محمية دبي الصحراوية
DUBAI DESERT CONSERVATION RESERVE

Comparative Study of Vegetation Structure and Regeneration between 2018, 2022, 2023 and 2024 Monitoring Surveys in the Dubai Desert Conservation Reserve

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1. Introduction

Monitoring builds on surveys by enabling the assessment of population trends for specific species over time. It involves the systematic collection of data aimed at detecting changes in particular situations. As an ongoing activity, monitoring provides data that can be analysed and compared, playing a crucial role in conservation by accurately recording the outcomes of conservation actions (Gregory, Gibbons, & Donald, 2004). Results may lead to land acquisition for species protection, new management practices, species recovery programs, or evaluation of government environmental policies. In the Dubai Desert Conservation Reserve (DDCR), monitoring is essential for evaluating the reserve's health.

The conservation efforts began with a core fenced area of 27 km², where wild animals like the Arabian Oryx were released. Initially, some farms with cattle and camels were included, but access to the fenced area was restricted. Over the years, reports have documented the reserve's biodiversity evolution. In 2003, all farms and livestock were removed, establishing the DDCR as a protected area of 225 km² through collaboration between Emirates Airlines and the Government of Dubai. It is recognized as the first national park in the UAE, dedicated to conserving the region's natural flora, fauna, and desert landscape.

Currently, wildlife in the DDCR includes the Arabian Oryx, Sand Gazelle, and Arabian Gazelle. Continuous monitoring helps identify any negative impacts from activities in the reserve and provides early warnings of declining conservation statuses, allowing for timely remedial actions (Dubai Desert Conservation Reserve, n.d.).

Mapping the vegetation and defining lineage between different floral communities, using multivariate analysis combined with GPS techniques was also an objective for this study. The floral diversity of DDCR changed dramatically since the 2009 report. This report was a thorough analysis surveying plots scattered all over the reserve covering a total of 2 km^2 whereas since 2018, permanent plots have been used.

This year we recorded a total of 57 species of which 13 species were not recorded in the last three reports using the same methodology (2018, 2022 and 2023). The identification of the plant species was with the help of the book of “The comprehensive guide to the wild flowers of the United Arab Emirates” by Marijcke Jongbloed (Jongbloed, 2003).

This report aims to provide information about the general status of the floral communities of DDCR to be able to assess the species diversity and making a comparison of floral communities in different habitats between different years.

2. Materials and Methods

The study area

The relevant work was done in the Dubai Desert Conservation Reserve (DDCR). It is a protected area of 225 km^2 located in Dubai. The habitat of DDCR is a sand dune desert ecosystem; dominated by low to medium size sand dunes and interspersed gravel plains. These two habitats are our main focus in the vegetation surveys since different species and floral communities can be observed. The altitude ranging from a maximum of 260m above sea level in the south and gradually decreases to 180m in the North.

Data collection

Following the same methodology of the previous survey taken in 2023, the annual monitoring was done from March 2024 to June 2024, with the following months to analyse the data. The results from the floral communities’ in sand dunes and in gravel plains is been compared with the results from previous surveys.

All vegetation surveys done in the last 5 years have monitored the same 10 sites. A total of 100 points were randomly selected considering the two main habitats: sand dunes (SD) and gravel plains (GP). In each site there were 10 plots (10m x 10m) giving a total of 100 plots (10000 m^2) being surveyed in the reserve (Figure 1). Important to note that 2 sites (1 and 3) are inside of the called Research Area (area with no access of ungulates, therefore,

with no expected grazing). Plant species in each given plot were tentatively recorded in the field and put in tabulated form, giving the authentication of their identification with the help of the local floristic work (Jongbloed, 2003).

The following parameters were measured for each species in every single plot (Density, Relative Density, Frequency, Relative Frequency, Abundance, Relative Abundance, Cover and Relative Cover). By calculating these parameters the Important Value Index (IVI) could be identified; the species with the highest IVI are considered to be the dominant species of the plot and the second highest species of IVI, the co-dominant species. These equations are described in Annex (1) (Khafaga, 2009). These parameters were used to assess the general condition of the vegetation cover and to determine the community structure quantitatively. Diversity indices were also used to quantitatively assess the diversity of the plant communities and to compare different habitats. Many quantitative values have been developed by landscape ecologist to measure the spatial and temporal changes of species richness and diversity of ecosystems and also to compare between different habitats.

Data analysis

Biodiversity represents the variety and heterogeneity of organisms at all levels of the hierarchy of life, from molecules to ecosystems. Typically, the focus is on species diversity which takes into account how individuals are distributed amongst those species (frequency distribution). Richness (S), or the number of species present in a given area, is the simplest metric used to represent diversity and it remains the most commonly applied. In fact, it turns out that nearly all quantitative measures of diversity are some combination of two components, species richness and evenness, where evenness describes how equally individuals are distributed amongst the species (Aslam , 2009).

There are multitude of indices proposed for this purpose. Indices aim to describe general properties of communities that allow us to compare different regions, taxa, and trophic levels. Therefore, they are of fundamental importance for environmental monitoring and conservation, although there is no consensus about which indices are more appropriate and informative (Morris, et al., 2014).

There are two recognised categories of diversity indices. Type I indices are most sensitive to change in rare species in the community sample while Type II indices are most sensitive to changes in the more abundant species. An example of Type I indices is Shannon-Wiener 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 (Khafaga, 2009). Margalef's index was also used as a simple measure of species richness. See Annex 2 for the formulas.

