habitat in the desert surrounding resort area in addition to providing the essential shade for the reintroduced desert antelope roaming around these plains. These assemblages have been excluded from the sampling scheme because they are irrigated systems and the conditions running in are not natural thus it is illogical to assess either the diversity or density of them or their associated species. The tree species in these assemblages are mixture of indigenous and exotic species. There were 4 indigenous tree species *Acacia nilotica*, *Acacia ehernbergiana*, *Prosopis cineraria* and *Ziziphus spina-cristi*. Exotic tree species were found to a lesser extent around the planted tree assemblages, these are *Pithacellubium dulce* and *Prosopis juliflora*. However, the latter is more seriously damaging and it is reported to be highly invasive species with very high competitive abilities. *P. juliflora* was reported to have detrimental impacts on the natural flora community in UAE. *P. juliflora* was observed to reduce the density and diversity of indigenous vegetation in floral communities studied in Sharjah, Fujairah and Ras Al Khaimah (El-Keblawy, 2002). Also, the effect of this invasive species was shown to be density dependant where effects were significantly higher with increasing density of the invasive tree. A strict measure is required to control the presence of this species in DDCR while it is still controllable. It is suggested to eliminate any individuals of this species in DDCR and impose vigilant monitoring for the emergence of any new individuals in the perimeter of DDCR especially knowing that the species is highly abundant in the villages around DDCR and primarily around Murquab village. **It is highly recommended to uproot or to extinguish these exotic trees as soon as possible in order to maintain the biological and ethical value of conservation in DDCR.** It is also recommended that to monitor and regulate future landscaping practices in Emirates Al Maha Desert Resort & Spa to maintain compliance to using indigenous species and to gradually replace all the existing invasive species currently used for landscaping purposes where ever possible.

1.8 Summary and Conclusion

In General the study area could be identified as having two major habitat types the Sand Dunes and Gravel Plains. Each is recognised for its unique terrain characteristics and floral community. The area does not show any endemism or species of any particular individual value, rather it is a good representation of the habitat of its surrounding ecosystem. Only 28 naturally occurring species were recorded throughout the study. Floral diversity is considered low to medium in DDCR. Biodiversity indices showed values 0.5-0.7 for Simpson index and 2.0 – 2.5 for Shannon-Weiner index.

DDCR and the AMR comprise one ecological unit as they are supposed to share the same physical and biological factors and processes occurring. However, land use and management regimes are drastically different in various parts of the region. In some vicinity severe overgrazing has been taking place over a long period and still continuing with increasing stocking rates, while in others strict conservation measures are in place for sustainable use of the resources. In conservation areas, grazing is replaced by wildlife herbivory thus representing more practical image of a natural dynamic desert ecosystem rather than excluding grazing completely. Thus the differences observed between the habitat structures in both areas are attributed to man-made impacts rather than natural processes.

AMR showed better habitat quality when compared to DDCR territories and signs of habitat regeneration were evident especially over the Gravel Plains habitat type. This regeneration is not so drastic but this could be attributed to the relatively short period of conservation and the rareness of rain events during that period. Biodiversity was very much better in AMR compared to the continually exploited DDCR habitats. Diversity indices showed higher values and tighter range of variation in AMR compared to those in DDCR. Densities of species that are still occurring on both areas showed the same drastic difference between the two areas emphasising the impact of the livestock over grazing.

Multi-variant analysis combined with geo-statistical techniques showed that certain patterns of floral communities are present in the study region and can be delineated if a good sample size is provided. Also this investigation showed that DDCR region is severely degraded and is exhibiting a high degree of habitat fragmentation. Analysis results showed that DDCR is composed of very fragmented landscape that do not share the soil-type and flora communities over large continuums, rather it comprises a group of isolated islands of different properties. The scale of fragmentation is higher in the northern part of the DDCR while in the southern part, a large area was recorded as totally void of vegetation. Needless to say that these areas void of vegetation are occurring in the immediate vicinity of the two largest camel farms in the southern range of DDCR. On the other hand AMR showed more discrete pattern of habitat distribution. In AMR the landscape was observed to be more organized and continuums of homogeneous habitats were more readily detectable and larger in spread over the study region. The landscape detected in AMR could be considered as the standard for Dubai Inland Desert except for the lack of tree species.

