

A preliminary survey of flower visiting by aculeate wasps and bees in the Dubai Desert Conservation Reserve, UAE

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Abstract

The present contribution is a first brief attempt to give an overview of flower visiting by aculeate wasps and bees in the Dubai Desert Conservation Reserve (DDCR), and as far as has been established the first of its kind for the United Arab Emirates. Seventeen sites within the reserve were well sampled and, in order to see the reserve in relation to its position in the peninsula, two one day transects were undertaken, one of brief sampling at six sites east from the reserve to the coast at Khor Kalba and the other of brief sampling at five sites west from the reserve to the coast in the marine reserve of the Emirates Marine Environmental Group (EMEC). Flower visitors were observed and sampled on 21 species of plants within the DDCR and on two additional species east of the DDCR and two west of the DDCR. Fifty-one species of aculeate wasps and 27 species of bees were recorded. Of the wasps, 34 species were from the DDCR and the additional 15 from transects east and west of the Reserve. Of the bees, 23 species were from the DDCR and the additional two from transects east and west of the Reserve. Flower sampling yielded flower visiting records for 39 species of aculeate wasps and 23 species of bees. Although this preliminary survey of flower visiting by wasps and bees in the DDCR was conducted over a limited period of time, during a dry spring, following seven dry years, it has provided sufficient data to draw some general conclusions: most of the plants attract visits from a complex of both wasps and bees; the flowers of some plants attract a wide range of wasps and bees but there were no flowers that were attractive to all available wasps and bees at any one site; very few species of the wasps and bees encountered were specialists; and the plants on which these specialist wasps and bees were dependent were not themselves dependent on these species for pollination.

Keywords

Aculeate wasps, pollen wasps, bees, distributions, flower visiting, potential pollinators

Introduction

The present contribution is a first brief attempt to give an overview of flower visiting by aculeate wasps and bees in the Dubai Desert Conservation Reserve, and, as far as has been established, the first of its kind for the United Arab Emirates.

In 2015 a preliminary survey of the aculeate wasps and bees of the Dubai Desert Conservation Reserve was undertaken by Sarah Gess assisted by Peter Roosenschoon, Conservation Officer. The focus was on flower visitation. The survey took place between 18 April 2015 and 4 May 2015 towards the end of spring.

The Dubai Desert Conservation Reserve (DDCR) lies approximately midway between the west and east coasts of the United Arab Emirates with sand plains to the west and the Hajar Mountains to the east (Figure 1).

Seventeen sites within the DDCR were well sampled and, in order to see the Reserve in relation to its position in the peninsula, two one day transects were undertaken, one of brief sampling at six sites east from the Reserve to the coast at Khor Kalba and the other of brief sampling at five sites west from the Reserve to the coast in the marine reserve of the Emirates Marine Environmental Group (EMEC). (see map Figure 1 and Table 1)

History of the DDCR (extracted from www.ddcr.org)

In 1999 the Al Maha Resort and Spa was established with an area of 27 square kilometres as a conservation reserve for the protection of the desert fauna and flora. Seventy Arabian oryx were introduced and indigenous trees and shrubs were planted. In 2002 the resort managers began an environmental audit of the surrounding areas. Researchers were tasked with exploring the then current and potential threats to endangered species and disappearing desert habitats. The Al Maha management then submitted proposals to the government for the formation of a formal national park.

The proposal was accepted and the Dubai Desert Conservation Board was established. In 2003 the DDCR with an area of 225 square kilometres was proclaimed. The Reserve constitutes 4.7% of Dubai's total land area. The first wildlife releases into the newly created reserve took place in 2004.

The Al Maha Resort lies within the boundaries of the Reserve but is being managed independently.

The DDCR is a member of IUCN and UNEP. The vision for it is “to create a permanently protected area which ensures the future of the region's desert habitats and bio-diversity managed according to sound scientific ecological principles, aimed at protecting natural resources (water being the most obvious one, but extending to many others as well), and maintaining original desert landscapes.”

The area enclosed to form the DDCR is principally made up of low to medium sized sand dunes interspersed with sand flats and gravel plains. At the extreme north of the reserve there is a rocky outcrop, Quarn Nazwa. The altitude of the Reserve ranges

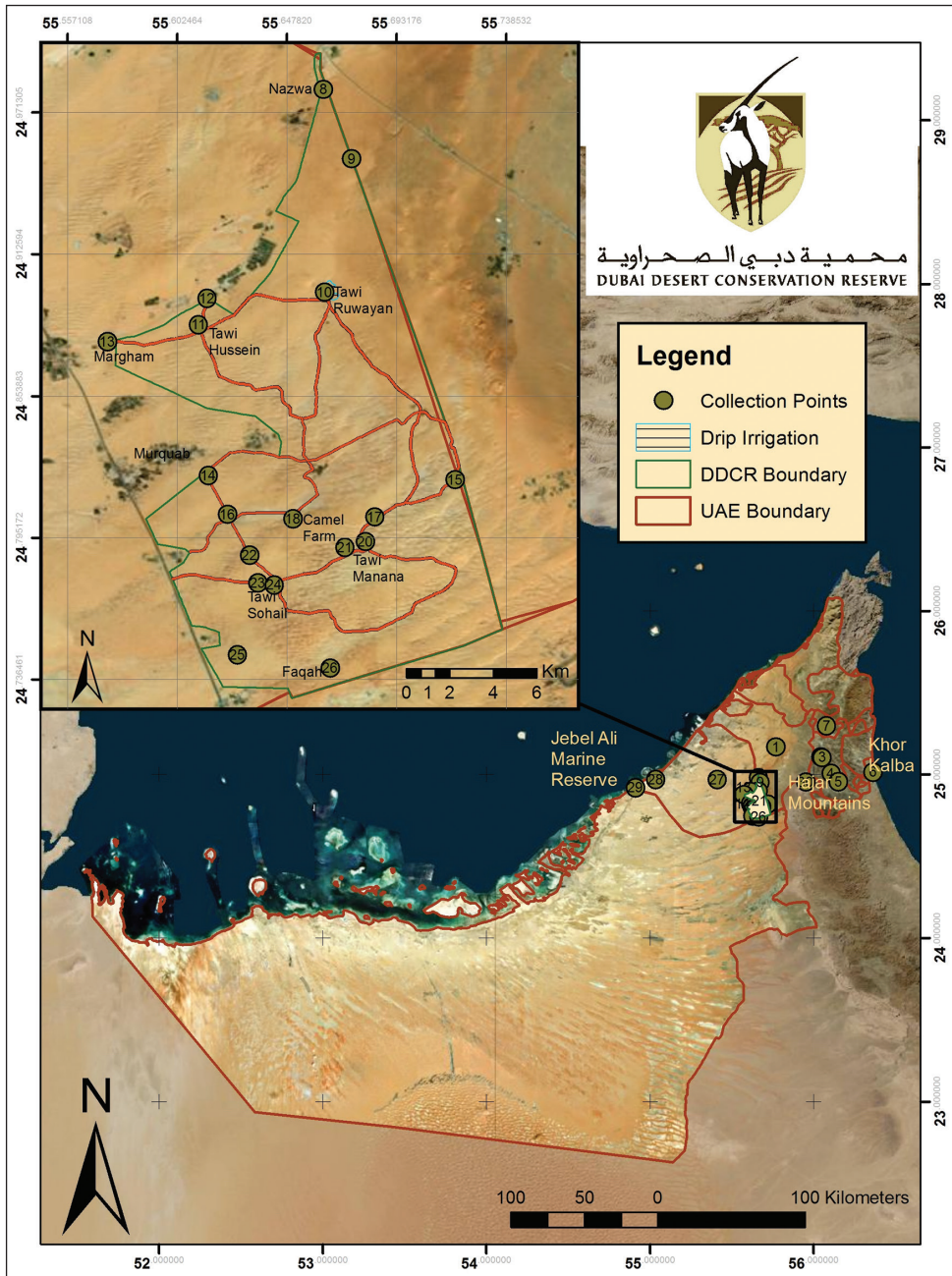


Figure 1. Map of the UAE with inset enlargement of the DDCR, giving the positions of the collection sites.

from 260m above sea level in the south to 180m in the north (Khafga 2009). Before enclosure the entire area had been heavily grazed by camels and domestic livestock. In 2004 the number of camels counted in the DDCR was 1,209, that is 5.37 camels per

Table 1. Study sites.

Site no.	Latitude	Longitude	Area	Name of site	Nature of site
1	25.1678	55.7696	east of DDCR		sandy roadside
2	25.1066	56.0441	east of DDCR	Shawka	area fringing dam
3	25.1024	56.0534	east of DDCR		Wadi
4	25.0065	56.1066	east of DDCR		Wadi
5	24.9563	56.1512	east of DDCR	Munay	outskirts of village
6	5.0152	56.3608	east of DDCR	Ramsa, Khor Kalba	sandy bank of lagoon
7	25.25.2967	56.078	east of DDCR		Wadi
8	24.9808	55.6628	DDCR	Quarn Nazwa	rocky outcrop
9	24.9521	55.6746	DDCR		sand dunes
10	24.8968	55.6635	DDCR	Tawi Ruwayyan	drip irrigation area
11	24.8834	55.6113	DDCR	Date Farm	palm grove
12	24.8943	55.6147	DDCR	Margham Gate	sand dunes
13	24.8763	55.5735	DDCR	Margham Road	sandy roadside
14	24.8210	55.6153	DDCR	Dune enclosure	sand dunes
15	24.8192	55.7174	DDCR		gravel plain
16	24.8048	55.6233	DDCR	Al Maha Gate	Sand
17	24.8037	55.6841	DDCR		irrigated trees in wire cages
18	24.8030	55.6503	DDCR	Camel Farm	palm grove
19	24.7935	55.6802	DDCR	Tawi Manana	drip irrigation area
20	24.7935	55.6802	DDCR	Tawi Manana	small lake
21	24.7912	55.6718	DDCR		sand dunes
22	24.7879	55.6358	DDCR		sand dunes
23	24.7764	55.6358	DDCR		sand dunes
24	24.7757	55.6427	DDCR	Lucerne Farm	sand dunes
25	24.7467	55.6275	DDCR		sand dunes
26	24.7412	55.6657	DDCR	Faqah	watering point
27	24.9696	55.4118	west of DDCR		sandy roadside
28	24.9684	55.0355	west of DDCR	Ghantoot	sandy plain
29	24.9110	55.9513	west of DDCR	EMEC	coastal sand inland from beach
30	24.9532	55.9512	west of DDCR	EMEC	coastal sand inland from beach

square kilometre (Alqamy 2004). By 2007 the number of camels had been reduced to around 600 and by December 2008 all domestic livestock had been removed (Khafga 2009). Arabian oryx, mountain gazelle and sand gazelle had been introduced.

At Tawi Manana a small lake, stocking fish, was completed in 2011.

Three areas, two of sand dunes and the third a gravel plain, have been fenced off to exclude grazing and browsing by oryx and gazelle. One fenced dune area surrounds a lucerne farm established in September 2012 to give supplementary feed for the oryx. The other, solely an enclosed dune area, was fenced in December 2012.

Date palm, *Phoenix dactilifera* L. (Arecaceae) had been cultivated and these remain as palm groves at two main sites, the Camel Farm at which the camels are confined within cages, and the Date Farm, and as the outer boundary of Tawi Manana irrigation plot.

Trees, protected by wire cages and irrigated, were planted in selected areas. Most, but not all, are indigenous to the area. In 2012, 9,830 trees were planted mainly around the lake and generators as well as close to Tawi Manana. Then in 2013, 15,700 trees were planted at the solar irrigation sites.

In order to encourage the regrowth of plants two drip irrigation plots, Tawi Ruwayyan in the north and Tawi Manana in the south, were established in 2013. These plots over which drip irrigation pipes have been laid are supplied with water pumped up from subterranean reservoirs. The pumps are run off power generated by solar panels.

Feeding points for the oryx had been used since they were introduced into the Al Maha Resort's reserve in 1999 and are also used in the DDCR. In order to minimize the impact of these gathering points they are moved every 4-6 weeks.

Watering points for the large mammals were created within the Al Maha reserve in 1999 and at various points within the DDCR in 2001.

Climate

The climate of this area is of a bi-seasonal Mediterranean type, characterized by low rainfall and high summer temperatures. Most precipitation is expected in the winter and spring between December and April. Mist and fog can occur throughout the year but they are more likely in the winter months and at the end of summer.

Very little was known about weather conditions in the UAE until the 1950s when oil prospecting began and it was not until the opening of the UAE international airports in the 1970s that full 24-hour weather records became available (Perry 2008). Rain is always localized, sporadic and shows considerable variation from year to year. The average annual rainfall for Sarjah airport for the 12 years 1992-2004 was 50mm (Alqamy 2004).

Winter, December to March, is the most unsettled season when active weather systems can bring rain and strong winds. Weather systems in the region are associated with the Sub-Tropical Jet Stream, which lies over the Middle East at this time of the year. The frequency of these westerly disturbances is governed by the weather pattern prevailing over Europe and the Mediterranean. They account for most of the annual rainfall, but both the amount and frequency of rain varies greatly from year to year.

Towards spring, April to May, the frequency of westerly disturbances decreases as the Sub-Tropical Jet Stream weakens and begins to move northwards. Rain and thunderstorms can still occur but are more likely over the northern Gulf. Maximum temperatures increase rapidly.