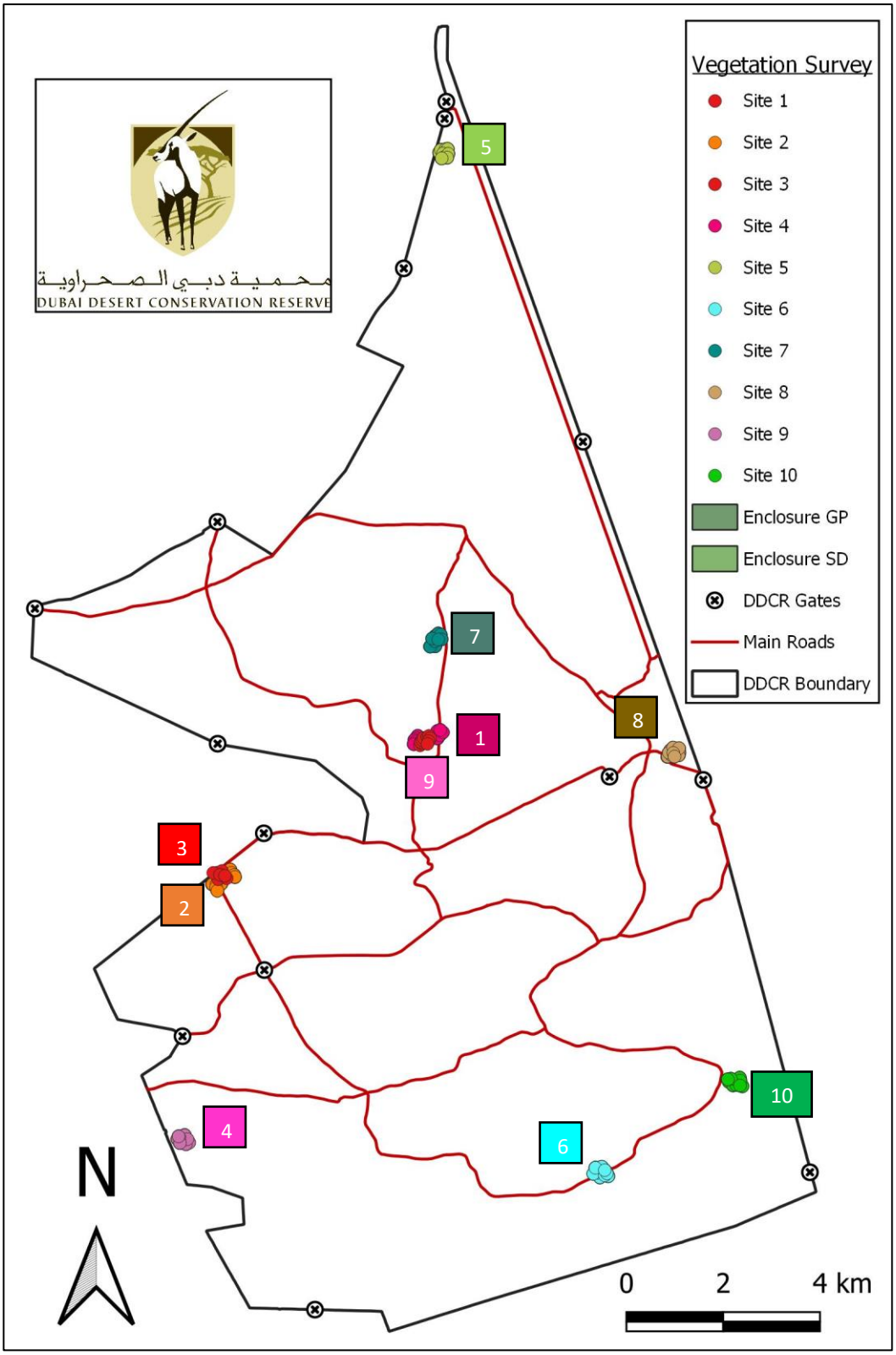

Figure 1 *DDCR map with the distribution of the vegetation sites*

3. Results and Discussion

In the 2024 survey, a total of 57 species were recorded across the 100 surveyed plots (Table 1), with 13 of those species being new to the plots compared to previous reports. The total number of species per site varies, ranging from 18 species at site 8 (sand dune habitat) to 36 species at site 10 (a mix of sand dunes and gravel plains). In terms of individual counts, site 8 also has the fewest individuals, totaling 2,571, while site 4 (gravel plain) has the highest number of individuals surveyed, with a total of 51,345 (see Table 2).

These results indicate an increase in biodiversity compared to last year's findings.

Total species - 2024		
Site	**N species**	Total # individuals
Site 1	28	24852
Site 2	21	5075
Site 3	33	71236
Site 4	25	33308
Site 5	22	5120
Site 6	35	50447
Site 7	19	40028
Site 8	18	2571
Site 9	23	8249
Site 10	36	21058

Table 2 *Total number of species and individuals on each site surveyed.*

- **Floral diversity and Species richness**
  - 2024 survey results

There aren't any endemic plant species in the United Arab Emirates, although there are some species restricted to Al Hajar Mountains. However, in the DDCR and its surroundings we find species that normally occur in the country. A total of 57 species were found in the quadrats surveyed. Some of them were recorded for the first time in the reserve. Since the number of species doesn't provide all the information about the diversity of a community, other parameters were calculated to estimate floral diversity (table 3). The indices used are Simpson and Shannon-Wiener for the floral diversity, while Margalef's index was calculated to assess the species richness of the sites. As mentioned before, the reserve includes two main habitats which are sand dunes and gravel plains. Some of these sites are in sand dunes, and others in gravel plains. According to these, and to facilitate the comparison of data, we divided the sites between the two habitats and created two communities: Sand dunes and Gravel plains. Note that some sites included quadrats in both habitats, so we analysed the data separating those quadrats as well.