Out of the community analysis yields, two species are considered as *Indicator Species* that should be utilised to monitor for habitat quality reclamation in the disturbed parts of DDCR. These are the shrub *Calotropis procera* and the sage *Cyprus conglomeratus*. The high IVI score of the former especially in the northern part of DDCR is indicating a maximum of over-grazing and habitat degradation. If grazing management practices are in place in some later point of time down the line a reduced *C. procera* IVI would indicate a positive response but the magnitude and time period for such a reaction to be recorded is variable. *C. conglomeratus* reflects a high capacity to re-colonisation an area after a disturbance, a high IVI score for *C. conglomeratus* means absence of other species while a reduced score indicates that grazing pressure is relieved to a degree that others are regenerating and in the process of establishment.

Gravel Plains only comprising a small fraction of the total DDCR surface area (>10%), nevertheless, unique floral species have been recorded as only found on Gravel Plains and not on the Sand Dunes. These two facts makes it a higher priority to device special conservation measures and rules concerning Gravel Plains and all activities (off-road driving, grazing, tourism) involving them. Gravel plains must be assigned as a very sensitive habitat type within the DDCR.

There is an issue about exotic and invasive species in DDCR. It could be considered as of relatively minor priority for the landscaping plants since these are very dependant on irrigation water and thus their spread and establishment threat is minimal. However, a strong and radical procedure is required promptly to control and eliminate the more invasive species *Prosopis juliflora*, this species is of high spread capacity and can withstand very arid conditions. The species is documented as an invasive threat in UAE.

References

Böer, B. (1997) A Vegetation Survey and Recommendations for Landscape Establishment with Indigenous Plants for the Al Maha Project, Dubai, United Arab Emirates. Un-published internal document, 16pp.

El-Keblawy, A. (2002) Causes and Consequences of the Invasion of the Exotic *Prosopis juliflora* to the Environment of the UAE in *Proceedings of Third Annual Conference for Research Funded by UAE University*, May 2002 Al Ain, UAE, pp 5-8.

Heltshe, J., and Forrester, N. E. (1985) Statistical evaluation of the Jackknife estimate of Diversity when using Quadrate Samples. *Ecology*, 66:107-111.

Hill, M.O. (1979). TWINSPAN–A FORTRAN programme for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, N.Y. 90 pp.

Ferguson, M., McCann, I., & Manners, G., (1998) Less Water, More Grazing. ICARDA Caravan, 8, 9-11.

Gallacher, D., Hill, J., (2004) Effects of Camel Grazing on the Ecology of Dwarf Shrubs and Sedges in the Dubai (UAE) Inland Desert. *Journal of Arid Environments*, in Press

Jongbloed, M. V. D., Feulner, G. R., Böer, B. and Western, A. R., (2003) *The Comprehensive Guide to the Wild Flowers of the United Arab Emirates*, published by Environmental Research and Wildlife Development Agency (ERWDA), Abu Dhabi, UAE, 575pp.

Maggio, R.C., and D.W. Long. (1991). Developing Thematic Maps from Point Sampling using Thiessen Polygon Analysis, in *Proceedings, GIS/LIS'91, Atlanta, GA, Volume 1. American Society for Photogrammetry and Remote Sensing*, Bethesda, MD. pp 1-10.

McAuliffe, J. R. (1990). A Rapid Method for the Estimation of Density and Cover in Desert Plant Communities, *Vegetation Science.*

Mueller-Dombois, D. and H. Ellenberg. (1974). *Aims and Methods of Vegetation Ecology*. John Wiley & Sons, New York.

Morisita, M. (1959). Measuring the Dispersion of Individuals and Analysis of Distributional Patterns. *Mem. Fac. Sci., Kyushu University*, Ser. E (Biol.) 2:215-235.

Routledge, R. D. (1980). Bias in Estimating the Diversity in Large, Uncensored Communities. *Ecology*, 61:276-281.

Shukla, R. S., and Chandle, P. S., (1996) *Plant Ecology and Soil Science*, S. CHAND & COMPANY LTD. Ramangar, New Delhi-110 055.