Summer, June to September, is characterized by hot and dusty conditions, resulting from intense solar heating establishing an area of low pressure over India and Pakistan gradually extending west into Iran and over the Gulf. During these months there may be some rain over the mountains and surrounding plains. Decreasing minimum temperatures towards the end of summer lead to an increase in the incidence of early morning fog.

Autumn, October to November, is characterized by the most settled weather conditions.

Vegetation

Until recently the vegetation of the UAE was poorly known. The work of A.R. Western (Western 1989) served as a major stimulus for floristic research in the UAE (Perry 2008). *The Comprehensive Guide to the Wildflowers of the United Arab Emirates* (Jongbloed 2003) incorporates the work of several active and enthusiastic botanists, including that of Benno Böer.

Two vegetation surveys have been conducted in the Al Maha reserve and the DDCR since the proclamation of the DDCR (Husam El Algamy 2004 and Tamer Khafga 2009). The total number of species recorded from the gravel plains within the DDCR in 2004 was 15 compared with 27 in 2009. Of the additional species 11 were perennial species and four were annual. This was considered to represent positive rehabilitation of the gravel plains during the five years between the two surveys. Similarly the total number of species recorded for the sand dunes in 2004 was 16 compared with 34 in 2009. What should also be taken into account is that the second survey was undertaken in 2008 a year of unusually good rains.

Due to the generally low rainfall, when good rains do occur they have, as in all hot arid areas, a more pronounced influence on biological activity than in more temperate regions of the world (Perry 2008). Rain is most effective for the vegetation when it occurs during the cooler part of the year due to the fact that less water is lost to evaporation and it is at this season that plant growth takes place.

Methods

As flower visitors were being targeted most of the sampling was undertaken using hand nets. At all sites plants in flower were sampled for flower visitors. In addition wasps and bees perching on plants, resting on the ground, cruising, nesting and visiting water were collected.

One malaise trap was set up at Tawi Ruwayyan. Bundles of six trap nests with two of the trap nests each of one of three diameter borings (Krombein design) were positioned in trees at Tawi Ruwayyan and on palm trunks at the Camel Farm, where naturally occurring borings were observed.

Plant and insect names listed with the author's name in the appendices are given without the author's name in the text and tables. Plant names not listed in the appendices are given with the author's name where they occur in the text.

Study sites within the DDCR

Site 8. Quarn Nazwa, southwestern foot (Figures 2 and 3)



Figures 2–7. Study sites in DDCR: **2** Site 8 – Quarn Nazwa, watering point **3** Site 8 – Quarn Nazwa, southeast slope **4** Site 10 – Tawi Ruwayyan **5** Site 14 – Dune grazing and browsing exclusion plot **6** Site 15 – Gravel plain without irrigation **7** Site 17. Irrigated planted trees in netting cages.

Quarn Nazwa is a rocky outcrop at the extreme north of the reserve. At its southwest foot is a level area within which is a watering point, a low vertical bank below an access road, and bordering the road to the south sand dunes. Around the watering point and the bases of the dunes facing it were plants in flower, principally *Aerva javanica* (Amaranthaceae), *Centaurea pseudosinaica* (Asteraceae), *Arnebia hispida* (Boraginaceae), *Dipterygium glaucum* (Capparaceae), and *Limeum arabicum* (Molluginaceae). On the other aspects of the outcrop most flowering plants were almost completely dried out.

Site 9. Sand dunes, A single *Calotropis procera* (Apocynaceae, Asclepiadoideae) tree.

Site 10. Tawi Ruwayyan (Figure 4)

The area sampled was the drip irrigation area together with the surrounding non-irrigated area. The drip area is mainly level with a strong growth of low shrubby perennials, principally *Heliotropium kotschyi* (Boraginaceae), *Dipterygium glaucum*, *Fagonia indica* and *Cyperus conglomeratus* Rottb. (Cyperaceae) growing along the irrigation lines. The area attracts grazing and browsing by oryx and gazelle and so there is little evidence of the more palatable plants, particularly annuals.

Within the irrigated area are small groups of fenced planted trees. Beyond the irrigated area the perennial plants are more widely dispersed and less succulent. On the surrounding dunes are scattered larger shrubs, *Leptadenia pyrotechnica* (Apocynaceae: Asclepiadoideae) and *Salvadora persica* (Salvadoraceae), and the small tree *Calotropis procera*. Also present beyond the irrigation plot is a clump of ghaf trees, *Prosopis cineraria* (Fabaceae: Mimosoideae) and tamarix, *Tamarix nilotica* (Tamaricaceae).

Site 11. Date Farm

A shady grove of date palms with outside the grove an area of irrigated planted trees in cages. Within the cages are growing palatable plants beyond the reach of browsers. Of interest was the presence in one of these cages of flowering *Sesuvium verrucosum* (Aizoaceae), not listed for the DDCR in Khafga (2009).

Site 12. Margham Gate

An area of low dunes with shrubs and hollows between dunes with almost entirely browsed off *Tribulus* (Zygophyllaceae)

Site 13. Roadside of Margham Road, just outside the DDCR

Well grown flowering *Tribulus* spp. were present along the sandy roadside.

Site 14. Dune grazing and browsing exclusion plot (Figure 5)

An area of dunes protected from grazing and browsing by oryx and gazelle. Noticeably better vegetated than the surrounding area. Of particular note was the presence of numerous well-grown plants of *Crotalaria aegyptiaca* (Fabaceae: Papilionoideae) in flower.

Site 15. Gravel plain without irrigation (Figure 6)

This gravel plain site adjoined one of the planted tree sites. Scattered across the gravel plain the dominant plant was a small shrubby perennial, *Rhanterium epapposum* (Asteraceae) with at intervals *Acacia tortilis* (Fabaceae: Mimosoideae). The planted trees are young ghaf trees, *Prosopis cineraria*. Within the cages around the trees, encouraged by the irrigation and protected from grazing, are plants of *Arnebia hispidissima* (Boraginaceae).

Site 16. Al Maha Gate

A non-irrigated sandy area with the dominant plant being *Heliotropium kotschyi* (Boraginaceae).

Site 17. Low sand dunes (Figure 7)

Irrigated planted trees in netting cages with *Launaea procumbens* (Asteraceae) growing within the cages.

Site 18. Camel Farm

A small grove of date palms watered by irrigation furrows. The camels are all restrained in cages. The banks of the furrows, cavities in palm tree stumps and insect borings in palm leaf bases offer nesting sites for wasps and bees. Also present outside the Date Palm grove are Ghaf trees.

Site 19/20 Tawi Manana lake (Figure 8) and drip irrigation area (Figure 9)

The area sampled for flower visitors was the main level drip irrigation area, which is surrounded on all four sides by a border of palm trees, the outer, less moist, sloping sandy drip area and the surrounding non-irrigated area. The drip area is mainly level with a strong growth of low shrubby perennials, principally *Dipterygium glaucum* with to a lesser degree than at Tawi Ruwayyan *Heliotropium kotschyi* and *Fagonia indica*, growing along the irrigation lines. The area attracts grazing and browsing by oryx and gazelle and so there is little evidence of the more palatable plants, particularly annuals. On the lower slopes of the dunes above the main drip area were a large number of flowering, well-grown, scattered plants of palatable *Limeum arabicum* (Molluginaceae). Also present are a *Calotropis procera* tree and a clump of ghaf trees, *Prosopis cineraria*.

Site 21. Sand dunes, *Calotropis procera* tree

Site 22. Sand dunes, *Calotropis procera* tree

Site 23. Sand dunes, *Calotropis procera* tree

Site 24. Lucerne Farm grazing and browsing exclusion area (Figures 10 and 11)

Between the fenced fields of lucerne, which are irrigated, and the perimeter fence is a large area of non-irrigated dunes protected from grazing and browsing by oryx and gazelle. In this area were a few scattered, well grown, flowering *Calotropis procera*, *Leptadenia pyrotechnica* and *Acacia tortilis* (Fabaceae: Papilionoideae), and numerous scattered flowering *Heliotropium kotschyi*, *Tribulus macropterus* with less abundantly flowering *Moltkiopsis ciliata* (Boraginaceae) and a few scattered flowering

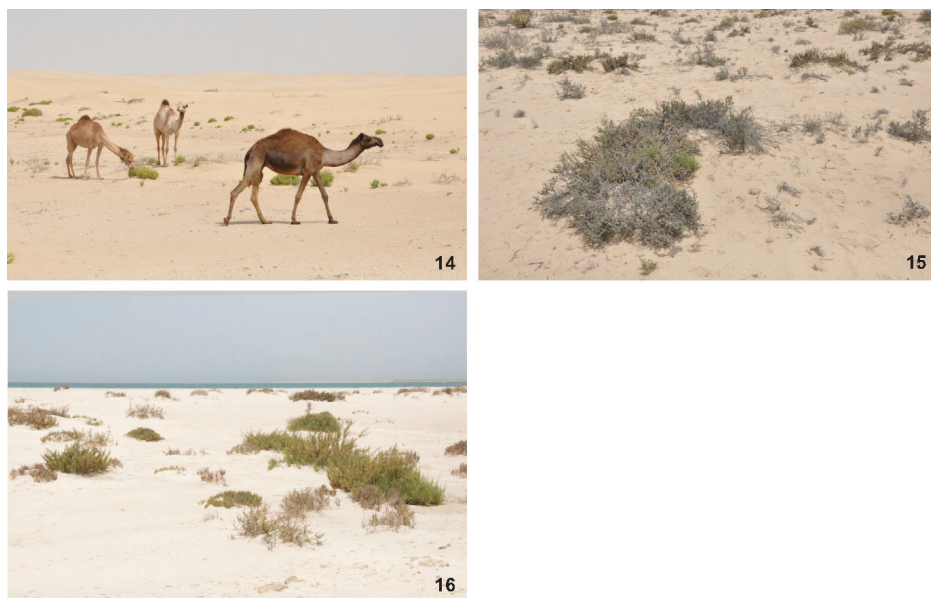


Figures 8–13. Study sites in DDCR: **8** Site 19/20 Tawi Manana Lake **9** Site 19/20 Tawi Manana drip irrigation area **10** Site 24 Lucerne Farm **11** Site 24 Lucerne Farm grazing and browsing exclusion area **12** Site 25 Sand dunes with isolated *Calotropis procera* trees **13** Site 26 Faqah watering point with planted *Prosopis cineraria*.

Polycarpaea repens (Caryophyllaceae) and *Neurada procumbens* (Neuradaceae). Only one plant each of *Indigofera intricata*, *Crotalaria aegyptiaca* and *Citrullus colocynthis* (Cucurbitaceae) were noted.

Site 25. Sand dunes with scattered *Calotropis procera* trees (Figure 12)

Site 26. Faqah watering point (Figure 13)



Figures 14–16. Study sites to the west of DDCR: **14** Crossing from the DDCR to the coast the dunes level out and the dominant plants are scattered plants of *Zygophyllum* species (Zygophyllaceae), not found within the DDCR **15** Site 28. Ghantoot. In addition to *Zygophyllum qatarense* (Zygophyllaceae), well grown plants of *Heliotropium kotschy* (Boraginaceae) were abundant and in flower **16** Site 30. EMEC, coastal sand inland from beach.

Faqah is in the extreme south of the Reserve, the last area from which camels and domestic stock were removed. The area surrounding the watering point was very dry with no plants in flower. The planted *Prosopis cineraria*, which were in flower, were therefore the only plants sampled for flower visitors.

Sites to the west of DDCR to the coast

Crossing from the DDCR to the coast the dunes level out and the dominant plants are scattered plants of *Zygophyllum* species (Zygophyllaceae), not found within the DDCR (Figure 14), until the coast is neared where the plants become more diverse.

Site 27. Roadside, sandy depression

The plants in the depression were more diverse than in the surrounding area. In addition to flowering *Zygophyllum simplex* and *Zygophyllum qatarense*, some plants of a species of Asteraceae were present.

Site 28. Ghantoot, sandy plain (Figure 15)

In addition to *Zygophyllum qatarense*, well grown plants of *Heliotropium kotschy* were abundant and in flower.

Site 29. EMEC, coastal sand inland from beach

The dominant plant in flower was *Zygophyllum qatarense*.

Site 30. EMEC, coastal sand inland from beach (Figure 16)

The dominant plant in flower in the dry sandy area was *Zygophyllum qatarense* with its root parasite *Cistanche tubulosa* (Schenk) Wright (Orobanchaceae). *Arthrocnemum macrostachyum* (Moric.) C. Koch (Chenopodiaceae) was also present in the more saline areas associated with channels. In this area of the coast there are in addition salt pans, where *Z. qatarense* is absent and the dominant plant is *Salsola imbricata* Forssk (Chenopodiaceae), and mud flats dominated by mangroves, *Avicennia marina* (Forssk.) Vierh. (Acanthaceae).

Study sites east of the DDCR to the coast

Most of the sites chosen east of the DDCR in the Hajar Mountains were localities from which *Anticharis arabica* Endl. (Scrophulariaceae: Aptosimae) has been recorded (coordinates of localities supplied by Tamer Khafaga). The reason for this choice being that in southern Africa all Aptosimae are visited by and pollinated by Masarinae (Gess and Gess 2014) and it was hoped that an equivalent association would be found. However, due to the dryness no plants of *A. arabica* were found. The sites in the Hajar Mountains, mostly wadis, ranged in elevation from 284 m to 355 m.