Biodiversity Parameters - 2024						
Site	Habitat	N species	Total # individuals	Simpson	Shannon	Margalef Richness Index
Site 1	SD	28	24852	0.1806	1.99	2.7
Site 2	SD	21	5075	0.3824	2.248	2.4
Site 3	GP	33	71236	0.1796	2.895	2.9
Site 4	GP	25	33308	0.6231	1.272	2.3
Site 5	SD	22	5120	0.2435	2.379	2.5
Site 6	GP	35	50447	0.2178	2.926	3.1
Site 7	GP	19	40028	0.8679	0.5356	1.7
Site 8	SD	18	2571	0.5527	1.469	2.2
Site 9	SD	23	8249	0.2035	2.654	2.4
Site 10	SD/GP	36	21058	0.4624	1.831	3.5

SD: Sand dune habitat
GP: gravel plain habitat

Table 3 *Diversity index results for each site during the survey in 2024.*

		Comparison of the survey data from 2018-2022-2023-2024									
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
2018	N species	22	16	17	18	17	21	18	17	17	22
	Total # individuals	1154	608	10983	4960	838	5740	2963	1346	764	2133
	Simpson	0.9	0.6	0.4	0.6	0.6	0.7	0.8	0.7	0.7	0.7
	Shannon	3.4	2.3	1.4	1.8	1.8	2.6	2.5	2.4	2.5	2.5
	Margalef Richness Index	3.0	2.3	1.7	2.0	2.4	2.3	2.1	2.2	2.4	2.7
2022	N species	17	9	20	12	13	15	13	8	14	19
	Total # individuals	2468	106	5731	5476	141	4559	3709	126	934	2811
	Simpson	0.2	0.3	0.4	0.9	0.2	0.7	0.8	0.3	0.6	0.6
	Shannon	2.1	1.7	1.4	0.4	1.9	0.8	0.5	1.4	1.0	1.0
	Margalef Richness Index	2.0	1.7	2.2	1.3	2.4	1.7	1.5	1.4	1.9	2.3
2023	N species	27	23	30	22	21	28	19	15	20	27
	Total # individuals	6784	4382	37626	51345	2037	35884	44592	539	5206	5246
	Simpson	0.1	0.2	0.4	0.8	0.4	0.4	0.9	0.4	0.6	0.6
	Shannon	2.4	2.2	1.4	0.5	1.5	1.2	0.2	1.4	0.9	1.1
	Margalef Richness Index	2.9	2.7	2.8	2.0	2.8	2.6	1.7	2.2	2.3	3.2
2024	N species	28	21	33	25	22	35	19	18	23	36
	Total # individuals	24852	4575	71236	33308	5120	50447	40028	2571	8249	21058
	Simpson	0.2	0.4	0.2	0.6	0.2	0.2	0.9	0.6	0.2	0.5
	Shannon	2.0	2.2	2.9	1.3	2.4	2.9	0.5	1.5	2.7	1.8
	Margalef Richness Index	2.7	2.4	2.9	2.3	2.5	3.1	1.7	2.2	2.4	3.5

Figure 2 *Data results from last surveys.*

No.	Species name	Family name
1	*Aerva javanica*	Amaranthaceae.
2	*Aristida adscensionsis*	Gramineae
3	*Arnebia hispidissima*	Boraginaceae
4	*Astragalus arpilobus*	Fabaceae
5	*Atractylis carduus*	Asteraceae
6	*Bassia muricata*	Amaranthaceae
7	*Calligonum comosum*	Polygonaceae
8	*Calotropis procera*	Apocynaceae
9	*Cenchrus ciliaris*	Gramineae
10	*Centaurea sinaica*	Asteraceae
11	*Centropodia forsskaolii*	Apocynaceae
12	*Chrozophora oblongifolia*	Euphorbiaceae
13	*Citrullus colocynthis*	Cucurbitaceae
14	*Crotalaria aegyptiaca*	Fabaceae
15	*Cyperus conglomeratus*	Cyperaceae
16	*Dipterygium glaucum*	Capparaceae
17	*Eragrostis barrelieri*	Gramineae
18	*Eremobium aegyptiacum*	Brassicaceae
19	*Fagonia indica*	Zygophyllaceae
20	*Farsetia linearis*	Zygophyllaceae
21	*Gisekia pharnaceoides*	Gisekiaceae
22	*Haloxylon salicornicum*	Chenopodiaceae
23	*Heliotropium digynum*	Boraginaceae
24	*Heliotropium kotschyi*	Boraginaceae
25	*Hippocrepis constricta*	Fabaceae
26	*Indigofera colutea*	Fabaceae
27	*Indigofera intricata*	Fabaceae
28	*Launaea capitata*	Asteraceae
29	*Launaea mucronata*	Asteraceae
30	*Leptadenia pyrotechnica*	Asclepiadaceae
31	*Limeum arabicum*	Molluginaceae
32	*Lotus halophilus*	Fabaceae
33	*Lycium shawii*	Solanaceae
34	*Moltkiopsis ciliata*	Boraginaceae
35	*Monsonia nivea*	Geraniaceae
36	*Montagnea arenaria*	Agaricaceae
37	*Neurada procumbens*	Neuradaceae
38	*Paronychia arabica*	Caryophyllaceae
39	*Pennisetum divisum*	Gramineae
40	*Plantago boissieri*	Plantaginaceae
41	*Plantago ciliata*	*Plantaginaceae*
42	*Plantago ovata*	Plantaginaceae
43	*Polycarpaea repens*	Caryophyllaceae
44	*Polygala erioptera*	Polygalaceae
45	*Portulaca oleracea*	Portulacaceae
46	*Prosopis cineraria*	Fabaceae
47	*Rhanterium epapposum*	Asteraceae
48	*Rhynchosia minima*	Fabaceae
49	*Salsola imbricata*	Amaranthaceae
50	*Savignya parviflora*	Brassicaceae
51	*Silene villosa*	Caryophyllaceae
52	*Stipagrostis drarii*	Gramineae
53	*Stipagrostis plumosa*	Gramineae
54	*Tragus racemosus*	Gramineae
55	*Tribulus arabicus*	Zygophyllaceae
56	*Tribulus pentandrus*	Zygophyllaceae
57	*Tulostoma sp.*	Agaricaceae