Zahl, S., (1977). Jackknifing an Index of Diversity, *Ecology*, 58:907-91

Annex I

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

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

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

8- Importance value: the overview picture of the ecological importance

(Shukla and Chandle 1996)

Annex II

Jackknife estimation procedure is as follows: For a pool of M=10 quadrates, calculate a diversity index D_o. Remove one quadrate from the pool and recalculate diversity index D^{-i}, repeat this for each of the M quadrates removed, replacing the other quadrates. This procedure would give M pseudo-values of D^{-i}, i=1 to M defined as

$D_j = MD_o - (M\text{-}1)\, D^{-i} \quad (i=1, 2, \ldots, \ldots, M)$

Then

The Jackknife estimate of diversity is the average of pseudo-values $\hat{D} = \frac{\sum_{i=1}^{M} D^{-i}}{M}$

The variance then is $Var(\hat{D}) = \frac{\sum_{i=1}^{M} (D_i - \hat{D})^2}{M(M-1)}$ and two sided confidence intervals are calculated as $\hat{D} \pm t_{M-1,\alpha}\sqrt{Var(\hat{D})}$. Although there is no general consensus of whether to use t-distribution or Z distribution for estimating these confidence intervals (Gary and Schuacny 1972, Hinkley 1977) the t-distribution is selected over Z-distribution since sampling has involved only 10 quadrates in each sampling session. For M≥40 results using either (t) or (Z) distributions are almost identical.

Diversity indices

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.

.

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

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 $\lambda = \sum_{iI=1}^{S} \frac{n_i(n_i - 1)}{N(N-1)}$

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

Annex III: Distribution Fit to Individual Species Spatial Patterns

Fagonia indica

Index of Dispersion Test

=========================

The ratio Observed Variance/Observed Mean =10.5

The two tailed X^2test for this ratio gives X^2= 326 with 31 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.2089 (Eq. 4.26)
Standardised Morisita Index = 0.5032 (Eq. 4.30 to 4.33)

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	6.9149E+254	450	0.000
Poisson	3.3999E+254	449	0.000
Binomial	6.9149E+254	448	0.000

Best fit is from the **Negative Binomial** (clusters) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 44.188 k =6057.3

Rhanitareum epapposum

For the 29 quadrates, the number of organisms counted has
Mean = 16.1 and variance = 168

Index of Dispersion Test

=========================

The ratio Observed Variance/Observed Mean = 10.5

The two tailed Chi-squared test for this ratio gives χ^2= 293 with 28 D.F.
The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.5679(Eq. 4.26)
Standardised Morisita Index = 0.5095(Eq. 4.30 to 4.33)

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	56.2664	42	0.045
Poisson	724379.2693	41	0.000
Binomial	2.11 E+18	40	0.000

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 1916.103 k =1.3342.

Heliotropium kotschyi

For the 30 quadrates, the number of organisms counted has mean 4.97 and variance=10.2

Index of Dispersion Test
==========================

The ratio Observed Variance/Observed Mean = 8.01

The two tailed χ^2 test for this ratio gives χ^2 = 59.8 with 29 D.F.
The probability of obtaining a χ^2 value at least this large is 0.0007

Morisita's Index of Dispersion = 1.2081
Standardised Morisita Index = 0.5016

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	13.3424	42	0.205
Poisson	38.9491	41	0.000
Binomial	298.4819	40	0.000

Best fit is from the **Negative Binomial** (clustered) distribution.
Parameter estimates for the Negative Binomial distribution:
Mean (μ) = 4.9667 k =4.1843

Heliotropium digynum

For the 48 quadrates, the number of organisms counted has mean 7.54 and variance = 60.5

Index of Dispersion Test
==========================

The ratio Observed Variance/Observed Mean = 8.02

The two tailed χ^2 test for this ratio gives χ^2 = 377 with 47 D.F.
The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.9137
Standardized Morisita Index = 0.5091

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	56.1171	35	0.007
Poisson	1.7E+10	34	0.000
Binomial	3.14E+14	33	0.000

Best fit is from the **Negative Binomial** (clustered) distribution.
Parameter estimates for the Negative Binomial distribution:
Mean (μ) = 7.5417 k = 1.3384

Moltkiopsis ciliata

For the 67 quadrates, the number of organisms counted has
Mean = 12.6 and variance = 319

Index of Dispersion Test
==========================
The ratio Observed Variance/Observed Mean = 25.3
The two tailed χ^2 test for this ratio gives χ^2= 1.1.67E+3 with 66 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 2.9106
Standardised Morisita Index = 0.5143

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	373.6471	104	0.000
Poisson	2.55E+31	103	0.000
Binomial	3.28E+27	102	0.000

Best fit is from the **Negative Binomial** (clustered) distribution.
Parameter estimates for the Negative Binomial distribution:
Mean (μ) = 12.567 k = 0.8376.