Site 1. Sandy roadside

Scattered plants of *Tribulus* spp., *Heliotropium kotschyi*, *Dipterygium glaucum* and a species of Convolvulaceae were in flower.

Site 2. Shawka

Rumex dentatus (Polygonaceae) was in flower, fringing the area from which the water had retreated. (Figure 17)

Site 3. Wadi

Very dry, little in flower other than *Acacia tortilis*. (Figure 18)

Site 4. Wadi

Very dry, almost all plants in fruit.



Figures 17–19. Study sites to east of DDCR: **17** Site 2. Shawka dam *Rumex dentatus* (Polygonaceae) fringing the area from which water had retreated **18** Site 3. Wadi in Hajar Mountains **19** Site 6. Khor Kalba, Ramsa outside Mangrove and Alhafeya Protected Area.

Site 5. Munay, outskirts of village

Most plants were dried up. *Solanum nigrum* (Solanaceae), in flower near a leaking tap, was sampled for flower visitors.

Site 6. Khor Kalba, Ramsa outside Mangrove and Alhafeya Protected Area

Heliotropium kotschy and *Zygophyllum qatarense* were in flower along the sandy bank of lagoon. *Avicennia marina* was in flower at water's edge. (Figure 19)

All other plants dried out.

Results

Flowering plants recorded

Forty-six plant species were recorded by Tamer Khafaga from the dunes and gravel plains of the DDCR in his 2008/2009 study of the vegetation after rain (Khafaga 2009). These include 41 species of dicots and only five species of monocots. Of the

dicots 33 were noted in the present survey (Table 2). The smaller number of species of plants noted can to a large degree be attributed to the sampling period in 2015 having followed seven dry years, resulting in a paucity of annual plants. *Launaea procumbens* (Asteraceae), widespread in the northern emirates, and an exotic weed, *Sesuvium verrucosum* (Aizoaceae) were found growing inside the cages surrounding planted trees.

The monocots are not included in Table 2 or in Appendix 1. They are the common and widespread palatable sedge, *Cyperus conglomeratus* (Cyperaceae), and four grass species (Poaceae). Grasses were noted in the present survey but were not identified. They were uncommon and outside the enclosures had been heavily grazed.

Flower visitors were observed and sampled on 21 species of plants within the DDCR and on two additional species east of the Reserve and two west of the Reserve (Table 3 and Appendix 1, giving global distributions). Of these 25 species, four species are known only from the Arabian Peninsula. The distributions of the other 19 variously include: the Mediterranean fringe; the Middle East; Asia; North Africa and Asia; North Africa; the Middle East and Asia; Africa from north to south; Africa from north to south together with the Middle East and Asia; and Europe-together with the Mediterranean and Asia.

Aculeate wasps and bees recorded

In the present first survey 53 species of aculeate wasps and 26 species of bees were recorded (Appendix 2, giving global distributions). Known distributions suggest that of these species, 11% are known only from the Arabian Peninsula, 65% include North Africa, 27% include in addition to North Africa, the Middle East and Asia, 9% further include Europe, 6% further include Africa from north to south and west to east, 8% in addition to Arabia have distributions only extending east into Asia, 8% have circum-Mediterranean distributions, 3% distributions from Arabia to southern Africa and 2% distributions from Arabia north into the Middle East as well as south through Africa.

Some understanding of the biogeography of bees in Sahara and Arabian deserts has resulted from the analysis by Patiny and Michez (2007), however, the taxa used in their study (19 species in seven sub-families) are not ones encountered in the present survey, making their conclusions of doubtful merit in the present context.

Of the wasps, 40 species were from the DDCR and the additional 11 from our transect to the east of and two from our transect to the west of the DDCR. Of the bees, 21 species were from the DDCR and an additional two from our transect to the east of the Reserve. Flower sampling yielded flower visiting records for 39 species of aculeate wasps and 23 species of bees. The results of flower sampling are presented in Tables 3 and 4.

Flowers visited by aculeate wasps and bees

Table 3 lists the plants, from the flowers of which aculeate wasps and bees were collected, together with the names, number and sex of the wasps and bees, and the collection sites.

Table 2. Dicotyledonous plants recorded for the DDCR by Khafaga (2009) and in the present survey, flower visitors collected and sites where sampled in the present survey.

Plant family	Plant genus and species	Recorded by Khafaga 2009	Recorded in present survey	Flowers visitors collected	Sites where sampled
Aizoaceae	<i>Sesuvium verrucosum</i> Raf.	-	+	+	Site 11.
Amaranthaceae	<i>Aerva javanica</i> (Burm. f.)	+	+	+	Site 8.
Apocynaceae: Asclepiadoideae (formerly Asclepiadaceae)	<i>Calotropis procera</i> (Aiton) W.T. Aiton	+	+	+	Sites 9, 10, 20, 21, 22, 23, 24
	<i>Leptadenia pyrotechnica</i> (Forssk.) Decne.	+	+	+	Site 24
	<i>Atractylis carduus</i> (Forssk.) C. Chr.	+	+	-	
	<i>Centaurea pseudosinaica</i> Czerep.	+	+	+	Site 8.
Asteraceae	<i>Launaea procumbens</i> (Roxb.) Ramayya & Rajogopal	-	+	+	Site 17
	<i>Rhanterium epapposum</i> Oliv.	+	+	+	Site 15.
	<i>Arnebia hispidissima</i> (Lehm.) DC.	+	+	+	Site 8.
	<i>Heliotropium digynum</i> (Forssk.) Asch. ex C. Chr.	+	+	-	
Boraginaceae	<i>Heliotropium kotschy</i> (Bge.) Gurke	+	+	+	Site 10, 16, 20, 24. Also outside DDCR, Site 28
	<i>Moltkiopsis ciliata</i> (Forssk.) I.M.Johnst.	+	+	+	Site 24.
	<i>Ogastemma pusillum</i> (Coss. & Durand ex Bonnet & Baratte) Brummitt	+	-	-	
	<i>Brassica muricata</i> (L.) Asch.	+	-	-	
Brassicaceae	<i>Eremobium aegyptiacum</i> (Spreng.) Boiss.	+	-	-	
	<i>Farseria linearis</i> Decne. Ex Boiss.	+	+	+	Site 24
	<i>Sisymbrium irymoides</i> Desf.	+	-	-	
Capparaceae	<i>Dipterygium glaucum</i> Decne.	+	+	+	Sites 8, 10, 20, 24
	<i>Polycarpha repens</i> (Forssk.) Asch. & Schweinf.	+	+	+	Site 24.
Caryophyllaceae	<i>Sclerocephalus arabicus</i> Boiss.	+	-	-	
	<i>Silene villosa</i> Forssk.	+	+	-	
Chenopodiaceae	<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	+	+	-	
Cucurbitaceae	<i>Citrullus colocynthis</i> (L.) Schrad.	+	+	-	

Plant family	Plant genus and species	Recorded by Khafaga 2009	Recorded in present survey	Flowers visitors collected	Sites where sampled
Euphorbiaceae	<i>Chrozophora oblongifolia</i> (Delile) Spreng.	+	+	-	
Fabaceae: Mimosoideae	<i>Acacia tortilis</i> (Forssk.) Hayne.	+	+	+	Site 20, also Site 3. Wadi to east
	<i>Prosopis cineraria</i> (L.) Druce.	+	+	+	Site 10, 20, 26
	<i>Crotalaria aegyptiaca</i> Benth.	+	+	+	Site 14, 24
Fabaceae: Papilionoideae	<i>Indigofera colutea</i> (Burm. f.) Merr.	+	+	-	
	<i>Indigofera intricata</i> Boiss.	+	+	-	
	<i>Monsonia nivea</i> (Decne.) Webb	+	-	-	
Geraniaceae	<i>Limeum arabicum</i> Fried.	+	+	+	Sites 8, 20, 24
Molluginaceae	<i>Neurada procumbens</i> L.	+	+	+	Site 24.
Plantaginaceae	<i>Plantago boissieri</i> Hausskn. & Bornm.	+	+	-	
Polygalaceae	<i>Polygala erioptera</i> DC.	+	-	-	
Polygonaceae	<i>Calligonum comosum</i> L' Her.	+	+	-	
	<i>Rumex dentatus</i> L.	-	-	+	Site 2. East of DDCR
Salvadoraceae	<i>Salvadora persica</i> L.	+	+	-	Site 10
Solanaceae	<i>Lycium shawii</i> Roem. & Schult.	+	+	+	
	<i>Solanum nigrum</i> L.	-	-	+	Site 5. East of DDCR
Tamaricaceae	<i>Tamarix aphylla</i> (L.) Karst.	+	+	-	
	<i>Fagonia indica</i> Burm. f.	+	+	-	
	<i>Fagonia</i> sp.	+	-	-	
Zygophyllaceae	<i>Tribulus macropterus</i> Boiss.	+	+	+	Site 24 also Site 13. roadside outside DDCR
	<i>Tribulus omanense</i> Hosni	+	+	+	Site 24
	<i>Tribulus pentandrus</i> Forssk.	+	+	-	
	<i>Zygophyllum qatariense</i> Hadidi	-	-	+	Sites 28, 29, 30 - west of DDCR
	<i>Zygophyllum simplex</i>	-	-	+	Site 27 - west of

Table 3. Plants with flowers visited by aculeate wasps and bees, the wasp and bee visitors, the number and sex of the voucher specimens and the sampling Sites.

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
AMARANTHACEAE			
	<i>Aerva javanica</i>	VESPIDAE: Polistinae <i>Polistes watti</i> Site 8 CRABRONIDAE: Crabroninae: Palarini <i>Palarus laetus</i> , 2 f, Site 8 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix freygesneri</i> , 1f, 1f, Site 8	MEGACHILIDAE: Megachilinae: Anthidiini <i>Pseudomethidium ochrognathum</i> , 1 Site 8
AIZOACEAE			
	<i>Sesuvium verrucosum</i>		HALICTIDAE: Nomioiinae <i>Nomioides klausii</i> 1f Site 11
APOCYNACEAE; Asclepiadoideae			
		CHRYSIDIDAE VESPIDAE: Eumeninae <i>Rhynchium oculatum</i> Site 24 POMPIDIDAE: Pompilinae <i>Telostegus argyrellus</i> 1f, Site 21 TIPHIIDAE 1m Site 9 f Site 24 SCOLIIDAE: Campsomerinae <i>Campsomeriella thoracica</i> 1f, 1f, Site 24 <i>Micromeriella byalina</i> 1f Site 21 SCOLIIDAE: Scolinae <i>Scolia flaviceps</i> 2f, Site 19/20 CRABRONIDAE: Crabroninae: Larrini <i>Tachytes comberi</i> 1m Site 26 CRABRONIDAE: Eremiasphecinae <i>Laphygogus</i> sp. nov 1m Site 21 CRABRONIDAE: Bembicinae: Bembicini	HALICTIDAE: Nomiinae <i>Ceylalicus karachiensis</i> 1f, 3m Site 9 APIDAE: Xylocopinae <i>Xylocopa fenestrata</i> <i>Xylocopa aestuans</i> APIDAE: Apinae: Anthophorini <i>Amegilla byssina</i> (carrying pollen), 1f & 2m Site 21 APIDAE: Apinae: Apini <i>Apis florea</i> (carrying pollen)
	<i>Calotropis procera</i>		

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
ASTERACEAE		<i>Bembix hauseri</i> 3f Site 19/20, 5f Site 9, 3 Crabronidae: Philanthinae: Philanthini <i>Philanthus coarctatus</i> 3f, Site 21 <i>Philanthus pallidus</i> 1m, Site 21 Grabronidae: Philanthinae: Cercerini <i>Cerceris chromatica</i> 1m, 1m, Site 9, 1m, Site 21 CRABRONIDAE: Crabroninae: Palarini <i>Palarus laetus</i> 1m Site 24 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix hameri</i> 1f Site 24	MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile concinna</i> 1f Site 24 <i>Megachile patellimana</i> 1m Site 24
	<i>Leptadenia pyrotechnica</i>		
		CRABRONIDAE: Crabroninae: Palarini <i>Palarus laetus</i> 2f Site 8 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix fregessneri</i> 1f Site 8 CRABRONIDAE: Philanthinae: Philanthini <i>Philanthus pallidus</i> 1f Site 8	MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile patellimana</i> 1f Site 8 APIDAE: Xylocopinae: Xylocopini <i>Xylocopa fenestrata</i> (Fabricius) 1f Site 8 APIDAE: Apinae: Anthophorini <i>Amegilla byssina</i> 1f Site 8
	<i>Rhanterium epapposum</i>	CRABRONIDAE: Crabroninae: Larrini <i>Gastrosericus moricei</i> 1f Site 15 CRABRONIDAE: Crabroninae: Palurini <i>Palarus laetus</i> 1f Site 15 CRABRONIDAE: Philanthinae: Philanthini <i>Philanthus coarctatus</i> 1m Site 15	two small halictid bees, Site 17
	<i>Launaea procumbens</i>		
BORAGINACEAE	<i>Arnebia hispidissima</i>	CRABRONIDAE: Crabroninae: Palurini <i>Palarus laetus</i> 2f Site 8 CHRYSIDIDAE One sp. 1 Site 10 POMPIDIDAE: Ceropalinae <i>Ceropades krichbaumeri</i> 1f Site 10	Apidae: Apinae: Anthophorini <i>Amegilla byssina</i> 1f, 1f, 1m Site 8 VESPIDAE: Masarinae <i>Celonites jousseaumei</i> (flying above flowers) 1f Site 10 <i>Quarinia rubiana</i> 2f Site 10 HALICTIDAE: Nomioinae