Table 1 *List of species recorded during the vegetation survey in 2024*

Simpson's index ranges from 0 to 1, with 0 representing infinite diversity and 1 indicating no diversity. Therefore, a higher value corresponds to lower diversity. In contrast, the **Shannon-Wiener index** indicates that a higher value signifies greater species diversity in a habitat. If the index equals 0, it indicates the presence of only one species in the community.

Considering Simpson's index, sites 1 and 3 have the lowest values (0.1806 and 0.1796, respectively), making them the most diverse. However, the results from the Shannon-Wiener index show that the most diverse sites are 3 and 6 (with values of 2.895 and 2.926, respectively) (Table 3, Figure 2).

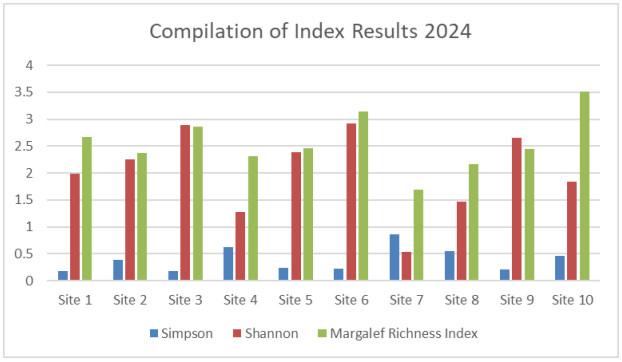

Figure 3 *Compilation of the Index Results for the different parameters in the survey done in 2024.*

This was expected, as sites 1 and 3 are in research areas that are not accessible to herbivores. Site 6 has one of the highest numbers of different species recorded, with a total of 35 species. The differing results between Simpson's and Shannon-Wiener indices may arise because Simpson's index is more sensitive to changes in the proportional abundance of the most common species, while the Shannon-Wiener index is more responsive to variations in the importance of the rarest species.

Regarding the least diverse site, this year's results align with those from last year. Site 7 is again identified as the least diverse according to both indices, with a Simpson's index of 0.8679 and a Shannon-Wiener index of 0.5356. Site 7 recorded a total of 19 species (out of 57), making it the second lowest in species count compared to the other sites. Additionally, its total number of individuals is 40,028, a decrease from last year's count of 44,592. This site exhibits a low diversity of species but a high number of individuals (Table 3, Figure 2).

On the other hand, **Margalef index** (Death, 2008) offers insights into the complexity and heterogeneity of species composition within a community or ecosystem. A higher Margalef diversity index indicates greater species diversity, which can be interpreted as a sign of robustness and resilience in the sampled ecosystem. A high Margalef index suggests that the ecosystem can support a variety of species and is resilient to changes in external conditions. Conversely, a lower value indicates reduced species richness.

According to the results presented in table 3, site 10 is identified as the most complex and heterogeneous in terms of species, with a Margalef index of 3.5. This site has one of the highest species counts, although the number of individuals is relatively low. In contrast, site 7 exhibits the lowest species diversity compared to the other sites, with the highest total number of individuals. Consequently, site 7 is determined to be the least diverse and least abundant of all the sites, based on the various indices calculated.

- <u>Comparison with previous reports</u>

As shown in Figure 3, there has been an increase in the total number of species across all sites since the survey conducted in 2018. Compared to last year's results, sites 6 and 10 now have the highest species counts, with 35 and 36 species, respectively. Site 10 features quadrats located in both sand dunes and gravel plains, allowing for a diverse representation of species that may prefer each habitat. Additionally, one of the tour operators allowed inside the reserve relocated its operations to this site, resulting in a reduction of ungulates that previously used the area as a shaded resting point. This change likely contributed to the regeneration of the area from grazing.

Site 6, located in a gravel plain, is of particular interest due to several artefacts found in the area. There is an ongoing project that analyses ground conditions to reconstruct past weather patterns. This highlights its significance as a refuge for inhabitants of the Arabian Peninsula. Once we receive the results from the current projects, we will be better equipped to determine the parameters that contribute to the high value of this location.

It is also important to note that March and April of 2024 experienced higher levels of precipitation compared to previous years. The composition of the gravel plains allows them to absorb and retain water effectively, facilitating vegetation growth. This observation aligns with the fact that the sites exhibiting the highest numbers of individuals and species counts—and overall biodiversity—are primarily located in gravel plains.

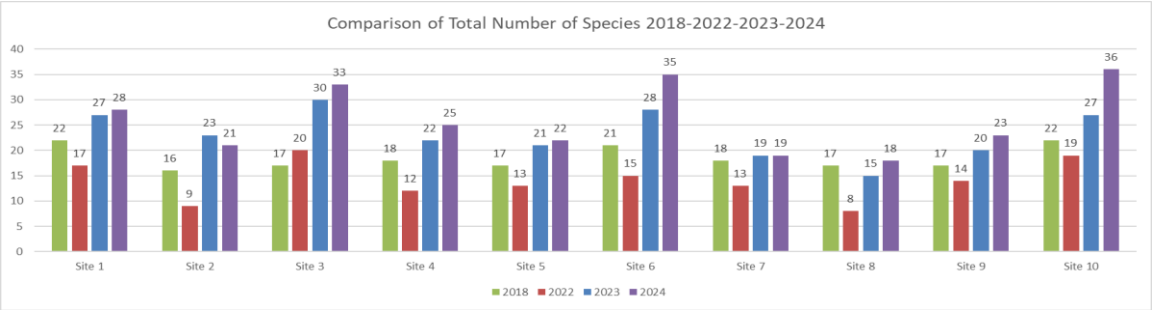

Figure 3 *Comparison of the total number of species per site between the surveys done in 2018, 2022, 2023 and 2024*