Leptodenia pyrotechnica

For the 52 quadrates, the number of organisms counted has
mean 2.6 and variance = 3.19

Index of Dispersion Test
==========================
The ratio Observed Variance / Observed Mean = 1.23

The two tailed χ^2 test for this ratio gives χ^2 = 62.6 with 51 D.F. The probability of obtaining a χ^2 value at least this large is 0.1279

Morisita's Index of Dispersion = 1.0866
Standardised Morisita Index = 0.2683

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	25.8586	5	0.190
Poisson	29.1232	7	0.281
Binomial	537.7763	5	0.030

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 2.5962 k = 14.581

Crotalaria aegyptiaca

Index of Dispersion Test

========================

The ratio Observed Variance/Observed Mean = 5.09

The two tailed χ^2 test for this ratio gives χ^2= 295 with 58 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.6780 (Eq. 4.26)
Standardised Morisita Index = 0.5053 (Eq. 4.30 to 4.33)

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	40.4027	24	0.010
Poisson	265966.9549	23	0.000
Binomial	707713822.3460	22	0.000

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 5.949 k = 1.7134 (Eq. 3.13)

Cyprus conglemeratus

Index of Dispersion Test

========================

The ratio Observed Variance/Observed Mean = 5.09

The two tailed χ^2 test for this ratio gives χ^2= 959 with 42 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.6726 (Eq. 4.26)
Standardised Morisita Index = 0.5078 (Eq. 4.30 to 4.33)

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	241.0015	142	0.010
Poisson	4.97 E+43	141	0.000
Binomial	1.36 E+44	140	0.000

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 31.744 k = 1.6986 (Eq. 3.13)

Indigofera intricata

Index of Dispersion Test

=========================

For the 22 quadrates, the number of organisms counted has mean 6.18 and variance = 31.5. The ratio Observed Variance/Observed Mean = 5.09

The two tailed χ^2 test for this ratio gives χ^2= 107 with 21 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000

Morisita's Index of Dispersion = 1.6368
Standardized Morisita Index = 0.5127

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	32.7266	23	0.049
Poisson	97601.4590	22	0.000
Binomial	614138.4716	21	0.000

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 6.1818 k = 1.5178.

Limeum arabicum

Index of Dispersion Test

=========================

For the 58 quadrates, the number of organisms counted has
Mean = 7.55 and variance = 54.1

The ratio Observed Variance / Observed Mean = 7.16
The two tailed Chi-squared test for this ratio gives Chi-squared = 408 with 57 D.F. The probability of obtaining a χ^2 value at least this large is 0.0000.

Morisita's Index of Dispersion = 1.8036
Standardised Morisita Index = 0.5066

Distribution	χ^2 Statistic	DF	Probability
Negative Binomial	58.3801	35	0.004
Poisson	1.358E+10	34	0.000
Binomial	2.143 E+14	33	0.000

Best fit is from the **Negative Binomial** (clustered) distribution. Parameter estimates for the Negative Binomial distribution: Mean (μ) = 7.5517 k = 1.2988.

Species recorded in DDCR and AMR during the base line study.

Species	Gravel Plains	Sand Dunes
1- Acacia errynberghianum	++	-
2- Acacia tortilis	+	-
3- Aerva javanica	+	+
4- Calligonum sp.	-	+
5- Calotropis procera	+	++
6- Citrullus colocynthis	+	++
7- Cistanche tubulosa	-	+
8- Crotalaria aegyptiaca	++	++
9- Crotalaria retusa	+	-
10- Cyprus conglemeratus	-	+++
11-Dipterigyum glocum	+	++
*12- Erucaria hispanica**	-	+++
13-Fagonia indica	++++	-
14- Haloxylon silicornicum	+	++
15-Heliotropium digynum	+++	+++
16-Heliotropium kotschyi	+++	-
17-Indigofera colutea	+++	+
18-Indigofera intricata	++	++
19-Leptodenia pyrotechnica	+	+++
20-Limium arabicum	++	++++
21-Lycium shawii	++	+
22-Moltkiopsis ciliata	+++	+
23- Panicum turgidum	-	++
24-Pennisetum divisum	+	+
25-Rhaniterium epoposum	+++	+
26- Rhycosia minima	-	+
27- Tribulus macropterus	-	++
28- Tribulus omanense	-	++

* Annual