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
		<p>SCOLIIDAE</p> <p><i>Micromeriella hyalina</i> 1m, Site 10</p> <p>CRABRONIDAE: Crabroninae: Palurini</p> <p><i>Palarus bisignatus</i> 1f Site 24</p> <p><i>Palarus laetus</i> 1f Site 10, 1f Site 24</p> <p>CRABRONIDAE: Bembicinae: Bembicini</p> <p><i>Bembix freygessneri</i> 1f, 1f & 2m, 1f Site 24</p> <p><i>Bembix hameri</i> 1f, 1f, 1m Site 24</p> <p><i>Bembix hauseri</i> 1f Site 19/20, 1f Site 24</p> <p><i>Bembix kohl</i> 1f Site 24</p> <p><i>Bembix rochei</i> 1f Site 24</p> <p><i>Bembix saadensis</i> 1m Site 24</p>	<p><i>Ceylalicus karachensis</i> 1f, 5m Site 10</p> <p><i>Ceylalicus punjabensis</i> 1f Site 10</p> <p><i>Ceylalicus variegatus</i> 1m Site 10</p> <p><i>Nomioides klaus</i> 1f, 2m, Site 10, 2 Site 19/20</p> <p>MEGACHILIDAE: Megachilinae: Megachilini</p> <p><i>Megachile concinna</i> 1f, 1m Site 24, 1f site 19/20</p> <p><i>Megachile patellimana</i> 1f & 1m, 2f Site 10, 1f & 1m, 1f & 1m, 1m Site 24, 1f & 2m Site 19/20</p> <p><i>Coelioxys indica</i> 1 Site 10</p> <p>Megachilinae: Anthidiini</p> <p><i>Pseudoanthidium ochrognathum</i>, 1f Site 10</p> <p>Megachilinae: Osmiini</p> <p><i>Haetosmia circumventa</i> 1f, Site 24, 2m, 3m, 6m Site 10, 2f Site 27</p> <p>APIDAE: Xylocopinae</p> <p><i>Ceratina parvula</i> Site 24</p> <p>APIDAE: Apinae: Anthophorini</p> <p><i>Anegilla byssina</i> 1f Site 19/20, 1f & 1m Site 24</p> <p><i>Anthophora tenella</i> 1m Site 10, 1m Site 28</p> <p>APIDAE: Apinae: Melectini</p> <p><i>Thyreus hyalinatus</i> 1m, 1f Site 10</p> <p>VESPIDAE: Masarinae</p> <p><i>Celonites jouseaumei</i> (flying above flowers) site record</p> <p>HALICTIDAE: Nomioidinae</p> <p><i>Ceylalicus karachensis</i> 1f Site 24</p> <p>MEGACHILIDAE: Megachilinae: Anthidiini</p> <p><i>Pseudoanthidium ochrognathum</i>, 1f Site 24</p> <p>APIDAE: Apinae: Anthophorini</p> <p><i>Anegilla byssina</i> 3f, 2f Site 24</p>
	<i>Moltisopsis ciliata</i>	<p>CRABRONIDAE: Bembicinae: Bembicini</p> <p><i>Bembix hauseri</i> 2f and 1m Site 24</p>	
BRASSICACEAE	<i>Farsetia linearis</i>		<p>APIDAE: Xylocopinae: Ceratinini</p> <p><i>Ceratina parvula</i> 1f Site 24</p>

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
CAPPARACEAE			
	<i>Dipterygium glaucum</i>	CHRYSIDIDAE Chrysidid 1 site 8 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix saadensis</i> 1f Site 24	APIDAE: Apinae: Anthophorini <i>Amegilla byssina</i> 1m Site 10 APIDAE: Apinae: Melectini <i>Thyreus elegans</i> 1f Site 8
CARYOPHYLLACEAE			
	<i>Polycarpha repens</i>	CRABRONIDAE: Crabroninae: Palurini <i>Palurus parvulus</i> 1m Site 24	
FABACEAE: Mimosoideae			
	<i>Acacia tortilis</i>	SCOLIIDAE <i>Micromerella hyalina</i> 1m Site 3 CRABRONIDAE: Crabroninae: Oxbelini <i>Oxybellus lamellatus</i> 1m Site 3 CRABRONIDAE: Bembicinae: Bembicini <i>Stizoides assimilis</i> 1f Site 3 <i>Bembix chopardi</i> 2m Site 3	HALICTIDAE: Nomioiinae 1 male <i>Ceylalictus variegatus</i> 1m Site 3 MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile concinna</i> 1f, 1m Site 3 APIDAE: Xylocopinae: Ceratinini <i>Ceratina tarsata</i> 1f Site 3 APIDAE: Apinae: Melectini <i>Thyreus hyalinatus</i> 1f Site 10
	<i>Prosopis cineraria</i>	SPHECIDAE: Sphecinae <i>Prionyx nigropunctinatus</i> 1f Site 26 CRABRONIDAE: Crabroninae: Miscophini <i>Plenoculus vanharteni</i> 1f Site 10 CRABRONIDAE: Crabroninae: Larrini <i>Tachysphex micans</i> 1f Site 26 CRABRONIDAE: Crabroninae: Palurini <i>Palurus lactus</i> 1f & 6m Site 26 <i>Palurus parvulus</i> 1m Site 26 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix freygesneri</i> 1f Site 26 CRABRONIDAE: Philanthinae <i>Cerceris albocincta</i> 5m Site 26 <i>Cerceris chromatica</i> 2f & 6m Site 26 <i>Cerceris</i> sp. 1 Site 10	HALICTIDAE: Nomioiinae <i>Ceylalictus karachiensis</i> 1f, 3m Site 9 <i>Ceylalictus punjabensis</i> 1f Site 10 <i>Ceylalictus variegatus</i> 1m Site 10, 1f Site 21 MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile minutissima</i> 1m Site 10 <i>Megachile patellimana</i> 1f Site 10 APIDAE: Apinae: Apini <i>Apis florea</i> hive Site 10

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
FABACEAE: Papilionoideae			MEGACHILIDAE: Megachilinae: Anthidiini <i>Icteranthisidum</i> sp., 1m, 1m & 3f Site 14 MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile patellimana</i> 1f Site 24 APIDAE: Apinae <i>Anegilla byssina</i> 2f Site 14
MOLLUGINACEAE	<i>Crotalaria aegyptiaca</i>	CRABRONIDAE: Eremiaspheciinae <i>Laphrogogus</i> n. sp. 2m Site 14	
	<i>Linum arabicum</i>	CRABRONIDAE: Crabroninae: Palurini <i>Palarus bisignatus</i> 1f & 4m, 1m Site 24 <i>Palarus dongalensis</i> 1 Site 24 <i>Palarus parvulus</i> 1m Site 8 CABRONIDAE: Eremiaspheciinae <i>Laphrogogus</i> n. sp. 1m Site 19/20 CRABONIDAE: Bembicinae: Bembicini <i>Bembix gazella</i> 1m Site 24 <i>Bembix saadensis</i> 1f Site 24	HALICTIDAE: Nominae <i>Pseudapis nilotica</i> 1f Site 24 APIDAE: Xylocopinae: Ceratinini <i>Ceratina parvula</i> 1f & 2m Site 24
NEURADACEAE			1 halictid bee
POLYGONACEAE	<i>Neurada procumbens</i>		
	<i>Rumex dentatus</i>	VESPIDAE: Eumeninae <i>Delta esuriens esuriens</i> 1 Site 2 VESPIDAE: Polistinae <i>Polistes watti</i> 2 Site 2 VESPIDAE: Vespinae <i>Vespa orientalis</i> POMPIDIDAE <i>Anoplius suspectus</i> 1f Site 2 SPHECIDAE: Sceliphronini <i>Sceliphron madraspatanum pictum</i> 1 Site 2 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix arenaria</i> 1f Site 2 <i>Bembix aculata</i> 2f Site 2	HALICTIDAE: Halictinae <i>Sceladonia lucidipennis</i> 1f, 1m Site 2

Plant Family	Plant genus and species	Wasps	Bees and Pollen Wasps
SOLANACEAE			
	<i>Solanum nigrum</i>	POMPILIDAE: Ceropalinae <i>Ceropales krieckbaumeri</i> 2f Site 5 SCOLIIDAE: Campsomerinae <i>Micromeriella hyalina</i> 1 Site 5 SPHECIDAE: Ammophilinae <i>Ammophila rubripes</i> 1m Site 5 CRABRONIDAE: Philanthinae <i>Cerceris</i> sp. 1 Site 5	HALICTIDAE: Nominae <i>Crociaspidia vespoides</i> 1m Site 5
ZYGOPHYLLACEAE			
	<i>Tribulus macropterus</i>	CRABRONIDAE: Crabroninae: Palurini <i>Palarus lactus</i> 1m, 1m Site 24 CRABRONIDAE: Bembicinae: Bembicini <i>Bembix fregessneri</i> 1f Site 24 <i>Bembix gazella</i> 1m, 4m, 1m Site 24 <i>Bembix kohli</i> 1f & 1male Site 24 <i>Bembix rocheti</i> 1f Site 13, 2f Site 24	HALICTIDAE: Nomioiinae 1 male <i>Nomioides klausii</i> 1m Site 24 MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile patellimana</i> 6f & 1m, 6f, 4f Site 24 APIDAE: Xyllocopinae: Ceratinini <i>Ceratina parvula</i> 1f, 2 Site 24
	<i>Zygophyllum qatarense</i>	POMPILIDAE: Pompilinae <i>Telostegus argyrellus</i> 2 Site 30 CRABRONIDAE: Crabroninae: Larrini <i>Gastrosericus ualtilii</i> 1m Site 30 CRABRONIDAE: Philanthinae <i>Cerceris albicincta</i> 1m <i>Cerceris chromatica</i> 1m Site 29	
	<i>Zygophyllum simplex</i>	TIPHIIDAE: Thynninae 1m Site 27 CRABRONIDAE: Crabroninae: Palurini <i>Palarus parvulus</i> 1m Site 27 CRABRONIDAE: Philanthinae <i>Cerceris</i> sp. 1 Site 27	MEGACHILIDAE: Megachilinae: Megachilini <i>Megachile</i> 1 Site 27

Table 4. Aculeate wasps and bees collected visiting flowers, plants, collection Sites and sex of wasp and bee voucher specimens.

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
CHRYSIDOIDEA			
CHRYSIDIDAE		APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1 Site 21
		BORAGINACEAE	<i>Heliotropium kotschy</i> 1 Site 10
		CAPPARACEAE	<i>Dipterygium glaucum</i> 1 Site 8
VESPOIDEA			
VESPIDAE: Masarinae			
	<i>Celonites jousseaumei</i> (flying above flowers)	BORAGINACEAE	<i>Heliotropium kotschy</i> 1f Site 10
	<i>Quartinia nubiana</i>	BORAGINACEAE	<i>Molkiopsis ciliata</i> site record
VESPIDAE: Eumeninae			<i>Heliotropium kotschy</i> 2f Site 10
	<i>Delta esuriens esuriens</i>	POLYGONACEAE	<i>Rumex dentatus</i> Site 2
	<i>Rhynchium oculatum</i>	APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> Site 24
Vespidae: Polistinae			
	<i>Polistes wattii</i>	AMARANTHACEAE	<i>Aerva javanica</i> Site 8
		POLYGONACEAE	<i>Rumex dentatus</i> 2 Site 2
POMPIDIDAE: Pompilinae			
	<i>Anoplius suspectus</i>	POLYGONACEAE	<i>Rumex dentatus</i> 1f Site 2
	<i>Telostegus argyrellus</i>	APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1f, Site 21
		ZYGOPHYLLACEAE	<i>Zygophyllum qatarense</i> 2 Site 30
POMPIDIDAE: Ceropalinae			
	<i>Ceropales kriebbaumeri</i>	BORAGINACEAE	<i>Heliotropium kotschy</i> 1f Site 10
		SOLANACEAE	<i>Solanum nigrum</i> , 2f Site 5
TIPHIIDAE		APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1, Site 9
TIPHIIDAE: Thynninae		ZYGOPHYLLACEAE	<i>Zygophyllum simplex</i> 1 Site 27
SCOLIIDAE: Campsomerinae			
	<i>Campsomeriella thoracica</i>	APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1f, 1f, Site 24