The Margalef index values for 2024 (Figure 4) have not changed drastically compared to last year's results, except for sites 6 and 10, which have experienced significant increases in biodiversity. This improvement coincides with the reduction in ungulate populations in the area due to human presence. Site 6 is relatively close to site 10, connected by a road currently used by the tour operator; however, this road will be closed to them starting next year. Overall, the results indicate higher values than in previous surveys, suggesting that the heterogeneity of the communities is improving. This indicates that the DDCR is fostering an increase in the variety of species rather than allowing a monopoly of certain plants.

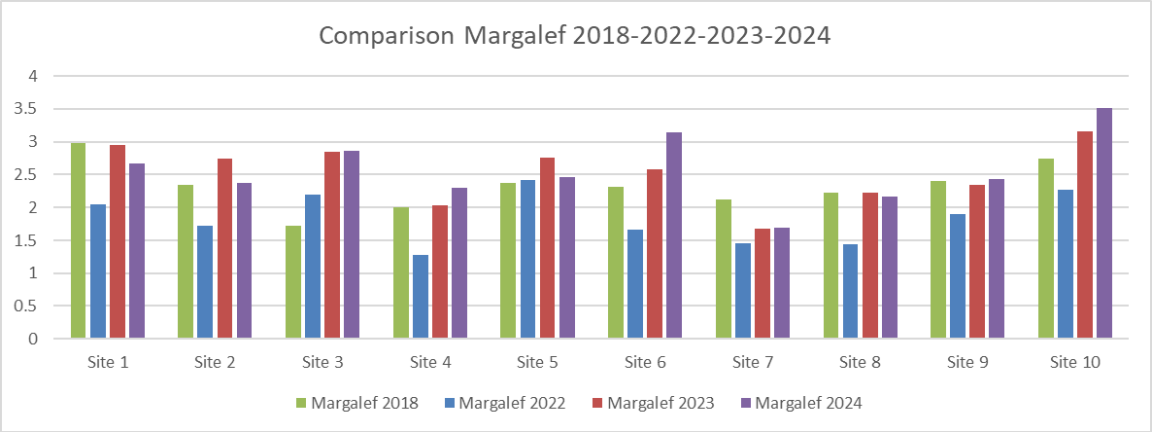

Figure 4 *Comparison of Margalef's index per site between the surveys done in 2018, 2022, 2023 and 2024*

3.1. Sand Dunes (SD)

The following sites (or in some cases specific quadrats) area located in SD: site 1, site 2, quadrat 8 of site 4, site 5, quadrat 2 of site 6, site 8, site 9 and quadrats 1,4,5,6,7,8,9 of site 10.

The IVI (Importance Value Index) indicates how dominant is a species in given area and it has been calculated for each species present in SD habitat (Annex 3). The 4 species with the highest IVI are shown in table 5:

The dominant species in SD is *Arnebia hispidissima*. The co-dominant species is *Cyperus conglomeratus*. The other two species are *Stipagrostis plumosa* and *Centropodia forsskaolii.*

If we compare the results with the values obtained in previous surveys, we can observe that there is a change in the floral communities.

Survey 2024	
Species with Highest IVI	**TOTAL IVI DUNE**
Arnebia hispidissima	621.0
Cyperus conglomeratus	391.0
Stipagrostis plumosa	216.0
Centropodia forsskaolii	112.0

Table 5 *IVI (Importance Value Index) of the species with the highest value for the survey in 2024 in Sand Dunes.*

Compared to the 2023 results, the dominant and co-dominant species remain the same, although their Importance Value Index (IVI) values have decreased, indicating an increase in the diversity of species within the sites. *Moltikiopsis ciliata* ranked among the top four species with the highest IVI last year; however, its IVI value for 2024 has dropped to 80. This year, it has been replaced by *Centropodia forsskaolii.*

In the study of plant communities, *Arnebia hispidissima* is typically classified as a secondary species and is not considered one of the main palatable species for ungulates. Its increase in prevalence is likely due to the presence of a greater variety of grazable species within the DDCR (Shaltout, El-Keblawy, & Mousa, 2008).

Survey 2018	
Species with Highest IVI	**TOTAL IVI DUNE**
Limeum arabicum	435.9
Arnebia hispidissima	372.0
Cyperus conglomeratus	324.6
Indigofera colutea	113.6

2022	
Species with Highest IVI	**TOTAL IVI DUNE**
Arnebia hispidissima	534.7
Cyperus conglomeratus	408.6
Limeum arabicum	152.4
Stipagrostis plumosa	132.1

Survey 2023	
Species with Highest IVI	**TOTAL IVI DUNE**
Arnebia hispidissima	629.3
Cyperus conglomeratus	496.9
Stipagrostis plumosa	149.7
Moltkiopsis ciliata	141.7

Table 6 *IVI (Importance Value Index) of the species with the highest value for the surveys in 2018, 2022 and 2023 in Sand Dunes.*

On the other hand, there are certain species that are rare in the SD, having the lowest values of IVI (table 7). The rarest species in the dunes, with one individual each one, are *Chrozophora oblongifolia, Astragalus arpilobus*, *Citrullus colocynthis* and *Tulostoma sp.* being the three latter found on site 10, and also recorded for the time in the last four vegetation surveys. *Citrullus colocynthis*, commonly known as apple bitter fruit, is an unpalatable species due to its toxic properties. It serves as an indicator of disturbed areas, as animals typically avoid it, allowing this species to thrive in spaces vacated by more palatable plants. Increased human activity in the area could have contributed to the dispersal of *C. colocynthis* seeds. This species was present in the early days of the reserve when management practices differed, and farms with camels and other livestock existed within the concession.

Survey 2024	
Species with Lowest IVI	**TOTAL IVI DUNE**
Astragalus arpilobus	1.0
Chrozophora oblongifolia	1.0
Citrullus colocynthis	1.0
Tulostoma sp.	1.0

Table 7 *IVI (Importance Value Index) of the species with the lowest value for the survey in 2024 in Sand Dunes.*

Compared to previous surveys, in 2024 there are more rare species recorded with just only individual. However, there are several species that were recorded in last surveys but not in 2024 including *Convulvulus cephalophodos* (table 8).

Survey 2018	
Species with Lowest IVI	**TOTAL IVI DUNE**
Polygala erioptera	6.4
Heliotropium kotschyi	4.9
Bassia muricata	4.6
Convulvulus cephalopodos	2.3

2022	
Species with Lowest IVI	**TOTAL IVI DUNE**
Plantago ciliata	12.0
Heliotropium kotschyi	8.1
Crotalaria aegyptiaca	5.5
Rhynchosia minima	1.2

Survey 2023	
Species with Lowest IVI	**TOTAL IVI DUNE**
Indigofera intricata	3.3
Prosopis cineraria	2.4
Convulvulus cephalopodos	1.7
Polycarpaea repens	1.6

Table 8 *IVI (Importance Value Index) of the species with the lowest value for the surveys in 2018, 2022 and 2023 in Sand Dunes.*

Key findings in SD (Annex 3)

- Note that in the survey of 2024, nine new species have been recorded in the SD compared to last surveys: *Aerva javanica, Aristida adscensionsis, Astragalus arpilobus, Calotropis procera, Citrullus colocynthis, Lotus halophilus, Stipagrostis drarii, Tragus racemosus, Tulostoma sp*.
- Two of these new species have only appeared in SD: *Calotropis procera*, *Stipagrostis drarii.*
- A total of seven species have been found to be restricted to SD habitats: *Citrullus colocynthis, Crotalaria aegyptiaca, Heliotropium kotschyi, Indigofera intricata, Rhynchosia minima, Silene villosa, Stipagrostis drarii.*

3.2. Gravel Plains (GP)

GP were found in the sites 3, site 4 (except in quadrat 8), site 6 (except quadrat 2), site 7 and in quadrats 2, 3 and 10 from site 10.

The Importance Value Index (IVI) was calculated for each species present in the sand dune (SD) habitat (see Annex 3). The four species with the highest IVI values are presented in Table 9. The dominant species remains *Arnebia hispidissima*, maintaining a significant lead over others. The two co-dominant species are *Monsonia nivea* and *Stipagrostis plumosa*. Notably, *Launaea mucronata* appears for the first time among the top four highest IVI values in the gravel plain habitat.

Species with Highest IVI	total IVI GP
Arnebia hispidissima	636.9
Monsonia nivea	144.9
Stipagrostis plumosa	116.0
Launaea mucronata	91.4

Table 9 *IVI (Importance Value Index) of the species with the highest value for the survey in 2024 in Gravel Plains.*

When comparing these results to those from previous surveys (Table 10), it is evident *that A. hispidissima* and *M. nivea* continue to hold their positions as dominant and co-dominant species, respectively, in gravel plain habitats. While *Plantago ciliata* is also present in 2024, its abundance has decreased compared to last year.

Survey 2018	
Species with Highest IVI	total IVI GP
Arnebia hispidissima	350.5
Monsonia nivea	312.7
Fagonia indica	140.0
Cyperus conglomeratus	77.5

Survey 2022	
Species with Highest IVI	TOTAL IVI GP
Arnebia hispidissima	772.1
Monsonia nivea	165.5
Stipagrostis plumosa	96.4
Fagonia indica	85.9

Survey 2023	
Species with Highest IVI	total IVI GP
Arnebia hispidissima	625.6
Monsonia nivea	152.1
Plantago ciliata	138.8
Stipagrostis plumosa	74.7

Table 10 *IVI (Importance Value Index) of the species with the lowest value for the surveys in 2018, 2022 and 2023 in Gravel Plains.*

In relation to the rare species present in gravel plains, six species were found to have the lowest IVI values. Among these, four are newly recorded on the sites: *Calotropis procera, Savignya parviflora, Cenchrus ciliaris* and *Portulaca oleracea. Calligonum comosum* maintains the same IVI value as last year, and *Gisekia pharnaceoides* appears for first time since the 2018 survey.