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
	<i>Micromeritella hyalina</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE FABACEAE: Mimosoideae SOLANACEAE	<i>Calotropis procera</i> 1f Site 21 <i>Heliotropium kotschy</i> 1m, Site 10 <i>Acacia tortilis</i> 1m Site 3 <i>Solanum nigrum</i> 1 Site 5
SCOLIIDAE: Scoliinae			
	<i>Scolia flaviceps</i>	APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 2f Site 19/20
SCOLIIDAE: Campsomerinae			
	<i>Campsomeritella thoracica</i> <i>Micromeritella hyalina</i>	APOCYNACEAE: Asclepiadoideae APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1f, 1f, Site 24 <i>Calotropis procera</i> 1f Site 21
APOIDEA: SPHECIFORMES			
SPHECIDAE: Sphecinae			
	<i>Prionyx nigropectinatus</i>	FABACEAE: Mimosoideae	<i>Prosopis cineraria</i> 1f Site 26
SPHECIDAE: Sceliphrinae			
	<i>Sceliphron madraspatanum pictum</i>	POLYGONACEAE	<i>Rumex dentatus</i> 1 Site 2
SPHECIDAE: Ammophilinae			
	<i>Ammophila rubripes</i>	SOLANACEAE	<i>Solanum nigrum</i> 1m Site 5
CRABRONIDAE: Crabroninae: Larrini			
	<i>Gastrosericus moricei</i>	ASTERACEAE	<i>Rhanterium epapposum</i> 1f Site 15
	<i>Gastrosericus waltlii</i>	ZYGOPHYLLACEAE	<i>Zygophyllum qatarense</i> 1m Site 30
	<i>Tachytes comberi</i>	APOCYNACEAE: Asclepiadoideae	<i>Calotropis procera</i> 1m Site 26
	<i>Tachysphex micans</i>	FABACEAE: Mimosoideae	<i>Prosopis cineraria</i> 1f Site 26
CRABRONIDAE: Crabroninae: Oxybellini			
	<i>Oxybellus lamellatus</i>	FABACEAE: Mimosoideae	<i>Acacia tortilis</i> 1m Site 3
CRABRONIDAE: Crabroninae: Palurini			
	<i>Palarus bisignatus</i>	BORAGINACEAE MOLLUGINACEAE	<i>Heliotropium kotschy</i> 1f Site 24 <i>Linum arabicum</i> 1f & 4m, 1m Site 24
	<i>Palarus dongalensis</i>	MOLLUGINACEAE	<i>Linum arabicum</i> 1 Site 24

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
	<i>Palarus laetus</i>	AMARANTHACEAE APOCYNACEAE: Asclepiadoideae ASTERACEAE BORAGINACEAE FABACEAE: Mimosoideae ZYGOPHYLLACEAE	<i>Aerva javanica</i> 2f Site 8 <i>Leptadenia pyrotechnica</i> 1f Site 24 <i>Centaurea pseudosinica</i> 2f Site 8 <i>Arnebia hispidissima</i> 2f Site 8 <i>Heliotropium kotschy</i> 1f Site 10, 1f Site 24 <i>Prosopis cineraria</i> 1f & 6m Site 26 <i>Tribulus macropterus</i> var. <i>arabicus</i> 1m, 1m Site 24
	<i>Palarus parvulus</i>	CARYOPHYLLACEAE MOLLUGINACEAE	<i>Polycarpha repens</i> 1m Site 24 <i>Limnium arabicum</i> 1f & 2m Site 24
CRABRONIDAE: Crabroninae: Mischophini	<i>Plenoculus vanharteni</i>	FABACEAE: Mimosoideae	<i>Prosopis cineraria</i> 1f Site 10
CRABRONIDAE: Bembicinae: Bembicini	<i>Bembix arenaria</i>	POLYGONACEAE	<i>Rumex dentatus</i> 1f Site 2
	<i>Bembix chopardi</i>	FABACEAE: Mimosoideae	<i>Acacia tortilis</i> 2m Site 3
	<i>Bembix freygesneri</i>	AMARANTHACEAE ASTERACEAE BORAGINACEAE ZYGOPHYLLACEAE	<i>Aerva javanica</i> 1f, 1f, Site 8 <i>Centaurea pseudosinica</i> 1f Site 8 <i>Heliotropium kotschy</i> 1f, 1f & 2m, 1f Site 24 <i>Tribulus macropterus</i> 1f Site 24
	<i>Bembix gazella</i>	MOLLUGINACEAE FABACEAE: Mimosoideae ZYGOPHYLLACEAE	<i>Limnium arabicum</i> 1m Site 24 <i>Prosopis cineraria</i> 1f Site 26 <i>Tribulus macropterus</i> 1m, 4m, 1m Site 24
	<i>Bembix hameri</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE	<i>Leptadenia pyrotechnica</i> 1f Site 24 <i>Heliotropium kotschy</i> (Bge.) Gurke, 1f, 1f, 1m Site 24
	<i>Bembix hauseri</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE	<i>Calotropis procera</i> 3f Site 19/20, 5f Site 9, 3f Site 24 <i>Heliotropium kotschy</i> 1f Site 19/20, 1f Site 24 <i>Molikiopsis ciliata</i> 2f & 1m Site 24
	<i>Bembix kohli</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE ZYGOPHYLLACEAE	<i>Calotropis procera</i> 1f, Site 2 (flying), 1m, Site 24 <i>Heliotropium kotschy</i> 1f Site 24 <i>Tribulus macropterus</i> 1f & 1m Site 24
	<i>Bembix oculata</i>	POLYGONACEAE	<i>Rumex dentatus</i> 2f Site 2

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
	<i>Bembix rochei</i>	BORAGINACEAE ZYGOPHYLLACEAE	<i>Heliotropium kotschyi</i> 1f Site 24 <i>Tribulus macropterus</i> 1f Site 13 2f Site 24
	<i>Bembix saadensis</i>	BORAGINACEAE CAPPARACEAE MOLLUGINACEAE	<i>Heliotropium kotschyi</i> 1m Site 24 <i>Dipterygium glaucum</i> 1f Site 24 <i>Limeum arabicum</i> 1f Site 24
	<i>Stizoides assimilis</i>	FABACEAE; Mimosoideae	<i>Acacia tortilis</i> 1m Site 3
CRABRONIDAE: Eremiaspheciinae: Eremiaspheciini			
	<i>Laphynagagus</i> sp. nov	APOCYNACEAE: Asclepiadoideae FABACEAE: Papilionoideae MOLLUGINACEAE	<i>Calotropis procera</i> 1m Site 21 <i>Crotalaria aegyptiaca</i> 2m Site 14 <i>Limeum arabicum</i> , 1m Site 19/20
CRABRONIDAE: Bembicinae Philanthinae: Philanthini			
	<i>Philanthus coarctatus</i>	APOCYNACEAE: Asclepiadoideae ASTERACEAE	<i>Calotropis procera</i> 3f, Site 21 <i>Rhanterium epapposum</i> , 1m Site 15
	<i>Philanthus pallidus</i>	APOCYNACEAE: Asclepiadoideae ASTERACEAE	<i>Calotropis procera</i> 1m, Site 21 <i>Centaurea pseudosinica</i> 1f Site 8
Bembicinae Philanthinae: Cercerini			
	<i>Cerceris albocincta</i>	FABACEAE: Mimosoideae ZYGOPHYLLACEAE	<i>Prosopis cineraria</i> 5m Site 26 <i>Zygophyllum qatarense</i> 1m
	<i>Cerceris chromatica</i>	APOCYNACEAE: Asclepiadoideae FABACEAE: Mimosoideae ZYGOPHYLLACEAE	<i>Calotropis procera</i> 1m, 1m, Site 9, 1m, Site 21 <i>Prosopis cineraria</i> 2f & 6m Site 26 <i>Zygophyllum qatarense</i> 1m Site 29
	<i>Cerceris</i> sp.	FABACEAE: Mimosoideae	<i>Prosopis cineraria</i> 1 Site 10
	<i>Cerceris</i> sp.	SOLANACEAE	<i>Solanum nigrum</i> 1 Site 5
	<i>Cerceris</i> sp.	ZYGOPHYLLACEAE	<i>Zygophyllum simplex</i> 1 Site 27
APOIDEA: APIFORMES			
HALICTIDAE: Halictinae			
	<i>Halictus lucidipennis</i>	POLYGONACEAE	<i>Rumex dentatus</i> 1f, 1m, Site 2

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
HALICTIDAE: Nomiinae			
	<i>Nomia vespoidea</i>	SOLANACEAE	<i>Solanum nigrum</i> 1m Site 5
	<i>Pseudapis nilotica</i>	MOLLUGINACEAE	<i>Lineum arabicum</i> 1f Site 24
HALICTIDAE: Nomioidinae			
	<i>Ceylalictus karachiensis</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE	<i>Calotropis procera</i> 1f, 3m, Site 9 <i>Heliotropium kotschy</i> 1f, 5m, Site 10 <i>Molkiopsis ciliata</i> 1f, Site 24 <i>Prosopis cineraria</i> 1f, 3m Site 9
	<i>Ceylalictus punjabensis</i>	FABACEAE: Mimosoideae BORAGINACEAE FABACEAE: Mimosoideae	<i>Heliotropium kotschy</i> 1f, Site 10 <i>Prosopis cineraria</i> 1f, Site 10
	<i>Ceylalictus variegatus</i>	BORAGINACEAE FABACEAE: Mimosoideae	<i>Heliotropium kotschy</i> 1m, Site 10 <i>Acacia tortilis</i> 1m, Site 3 <i>Prosopis cineraria</i> 1m Site 10, 1f Site 21
	<i>Nomioides klausii</i>	AIZOACEAE BORAGINACEAE ZYGOPHYLLACEAE	<i>Sesuvium verrucosum</i> 1f Site 11 <i>Heliotropium kotschy</i> 2 Site 19/20 <i>Tribulus macropterus</i> 1m Site 24
MEGACHILIDAE: Megachilinae: Megachilini			
	<i>Megachile concinna</i>	APOCYNACEAE: Asclepiadoideae BORAGINACEAE FABACEAE: Mimosoideae	<i>Lepadenia pyrotechnica</i> 1f Site 24 <i>Heliotropium kotschy</i> 1f, 1m Site 24, 1f Site 19/20 <i>Acacia tortilis</i> 1m Site 3
	<i>Megachile minutissima</i>	FABACEAE: Mimosoideae	<i>Prosopis cineraria</i> 1m Site 10
	<i>Megachile patellimana</i>	APOCYNACEAE: Asclepiadoideae ASTERACEAE BORAGINACEAE	<i>Lepadenia pyrotechnica</i> 1m Site 24 <i>Centaurea pseudostindica</i> 1f Site 8 <i>Heliotropium kotschy</i> 1f & 1m, 2f Site 10, 1f & 1m, 1f & 1m, 1m Site 24, 1f & 2m Site 19/20 <i>Faresetia linearis</i> 1f Site 24
		BRASSICACEAE FABACEAE: Mimosoideae FABACEAE: Papilionoideae ZYGOPHYLLACEAE	<i>Prosopis cineraria</i> 1m Site 10 <i>Crotalaria aegyptiaca</i> 1f Site 24 <i>Tribulus macropterus</i> 6f & 1m, 6f, 4f Site 24 <i>Heliotropium kotschy</i> Site 10
	<i>Coelioxys indica</i>		

Aculeate Family and Subfamily	Aculeate genus and species	Plant Family	Plant genus and species
MEGACHILIDAE: Megachilinae: Osmiini	<i>Haetosmia circumventa</i>	BORAGINACEAE	<i>Heliotropium kotschy</i> 1f Site 24, 2m, 3m, 6m Site 10, 2f Site 27
MEGACHILIDAE: Megachilinae: Anthidiini	<i>Icteranthis n. sp.</i> <i>Pseudanthidium ochrognathum</i>	FABACEAE: Papilionoideae AMARANTHACEAE BORAGINACEAE	<i>Crotalaria aegyptiaca</i> , 1m, 1m&3f Site 14 <i>Aerva javanica</i> , 1f, Site 8 <i>Heliotropium kotschy</i> , 1f, 3 Site <i>Molkiopsis ciliata</i> , 1f, site 24
APIIDAE: Xylocopinae: Xylocopini	<i>Xylocopa fenestrata</i> <i>Xylocopa aestuans</i> <i>Ceratina parvula</i>	APOCYNACEAE: Asclepiadoideae ASTERACEAE APOCYNACEAE: Asclepiadoideae BORAGINACEAE MOLLUGINACEAE ZYGOPHYLLACEAE	<i>Calotropis procera</i> 1f Site 8 <i>Centaurea pseudosinaica</i> 1f Site 8 <i>Calotropis procera</i> site records <i>Heliotropium kotschy</i> 1 Site 24 <i>Linum arabicum</i> 1f & 2m Site 24 <i>Tribulus macropterus</i> 1f, 2 Site 24 <i>Acacia tortilis</i> 1f Site 3
APIIDAE: Apinae: Anthophorini	<i>Amegilla byssina</i>	APOCYNACEAE: Asclepiadoideae ASTERACEAE BORAGINACEAE CAPPARACEAE FABACEAE: Papilionoideae BORAGINACEAE	<i>Calotropis procera</i> 1f & 2m Site 21 <i>Centaurea pseudosinaica</i> 1f <i>Arnebia hispidissima</i> 1f, 1f, 1m Site 8 <i>Heliotropium kotschy</i> 1f & 1m Site 24 <i>Molkiopsis ciliata</i> 3f, 2f Site 24 <i>Dipterygium glaucum</i> 1m Site 10 <i>Crotalaria aegyptiaca</i> 2f Site 14 <i>Heliotropium kotschy</i> 1m Site 10, 1m Site 28
APIIDAE: Apinae: Melectini	<i>Thyreus elegans</i> <i>Thyreus hyalinatus</i>	CAPPARACEAE BORAGINACEAE FABACEAE: Mimosoideae	<i>Dipterygium glaucum</i> 1f Site 8 <i>Heliotropium kotschy</i> 1m, 1f Site 10 <i>Prosopis cineraria</i> 1f Site 10
APIIDAE: Apinae: Apini	<i>Apis florea</i>	APOCYNACEAE: Asclepiadoideae FABACEAE: Mimosoideae	<i>Calotropis procera</i> (carrying polinia) <i>Prosopis cineraria</i> (hive in tree) Site 10

Visits by hunting wasps and nest parasites were for imbibing nectar and visits by bees and pollen wasps for imbibing nectar and/or gathering pollen. Pollen and nectar collecting visits were not distinguished. Following Jongbloed (2003, *The comprehensive guide to the wild flowers of the United Arab Emirates*) the plant families have been arranged in alphabetical order not grouped under Orders.