The difference of the rarest species found in GP in this year's survey, in comparison with the previous reports, is noticeable (table 12). *Indigofera intricata* wasn't recorded in gravel plains during this survey (only appears in SD), which is expected since it is a species that prefers sandy plains, same as *C. comosum.*

Species with Lowest IVI	TOTAL IVI GP
Calotropis procera	1.0
Savignya parviflora	1.0
Cenchrus ciliaris	0.7
Calligonum comosum	0.7
Portulaca oleracea	0.7
Gisekia pharnacioides	0.6

Table 11 *IVI (Importance Value Index) of the species with the lowest value for the survey in 2024 in Gravel Plains.*

Survey 2018	
Species with Lowest IVI	TOTAL IVI GP
Pennisetum divisum	1.4
Indigofera intricata	1.2
Atractylis carduus	1.2
Launaea mucronata	1.2

Survey 2022	
Species with Lowest IVI	TOTAL IVI GP
Bassia muricata	4.0
Lycium shawii	2.1
Centaurea sinaica	2.0
Calligonum comosum	1.1
Chrozophora oblongifolia	1.1
Suaeda aegyptiaca	1.1

Survey 2023	
Species with Lowest IVI	TOTAL IVI GP
Indigofera intricata	1.0
Salvadora persica	0.7
Calligonum comosum	0.7
Lycium shawii	0.7
Hippocrepis constricta	0.7

Table 12 *IVI (Importance Value Index) of the species with the lowest value for the surveys in 2018, 2022 and 2024 in Gravel Plains.*

Key findings in GP (Annex 3)

- Note that in the survey of 2024, twelve new species have been recorded in the GP compared to last surveys: *Aerva javanica, Aristida adscensionsis, Astragalus arpilobus, Calotropis procera, Cenchrus ciliaris, Eragrostis barrelieri, Lotus halophilus, Paronychia arabica, Portulaca oleracea, Salsola imbricata, Tragus racemosus, Tulostoma sp*.
- Four of these new recorded species appear only in GP: *Cenchrus ciliaris, Eragrostis barrelieri, Portulaca oleracea, Salsola imbricata.*
- Three species have not been recorded compared to last year: *Indigofera intricata*, *Salvadora persica, Schismus barbatus* and *Suaeda agyptiaca.*
- Twelve species have been found to be restricted to GP: *Cenchrus ciliaris, Eragrostis barrelieri, Gisekia pharnacioides, Hippocrepis constricta, Lycium shawii, Paronychia arabica, Plantago ciliata, Plantago ovata, Portulaca oleracea, Rhanterium epapposum, Salsola imbricata* and *Savignya parviflora.*

4. Summary and Conclusions

In general, the areas studied have two major types of habitats: Sand Dunes and Gravel Plains. Each one of them having unique characteristics in terms of soil and plant communities. A total of 57 species have been recorded in the 10 preselected sites, none of them being endemic species or species with a secluded distribution.

There is a general increase in the diversity of the reserve, since we have a total of thirteen species appearing for first time in the preselected sites that have been surveyed since 2018. General abundance of species increased as well.

One species considered as an *indicator* is *Cyperus conglomeratus*. This species has a high capacity to re-colonise an area after a disturbance. Therefore, a high IVI score would mean absence of other species while a reduced IVI value would indicate that grazing pressure is relieved to a degree that others are regenerating and in process of establishment. *C. conglomeratus* is still co-dominant in sand dunes habitats, but not anymore in gravel plains.

However, there is a concern about *Arnebia hispidissima.* This is an annual or bi-annual species which branches and leaves are covered in white brittle hairs. This is not a palatable plant, so it is not grazed. If the pressure of over-grazing continues, *A. hispidissima* and other non-palatable species will dominate the landscape.

It is important to also mention the presence of *Citrullus colocynthis* and *Calotropis procera* in the reserve. These two species are indicators of disturbed areas since they contain toxins that animals tend to avoid. Both species used to be abundant during the first years after establishing the reserve since the area was, indeed, disturbed, with high presence of humas and overgrazing. However, their numbers decreased to almost disappear until this year's survey. Apart from the newly recent human presence in the south of the reserve (site 10), there are no other conditions that could lead to believe there is high disturbance in the reserve. however, we will monitor these species closely.

Throughout the years different strategies took part in controlling the population of herbivorous, such as relocating them to separate areas or out of the reserve, or supplement feeding. However, their numbers are still over the maximum carrying capacity. Even though there is a growth in the number of species present in the reserve and their populations (in general), the effect of overgrazing is noticeable. There are different plans to reduce the number of ungulates inside the reserve to keep it under the maximum carrying capacity. Once this is achieved, then we will be able to see an improvement in the results of vegetation. Despite all this, we have better results now and, in short, we want to continue improving.

Annex 1. Vegetation Parameters.

The Importance Value Index (IVI) of each species was estimated as IVI = RA+RD+ RF, where RA is relative abundance calculated as the number of individuals per species per hectare, RD is relative dominance defined as the basal area per species per hectare and RF is relative frequency (per ha) estimated as the proportion of plots in preselected sites where the species occurred at least once.

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

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

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

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

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

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

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

Annex 2. Diversity Index.

a) Shannon-Wiener Index (1949)

$$H' = -\Sigma\ Pi \ln(Pi)$$

where Pi is the observed proportional abundance of species i.

b) Simpson's Index (1949)

$$S' = 1 - \Sigma\ Pi^2$$

c) Margalef's Index (1958)

$$M = {}^{S-1}/_{\ln N}$$

S = total number of species, N = total number of individuals in the sample, In = natural logarithm

Annex 3. IVI values for Sand Dunes and Gravel Plains for surveys done in 2018, 2022, 2023 and 2024.