Discussion

The Arabian Peninsula lies between similar latitudes in the northern hemisphere as do the semi-arid to arid desertic areas in southern Africa, the principal area in which Sarah Gess with Friedrich Gess made a 40 year study of aculeate wasps and bees. Although the preliminary survey of flower visiting by aculeate wasps and bees here reported and discussed spanned only a matter of weeks it is of interest and informative to make some comparisons.

Amaranthaceae

Jongbloed (2003) gives accounts for 10 species of Amaranthaceae occurring in the UAE, most to the east or west of the DDCR. Only one species, *Aerva javanica* (Figure 20), the only species widespread in the central dune desert, has been recorded for the DDCR (Khafaga 2009). By comparison Amaranthaceae forms a notable component of the vegetation of northern Namaqualand and Namibia where the most numerous species of solitary wasp and bee visitors belong to the Crabronidae: Bembicinae (formerly Nyssonidae) and of solitary bees to the Megachilidae (Gess and Gess 2006). It is perhaps significant that in the present study these two taxa are represented amongst the small number of wasps and bees recorded from *Aerva javanica*. The only other wasp visiting the flowers was *Polistes wattii* (Polistinae) and the only bee, unexpectedly, the small anthidiine, *Pseudoanthidium ochrognathum*, otherwise collected from Boraginaceae both in the reserve and to the east.

Aizoaceae

Whereas Aizoaceae, both Mesembryanthema (formerly Mesembryanthemaceae) and non-Mesembryanthema are widespread and species diverse in the semi-arid to arid areas of Southern Africa only one species of Mesembryanthema and three species of non-Mesembryanthema, all coastal species, are recorded from the UAE in Jongbloed (2003).

In the present study one species *Sesuvium verrucosum* (non-Mesembryanthema) was recorded. It was growing inside the cage of an irrigated planted tree in the DDCR (Figure 21). It is an American species, which has become naturalized in the UAE where



Figure 20–21. 20 Amaranthaceae, *Aerva javanica* 21 Aizoaceae, *Sesuvium verrucosum* in tree cage.

it is most usually found along the west coast. One halictid bee, a female *Nomioides klausii*, was visiting the flowers. At other sites this bee was visiting *Heliotropium kotschyi* (Boraginaceae) and *Tribulus macropterus* (Zygophyllaceae).

Apocynaceae: Asclepiadoideae

Jongbloed (2003) gives accounts for eight species of Asclepiadoideae in the UAE. Of these most occur to the east of the DDCR. Two species of perennial woody Asclepiadoideae, *Calotropis procera* (Figures 22 and 23) and *Leptadenia pyrotechnica* (Figures 24 and 25), which are characteristic of the central dune desert, are listed for the DDCR in Khafaga (2009). They are widely present on the dunes where, not being palatable, they are often the only plants. Samples of wasps and bees visiting *C. procera* were taken at five widely separated sites. Wasps represented in total were of the wasp families Chrysididae (1 sp.), Tiphidae (1 sp.), Vespidae: Eumeninae (1 sp.), Scoliididae (2 spp.), Pompilidae (1sp.), Crabronidae: Bembicinae (2 spp.), Eremiaspheciinae (1 sp.) and Philanthinae (2 spp.) and the bee family Apidae (Apinae: Apini (1 sp.) and Anthophorini (1 sp.) and Apidae: Xylocopinae (2 spp.)).

In a detailed study of the pollination of *Calotropis procera* in Pakistan (Ali and Ali 1988) a much more limited range of visitors was recorded. Insects bearing pollinia were classified as pollinators. On this basis those authors concluded that two Apidae, *Xylocopa pubescens* Spinola and *X. fenestrata* were the main pollinators and that a third *Apis florea* was a minor pollinator. It is likely that in the DDCR *Xylocopa fenestrata* and *X. aestuans* are similarly potential pollinators of *C. procera*. In the



Figures 22–25. Apocynaceae, Asclepiadoideae: **22, 23** *Calotropis procera* **24, 25** *Leptadenia pyrotechnica*.

present survey visitors carrying pollinia were two Apidae, *Amegilla bysina* and *Apis florea*, and one crabronid, *Bembix kohli*, making them additional potential pollinators of this plant.

The diversity of visitors to *Calotropis procera*, though not as great, is comparable with that to a shrubby species of Asclepiadoideae, *Gomphocarpus filiformis* (E. Mey.) Dietr., in the western semi-arid to arid areas of southern Africa, which also includes Chrysididae (2 spp.), Vespidae, Pompilidae (9 spp.), Scoliidae (3 spp.), Crabronidae: Crabroninae (7 spp.) and Bembicinae (2 spp.), Apidae: Apinae (6 spp.) and Xylocopinae (2 spp.) with, however, in addition Tiphiidae (4 spp.), Sphecidae (7 spp.), and one species each of Bradynobaenidae, Halictidae, Colletidae, and Melittidae (Gess and Gess 2003 and Gess and Gess 2006).

Leptadenia pyrotechnica, though widespread, was being less commonly visited, flower visitors having been observed only at Site 24, the Lucerne Farm enclosure. There the visitors obtained were less diverse, wasps of Crabronidae: Crabroninae (1sp.) and Bembicinae (1 sp.) and Palurini (1 sp.), and bees of Megachilidae: Megachilinae: Megachilini (2 spp.), with sight records for *Apis florea*.

Asteraceae

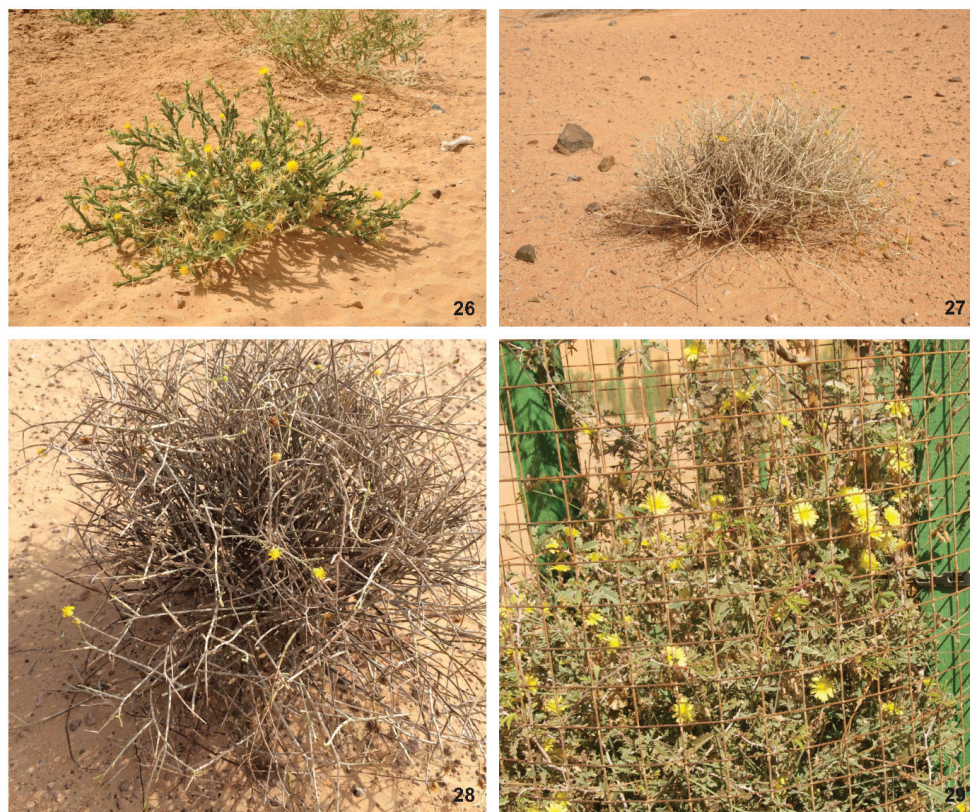
Jongbloed (2003) gives accounts for 58 species of Asteraceae in the United Arab Emirates most having been recorded from the mountainous area to the East of the DDCR. Khafaga (2009) recorded only three, *Atractylis carduus*, *Centaurea pseudosinaica* and *Rhanterium eppaposum*, from the DDCR (Table 2). Of these *C. pseudosinaica* (Figure 26) and *R. eppaposum* (Figures 17 and 18) were found in flower and in addition *Launaea procumbens* (Figure 29), a common and widespread weed, was found growing and flowering, like *S. verrucosum*, inside the cage of a planted tree.

At the time of sampling, *Centaurea pseudosinaica* was being visited by three species of aculeate wasps of three sub-families of Crabronidae, one species of Megachilidae and two species of Apidae, one each of Apinae and Xylocopinae. However, *Rhanterium eppaposum* was visited solely by Crabronidae of two sub-families and *Launaea procumbens* by two small halictid bees.

A greater diversity of visitors had been expected. In the semi-arid to arid areas of southern Africa, where Asteraceae is the largest family in the Karoo-Namib Region (Cowling and Hilton Taylor 1999), it was recorded as being visited by a diverse range of aculeate wasps of eight families, including pollen wasps, and all families of bees (Gess and Gess 2006).

Boraginaceae

Jongbloed (2003) gives accounts for 22 species of Boraginaceae occurring in the UAE. Of these, four species are given as widespread in the central desert, all are listed in Khafaga (2009) for the DDCR. In the present study all four, *Arnebia hispidissima* (Figure 30), *Heliotropium digynum*, *Heliotropium kotschyi* (Figures 31 and 32) and *Moltkiopsis ciliata* (Figure 33 and 34), were sampled for flower visitors. The only species not being visited at that time was *H. digynum*. *Heliotropium kotschyi*, the most widespread and abundant species, was sampled for flower visitors at three sites within the DDCR and one site near to the coast west of the DDCR. At all three sites in the reserve wasps of the family Crabronidae (sites grouped, Crabroninae: Palurini, 2 spp. and Bembicinae: Bembicini, 6 spp.) and bees of the families Megachilidae (sites grouped together, Megachilinae: Megachilini 3 spp., Osmiini 1 sp. and Anthidiini 1 sp.) and Apidae (sites grouped together Xylocopinae: Ceratinini 1 sp., Apinae: Anthophorini 2 spp.) were recorded, with in addition from the drip area at Tawi Ruwayyan wasps of the families,



Figures 26–29. Asteraceae: **26** *Centaurea pseudosinaica* **27, 28** *Rhanterium epapposum* **29** *Launaea procumbens*.

Chrysididae (1 sp.), Vespidae: Masarinae (2 spp.), Pompilidae (1sp.), Scoliidae (1 sp.), and from the drip area at Tawi Manana bees of the family Halictidae (4 spp.). Other noticeable but not common visitors to the flowers were braconid wasps in the DDCR and bombyliid flies both in the DDCR and at Ghantoot, inland from the west coast.

The two species of Masarinae were *Quartinia nubiana* (2 females caught visiting flowers) and *Celonites jousseaumei* (flying over flowers).

Of particular interest was the presence of an oligolectic osmiine bee, *Haetosmia circumventa*, which specialises in collecting pollen from the flowers of *Heliotropium* (Gotlieb et al. 2014).

Arnebia hispidissima and *Moltkiopsis ciliata* were only present and sampled at one site each, Quarn Nazwa and the dune enclosure at the Lucerne Farm respectively. Both, like *Heliotropium kotschy*, were receiving visits from *Amegilla byssina* (Apidae: Apinae) with the former in addition *Palarus laetus* (Crabronidae: Crabroninae: Palurini) and the latter *Bembix hauseri* (Crabronidae: Bembicinae) and *Ceylalictus karachiensis* (Halictidae: Nomiinae). Of particular interest was a site record for *M. ciliata* of a *Celonites*, presumably *jousseaumei*.



Figures 30–34. Boraginaceae: **30** *Arnebia hispidissima* **31, 32** *Heliotropium kotschyi* **33, 34** *Moltkiopsis ciliata*.

The associations with *Celonites jousseaumei* are of further interest when considered together with a close association of this pollen wasp with *Heliotropium* in Morocco (Volker Mauss, pers. com.) and close associations between *Heliotropium* and other masarines, *Trimeria buyssoni* Brethes in South America (Neff and Simpson 1985) and

Jugurtia namibicola Gess and *Celonites heliotropii* Gess with *Heliotropium tubulosum* Gess in Namibia (Gess, F.W. 2004, Gess, F.W. 2007, Gess, S.K. and Gess, F.W. 2010, Gess, S.K. and Gess, F.W. 2014).

In the semi-arid to arid areas of southern Africa six genera of Boraginaceae (sensu lato) were sampled. Grouped together they were recorded as visited by 12 species of wasps representing four families, including pollen wasps, and 52 species of bees representing five families. In addition to the two apparently monophagous species of pollen wasps closely associated with *Heliotropium tubulosum* E. Mey. Ex A.DC., two further species of pollen wasps, *Jugurtia codoni* Gess and *Quartinia codoni* Gess (Gess 2007) were found to be closely associated with *Codon royeri* L.