	2018	2022	2023	2024
	TOTAL IVI DUNE	TOTAL IVI DUNE	TOTAL IVI DUNE	TOTAL IVI DUNE
Aerva javanica				72.0
Aristida adscensionsis				8.0
Arnebia hispidissima	372.0	534.7	629.3	621.0
Astragalus arpilobus				1.0
Atractylis carduus		14.0	6.8	8.0
Bassia muricata	4.6	17.2	31.6	54.0
Calligonum comosum	8.5	34.5	32.2	16.0
Calotropis procera				2.0
Cenchrus ciliaris				
Centaurea sinaica	26.6	12.8	8.0	25.0
Centropodia forsskaolii	88.0	116.5	87.7	112.0
Chrozophora oblongifolia			6.8	1.0
Citrullus colocynthis				1.0
Convulvulus cephalopodos	2.3		1.7	
Crotalaria aegyptiaca	13.5	5.5	44.4	13.0
Cyperus conglomeratus	324.6	408.6	496.5	391.0
Dipterygium glaucum	87.3	91.5	64.9	48.0
Eragrostis barrelieri				
Eremobium aegyptiacum	75.5	49.3	74.0	92.0
Fagonia indica	45.4	39.2	60.8	26.0
Farsetia linearis	17.2	31.1	23.8	23.0
Gisekia pharnacioides	28.1			
Haloxylon salicornicum	34.3	29.7	17.9	15.0
Heliotropium digynum	81.6	110.1	61.1	47.0
Heliotropium kotschyi	4.9	8.1	31.8	5.0
Hippocrepis constricta				
Indigofera colutea	113.6	14.9	38.5	64.0
Indigofera intricata	9.6		3.3	2.0
Launaea capitata	19.0		22.3	31.0
Launaea mucronata		19.3	41.1	84.0
Leptadenia pyrotechnica		33.3	21.3	19.0
Limeum arabicum	435.9	152.4	79.9	50.0
Lotus halophilus				11.0
Lycium shawii				
Moltkiopsis ciliata	95.4	81.6	141.5	82.0
Monsonia nivea	70.8	39.3	46.0	51.0
Montagnea arenaria			6.7	9.0
Neurada procumbens	71.6	58.4	44.0	65.0
Ogastema pusillum	26.6		3.8	
Paronychia arabica				
Pennisetum divisum	6.6		6.7	16.0
Plantago boissieri	10.7			6.0
Plantago ciliata		12.0		
Plantago ovata	22.1		8.3	
Polycarpaea repens			1.6	10.0
Polygala erioptera	6.4		9.0	28.0
Portulaca oleracea				
Prosopis cineraria			2.4	4.0
Rhanterium epapposum				
Rhynchosia minima		1.2	6.6	5.0
Salsola imbricata	C			
Salvadora persica	10.8			
Savignya parviflora				
Schismus barbatus			14.5	
Silene villosa	48.0		6.9	4.0
Stipagrostis drarii				5.0
Stipagrostis plumosa	50.0	132.1	149.7	216.0
Suaeda aegyptiaca	19.0		6.7	
Tragus racemosus				2.0
Tribulus arabicus	71.5	25.8	33.9	19.0
Tribulus pentandrus	97.9	26.7	12.7	29.0
Tulostoma sp.				1.0

	2018	2022	2023	2024
	TOTAL IVI GP	TOTAL IVI GP	TOTAL IVI GP	TOTAL IVI GP
Aerva javanica				2.1
Aristida adscensionsis				4.9
Arnebia hispidissima	350.5	772.1	625.6	636.9
Astragalus arpilobus				2.5
Atractylis carduus	1.2	11.3	7.5	8.8
Bassia muricata	6.8	4.0	10.8	12.6
Calligonum comosum		1.1	0.7	0.7
Calotropis procera				1.0
Cenchrus ciliaris				0.7
Centaurea sinaica		2.0	3.4	10.5
Centropodia forsskaolii	10.4	15.9	29.9	31.9
Chrozophora oblongifolia	6.3	1.1	3.8	2.0
Citrullus colocynthis				
Convulvulus cephalopodos				
Crotalaria aegyptiaca	51.6			
Cyperus conglomeratus	77.5	55.4	32.2	62.5
Dipterygium glaucum	29.0	28.3	19.3	17.8
Eragrostis barrelieri				1.2
Eremobium aegyptiacum	20.0	10.7	6.1	6.7
Fagonia indica	140.0	85.9	50.4	90.5
Farsetia linearis	19.4	27.5	40.3	59.8
Gisekia pharnacioides	5.9			0.6
Haloxylon salicornicum	10.6	13.7	7.5	6.2
Heliotropium digynum	11.5	4.6	6.6	2.0
Heliotropium kotschyi				
Hippocrepis constricta			0.7	5.0
Indigofera colutea	3.6		1.4	4.0
Indigofera intricata	1.2		1.0	
Launaea capitata	5.8	6.2	20.4	43.0
Launaea mucronata	1.2	15.1	27.5	91.4
Leptadenia pyrotechnica	10.9	15.8	11.5	28.6
Limeum arabicum	40.6	8.0	8.6	5.0
Lotus halophilus				5.1
Lycium shawii	3.0	2.1	0.7	1.3
Moltkiopsis ciliata	55.5	32.4	50.7	45.2
Monsonia nivea	312.7	165.5	152.1	144.9
Montagnea arenaria			2.7	37.3
Neurada procumbens	56.9	47.2	30.9	48.9
Ogastema pusillum				
Paronychia arabica				2.2
Pennisetum divisum	1.4		14.0	15.8
Plantago boissieri	67.4	13.5	7.3	49.1
Plantago ciliata	19.2	20.9	138.8	91.0
Plantago ovata			15.0	16.4
Polycarpaea repens	28.2	4.2	18.4	54.6
Polygala erioptera		4.6	25.4	33.6
Portulaca oleracea				0.7
Prosopis cineraria			1.2	35.7
Rhanterium epapposum	18.0	10.4	9.5	10.0
Rhynchosia minima				
Salsola imbricata				2.0
Salvadora persica			0.7	
Savignya parviflora				1.0
Schismus barbatus			10.3	
Silene villosa				
Stipagrostis drarii				
Stipagrostis plumosa	59.1	96.4	74.7	116.0
Suaeda aegyptiaca		1.1	1.5	
Tragus racemosus				10.0
Tribulus arabicus	2.7		1.6	3.7
Tribulus pentandrus	71.6	23.1	10.9	18.4
Tulostoma sp.				1.2

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