Brassicaceae

Brassicaceae is well represented in the UAE, 23 species having been recorded in Jongbloed (2003). Of these most are found to the east of the DDCR. Khafaga (2009) lists three annuals, *Brassica muricata*, *Eremobium aegyptiacum*, *Sisymbrium erysimoides*, and one perennial, *Farsetia linearis*, within the DDCR.

Farsetia linearis was encountered only in the enclosure at the Lucerne Farm where only one flower visitor, a female *Ceratina parvula* (Xylocopinae) was recorded.

Capparaceae

Jongbloed (2003) gives an account of 11 species of Capparaceae occurring in the UAE. Most species occur to the east or west of the central desert. Only two species are expected in the central desert, the most widespread, *Dipterygium glaucum*, is the only species recorded from the DDCR by Khafaga (2009) and the only species found in flower and sampled in the present study. The other species likely to be found within the DDCR is *Cleome amblyocarpa* Barr. & Murb.

During the present study the flowering of *Dipterygium glaucum* (Figure 35) was nearing its end and very few flower visitors were observed. At Quarn Nazwa one chry-



Figure 35. Capparaceae: *Dipterygium glaucum*.

sidid and one *Thyreus elegans* (Apidae: Apinae: Melectini) were recorded, from Tawi Ruwayan one *Amegilla byssina* (Apidae: Apinae) and one megachilid, and from the enclosed dune area at the Lucerne Farm one *Bembix saadensis* (Crabronidae: Bembicinae). This is unlikely to be truly representative. Petals were being eaten by two species of meloid beetles.

Caryophyllaceae

Twenty-one species of Caryophyllaceae are given in Jongbloed (2003), most to the east or west of the central desert and are therefore not expected in the DDCR. Khafaga (2009) recorded *Polycarpha repens*, *Sclerocephalus arabicus* and *Silene villosa*. In the present study none was common, however, scattered plants of *P. repens* and *S. villosa* were present in flower in the enclosed area of the Lucerne Farm. Only one visitor to *P. repens*, *Palarus parvulus* (Crabronidae: Crabroninae: Palurini), was recorded.

Fabaceae: Mimosoideae

Jongbloed (2003) gives accounts for three species of *Acacia* and three species of *Prosopis*, one exotic, occurring in the UAE. Of these Khafaga (2009) recorded *Acacia tortilis* and *Prosopis cineraria* from the DDCR. *Acacia nilotica* (L.) Delile has been introduced in various areas where trees have been planted.

Surprisingly, within the DDCR *Acacia tortilis* (Figures 36 and 37) was receiving very few visits, only *Thyreus hyalinatus* (Apidae: Apinae: Melectini) having been recorded. However, at a site to the east of the reserve, in a single sampling, Scoliididae (1 sp.), Crabronidae (Crabroninae 3 spp., Bembicinae 2 spp.), Halictidae (Nomiodinae 1 sp.), Megachilidae (Megachilinae: Megachilini 1 sp.), and Apidae (Apinae: Anthophorini 1 sp., Xylocopinae: Ceratinini 1 sp) were recorded.

Prosopis cineraria (Figures 38–40) in some parts of the reserve was receiving very few visits whereas in others it was well visited, receiving visits from wasps Sphecidae: Sphecinae, Crabronidae (Crabroninae 4 spp., Bembicinae 1 sp.) and Philanthinae (3 spp.) and bees Halictidae (Nomiodinae 3 spp.), Megachilidae (Megachilinae (2 spp.), and Apinae (*Apis* (*Micrapis*) *florea* which had a hive in one of the trees at Tawi Ruwayan). Occasionally the flowers were visited by braconid wasps.

It seems probable that in a good season there would be a much greater diversity of flower visitors. In the semi-arid to arid areas of southern Africa activity varies considerably from year to year, however, in the survey by the Gesses over many years, the total number of wasp species visiting Mimosoideae was 114 species representing eight families (30.04% of the total number of species of wasps recorded from flowers) with, however, only 28 species of bees, all polyphagous, of four families (6.2% of the total number of species of bees recorded from flowers) (Gess and Gess 2006).



36



37



38



39

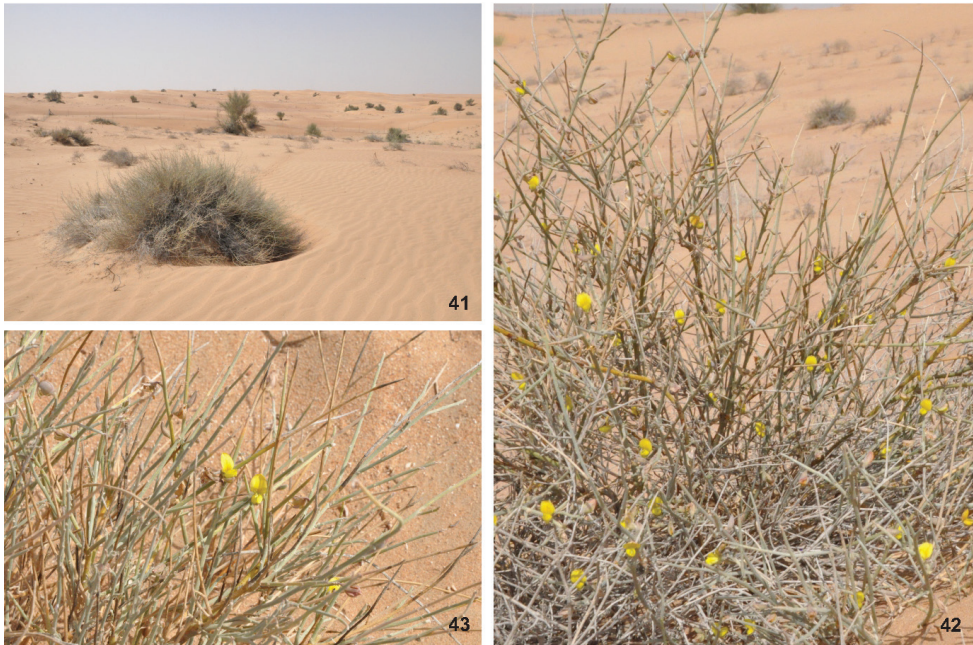


40

Figures 36–40. Fabaceae, Mimosoideae: **36, 37** *Acacia tortilis* **38–40** *Prosopis cineraria*.

Fabaceae: Papilionoideae

Papilionoideae are well represented in the UAE by 44 species (Jongbloed 2003). Most species occur to the east and west of the central desert. As could be expected from



Figures 41–43. Fabaceae: Papilionoideae: *Crotalaria aegyptiaca*.

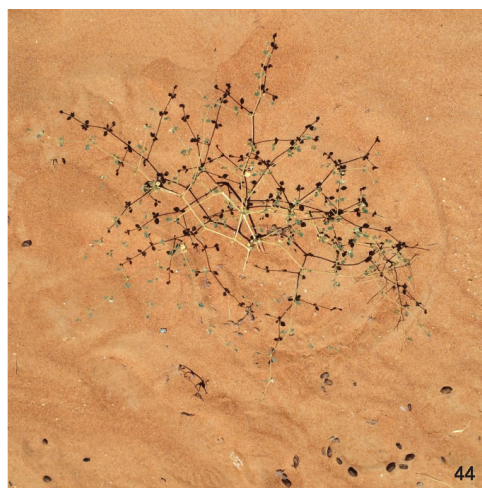
known distributions Khafaga (2009) recorded three species, *Crotalaria aegyptiaca*, *Indigofera colutea* and *I. intricata* from the DDCR.

During the present study *Crotalaria aegyptiaca* and *Indigofera intricata* were found in flower and were observed for flower visitors, the former in the dune enclosure where there were a good number of plants and the Lucerne Farm dune enclosure where only one plant each of this species and of *I. intricata* were found.

Within the Dune Enclosure *Crotalaria aegyptiaca* (Figures 41–43) was well visited by two species of bees, an un-described species of *Icteranthidium* (Megachilidae: Anthidiini), not recorded from any other plant and therefore possibly specializing in visiting the flowers of the Papilionoideae, and by polyphagus *Amegilla byssina* (Apidae: Apinae). Both in size and behavior are potential pollinators, however, *Icteranthidium* is likely to be the most reliable pollinator. The only other visitor to the flowers was a small polyphagous wasp, an undescribed species of *Laphrogogus* (Crabronidae: Eremiasphacinae), which can be discounted as a potential pollinator.

The presence of Anthidiini in the samples from Papilionoideae but not from Mimosoideae is expected, if comparison is made with Papilionoideae and Mimosoideae in southern Africa (Gess and Gess 2006).

The only visitor recorded as visiting *Crotalaria aegyptiaca* in the Lucerne Farm dune enclosure was a polyphagous bee, *Megachile patellimana* (Megachilini), also recorded from Apocynaceae, Boraginaceae, Brassicaceae, and Zygophyllaceae in the dune enclosure at the Lucerne Farm. It is of interest that *M. patellimana*, in Namibia was recorded from flowers of *Crotalaria podocarpa* DC (Papilionoideae) (Gess and Gess 2003).



Figures 44–45. Molluginaceae: *Limeum arabicum*.

Molluginaceae

Only one species of Molluginaceae, *Limeum arabicum*, was listed for the DDCR by Khafaga (2009). However, Jongbloed (2003) gives in addition two other species, *Limeum obovatum* and *Gisekia pharnaceoides* L., occurring in the central desert. *Gisekia pharnaceoides* is known to occur in the DDCR after rain (Greg Simkins pers. com.) and *Limeum obovatum* may well be found in the DDCR.

During the present survey *Limeum arabicum* (Figures 44 and 45), growing on sand dunes, was sampled for flower visitors in the Lucerne Farm dune enclosure, at Tawi Manana and at Quarn Nazwa. At all three sites the flowers were being visited by polyphagous crabronid wasps, represented in the Lucerne Farm dune enclosure by two species of *Palarus* (Crabroninae) and two species of *Bembix* (Bembicinae), at Quarn Nazwa by a third species of *Palarus* and at Tawi Manana by the undescribed species of *Laphrogogus*. At the Lucerne Farm, only, bees were amongst the visitors. They were of two families Halictidae, represented by *Pseudapis nilotica* (Nomiinae), and Apidae, represented by *Ceratina parvula* (Xylocopinae). Three species of meloid beetles were present on the flowers, eating them.

In the arid areas of southern Africa although all Crabronidae visiting *Limeum* are polyphagous, flowers of *Limeum* species are considered to be an important nectar source for these wasps and that in all probability they provide a pollination service (Gess and Gess 2006).

Neuradaceae

Neuradaceae is a small family restricted to semi-arid to arid regions. One genus *Neurada* is represented in North Africa across the Middle East and Arabia to India. In southern Africa it is represented by two genera *Grielum* and *Neuradopsis*.



Figure 46. Neuradaceae: *Neurada procumbens*.

In the UAE (Jongbloed 2003) Neuradaceae appears to be represented by only one species, *Neurada procumbens* (Figure 46), common and widespread except in the mountains. It is recorded from the DDCR (Khafaga 2009). During the present study *N. procumbens* was found in very small numbers only in the Lucerne Farm dune enclosure where the only recorded visitor to its small white flowers was a small halictid bee (Tables 3 and 4).

The southern African species have larger yellow flowers that attract bees from five families, including Halictidae. Also amongst their visitors is a pollen wasp, a species of *Quartinia*, and a chrysidid.

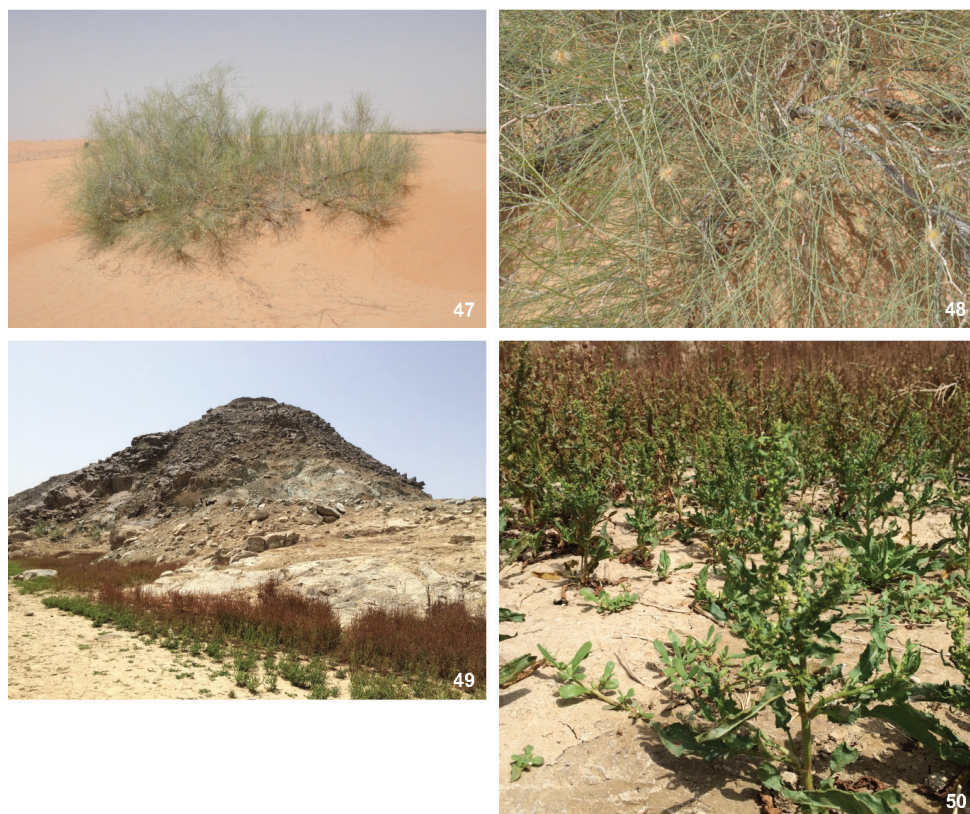
Polygonaceae

For Polygonaceae Jongbloed (2003) gives accounts for eight species in four genera. Of these only the woody shrub *Calligonum comosum* (Figures 47 and 48), common on sand dunes and plains in the UAE, was recorded from the DDCR (Khafaga 2009). At the time of this survey no plants were found in flower.

To the east of the Reserve *Rumex dentatus*, recorded by Jongbloed from scattered locations along the Gulf Coast, was found in flower fringing the area from which the water had retreated at Shawka dam in the Haja Mountains. At this site *R. dentatus* (Figures 49 and 50) was attracting visits from aculeate wasps of the families, Vespidae (Eumeninae and Polistinae), Pompilidae, Sphecidae, Crabronidae and bees of the family Halictidae (Tables 3 and 4).

Solanaceae

For Solanaceae Jongbloed (2003) gives accounts for eight species, in seven genera. Of these all but one, a woody shrub, *Lycium shawii* (Figures 51 and 52), are absent from the central desert and it is only this species that is listed for the DDCR (Khafaga 2009). In the present study *L. shawii* was observed for flower visitors at several scat-



Figures 47–50. Polygonaceae: **47, 48** *Calligonum comosum* **49, 50** *Rumex dentatus*.

tered localities, including Quarn Nazwa, where it was growing on the sides of dunes. From sampling *Lycium* flowers in the semi-arid to arid areas of southern Africa it was expected that the flowers would be visited by diverse wasps and bees (Gess and Gess 2006), however, no visitors were observed.

An exotic weed, *Solanum nigrum* (Figure 53), which offers nectar produced from extra-floral nectaries on petioles, leaves and stems (Anderson and Simon 1985), was growing near a dripping tap on the outskirts of the village of Munay in the east. It was sampled, yielding one species each of the families Pompilidae, Scoliidae, Sphecidae, Crabronidae and Halictidae.

Zygophyllaceae

Jongbloed (2003) gives accounts for 11 species of Zygophyllaceae, three species of *Fagonia*, five species of *Tribulus*, and three species of *Zygophyllum*. Of these Khafaga (2009) lists *Fagonia indica*, *Fagonia* sp., *Tribulus macropterus*, *T. omanense*, and *T. pentandrus*.



Figures 51–53. Solanaceae: **51–52** *Lycium shawii* **53** *Solanum nigrum*.

Fagonia indica (Figure 54) was in flower during the present survey but no visitors to its flowers were observed.

Well grown plants of *Tribulus macropterus* (Figures 55 and 56) in full flower were abundant within the Lucerne Farm dune enclosure where they were being well visited. Sampling was undertaken on three days, yielding most commonly five species of crabronid wasps, *Palarus laetus* (Crabroninae: Palurini) and four species of *Bembix* (Bembicinae: Bembicini), and by a megachilid bee, *Megachile patellimana*. Less commonly two other bees were represented, *Ceratina parvula* (Apidae: Xylocopinae: Ceratinini) and *Nomioides klausii* (Halictidae: Nomiodinae). Several species of meloid beetles were commonly present, eating the petals of the flowers. Outside the enclosure scattered remnants of grazed plants were occasionally found.

Along the side of the Margham Road outside the DDCR large plants of *Tribulus macropterus* were in flower. Some of these were checked, briefly, for visitors. The only visitor recorded was a single female of *Bembix rochei*, one of the four species of *Bembix* recorded at the Lucerne Farm.

Although it would appear from distributions given in Jongbloed (2003) that some species of *Zygophyllum* might be found in the DDCR none was recorded by Khafaga (2009) and none was found in the DDCR during the present survey.



Figures 54–59. Zygophyllaceae: **54** *Fagonia indica* **55, 56** *Tribulus macropterus* **57, 58** *Zygophyllum qatarense* **59** *Zygophyllum simplex*.

Zygophyllum species are amongst the dominant plants across the sandy plains to the west coast. *Zygophyllum qatarense* (Figure 33), a perennial dwarf shrub, and *Z. simplex* (Figure 34), a succulent annual, were sampled to the west of the reserve during the one-day transect to the west coast.

Zygophyllum qatarense (Figures 57 and 58) and *Z. simplex* (Figure 59), like *Tribulus macropterus*, were principally visited by Crabronidae, however, the assemblages did

not share species in common. Recorded were two species of *Cerceris* (Philanthinae) and *Gastrosericus waltlii* (Larrini) also recorded visiting flowers of *Z. simplex* in Namibia, southern Africa (Gess and Gess 2003). In addition *Telostegus argyrellus*, the only pompilid recorded from Zygophyllaceae was visiting *Z. qatarense* at the coast.

In southern Africa, *Zygophyllum* is more species diverse and more diverse in habit than in Arabia and the suites of visitors are, not surprisingly, more diverse. However, comparable species are *Z. simplex*, which is widespread from northern Richtersveld northwards through Namibia, and several northern coastal and desert perennial dwarf shrubs. *Z. simplex* is an important resource for wasps and bees in that area. Amongst the visitors Gess and Gess (2006) recorded 21 species of hunting wasps representing six families, five species of pollen wasps and 15 species of bees. The perennial dwarf shrubs are equally attractive to hunting wasps, pollen wasps and bees although they never attract as great a diversity and as great a number of individuals as does *Z. simplex*.

Aculeate wasps and bees visiting flowers

Table 4 lists the names of the aculeate wasps and bees recorded from flowers with the plant names together with the numbers and sex of the visitors and the collection sites.

Chrysidoidea

Chrysididae

Very few Chrysididae were observed during the survey. Single specimens, not identified beyond family, were collected from flowers of Asclepiadoideae, *Calotropis procera*, Boraginaceae, *Heliotropium kotschy*, and Capparaceae, *Dipterygium glaucum*, at three widely separated sites within the DDCR.

Vespoidea

Vespidae

Masarinae

At the time of the survey Masarinae were uncommon, two species, *Celonites jousseaumei* and *Quartinia nubiana*, were collected within the DDCR and one, *Celonites yemenensis*, to the east of the reserve.

The flower associations were for two species of Boraginaceae. *Quartinia nubiana*, represented by two females, was visiting flowers of *Heliotropium kotschy* at Tawi Ruwayyan. One specimen of *C. jousseaumei* was caught flying over flowering *Heliotropium kotschy* at the same site and another was observed flying away from an isolated

plant of *Moltkiopsis ciliata* at the Lucerne Farm, suggesting an association with *Heliotropium* and its allies, supported by an association of this species with *Heliotropium* in Morocco (Volker Mauss pers. com.).

Two specimens of *Celonites yemenensis* in flight, not associated with flowers, were collected, one in a wadi in the Hajar Mountains and the other on the bank of the lagoon at Khor Kalba where it was flying between *Zygophyllum qatarense* and *Heliotropium kotschyi*.

Of interest is the photographic record of M. Hauser of *Jugurtia yemenensis* Kostylev visiting flowers of Asteraceae (plate 74 in Gusenleitner 2010). No locality is given, however, the collection records given for this species are all wadis in the Hajar Mountains.

Eumeninae

Remarkably few Eumeninae were encountered during the present survey. Within the DDCR the only eumenine observed visiting flowers was *Rhynchium oculatum*, which was recorded from flowers of *Calotropis procera* (Asclepiadoideae). The only other species taken from flowers was *Delta esuriens esuriens* visiting *Rumex dentatus* (Polygonaceae), growing around Shawka Dam east of the reserve.

Polistinae

One species of Polistinae, *Polistes watti*, was encountered at two sites within the DDCR, Quarn Nazwa watering point at the northern end of the reserve and the palm grove at the Camel Farm, and one site, Shawka Dam, east of the reserve. Water was being imbibed at all sites, and nests were present in the palm grove. Flower visiting was observed at only two plants, *Aerva javanica* (Amaranthaceae) at Quarn Nazwa and *Rumex dentatus* (Polygonaceae) at Shawka Dam.

Vespinae

Vespa orientalis was not observed in the DDCR but was present to the east at Shawka Dam where it was associated with plants of *Rumex dentatus* (Polygonaceae).

Pompilidae

Remarkably few pompilids were encountered during the present survey: three species of Pompilinae, *Anoplius suspectus*, visiting *Rumex dentatus* (Polygonaceae) to the east of the reserve at Shawka Dam; *Telostegus argyrellus*, visiting *Calotropis procera* (Asclepiadoideae) at one site in the reserve, and *Zygophyllum qatarense* to the west of the reserve; and one species of Ceropalinae, *Ceropales kriebhbaumeri* on *Heliotropium kotschyi* (Boraginaceae) within the reserve and on the solanaceous weed, *Solanum nigrum*, to the east.

Tiphiidae

In the present survey only two species of tiphiids were observed visiting flowers: *Calotropis procera* (Asclepiadoideae) within the DDCR, and *Zygophyllum simplex* to the west of the reserve.

Mutillidae

No mutillidae were observed visiting flowers. Those seen were males coming to the light in the evening.

Scoliidae

Scoliids were observed principally visiting the flowers of *Calotropis procera* (Asclepiadoideae) from which, due to the size of the plant, they were difficult to catch, however, voucher specimens of two Campsomerinae, *Campsomeriella procera* (two females, one on each of two days) and *Micromeriella hyalina* (one female), and one Scoliinae, *Scolia flaviceps* (four females, two on each of two days) were taken from three sites within the DDCR, two of which offered a good diversity of flowers. Clearly, though not restricted to *C. procera*, scoliids appear to be strongly attracted to this plant. They are, however, only one of six families of wasps and one family of bees visiting this plant.

Males of the third species, *Micromeriella hyalina*, were caught on *Heliotropium kotschy* (Boraginaceae) at a fourth site in the reserve, and at two sites east of the reserve, at one on *Acacia tortilis* (Mimosoideae) and at the other on a weed, *Solanum nigrum* (Solanaceae) on the outskirts of a village.

Apoidea - Spheciformes

Sphecidae

Sphecidae were remarkably uncommon. Only one species was encountered within the reserve, namely *Prionyx nigropectinatus* (Sphecinae), which was visiting the flowers of *Prosopis cineraria* (Mimosoideae) at the Faqah watering point at the southern end of the reserve.

Two other species were found east of the reserve: *Ammophila rubripes* (Ammophilinae) visiting the solanaceous weed, *Solanum nigrum*; and *Sceliphron madraspatanum pictum* (Sceliphrinae) visiting *Rumex dentatus* (Polygonaceae).

Crabronidae

Crabronidae was the only family of wasps well represented during the present survey, with 27 species from within the DDCR, five additional species to the east and another

one to the west – in all 33 species representing 14 genera, nine tribes and five sub-families with almost a third of the species belonging to the genus *Bembix*.

In all Crabronidae were recorded from 10 plant families, 59% of the families from which flower visitors were recorded. The percentages of these species visiting these 10 families was 57% Fabaceae (Mimosoideae), 43% Zygophyllaceae, 38% Apocynaceae (Asclepiadoidea), 38% Boraginaceae, 29% Molluginaceae, 24% Asteraceae, and 10% and fewer Amaranthaceae, Capparaceae, Caryophyllaceae, Fabaceae (Papilionoideae), Solanaceae and Polygonaceae.

Of interest, a specimen of *Bembix kohli*, collected from *Calotropis procera*, was carrying pollinia, making it a potential pollinator of this plant.

Apoidea – Apiformes

The total number of species of bees (23 spp.), 20 from within the DDCR and an additional three from the east, was surprisingly low, compared with the number of Crabronidae.

Halictidae

Of the large family Halictidae only six species representing four genera were recorded from flowers: within the DDCR – *Nomia* (*Pseudapis*) (1 sp.) (Nomiinae), and *Ceylallictus* (3 spp.) and *Nomioides* (1 sp.) (Nomioidinae); and to the east the same species of *Nomia* (*Pseudapis*) plus *Nomia* (*Crocisaspidia*) (1 sp.). Strangely no Halictinae were recorded.

In total, flowers of five families of plants within the reserve and two further to the east, were recorded as visited, the number of families visited by single species ranging from one to three. The plant families visited by more than one species were Borgaginaceae, four species, and Fabaceae (Mimosoideae) three species, all within the reserve.

In the semi-arid to arid areas of southern Africa Halictidae are species diverse and include some of the commonest bees (Eardley et al. 2010, Eardley and Urban 2010, Gess and Gess, 2014). Gess and Gess (2004 and 2014) recorded a high incidence of polyphagy throughout the family with possible preferences being discernable in the Halictinae.

Colletidae

One species only of Colletidae was collected but it was not associated with a flower.

Megachilidae

Megachilidae collected in the DDCR were represented by seven species of Megachilinae: five Megachilini, *Megachile concinna*, *M. minutissima*, *M. patellimana*, *M. maxillosa* and

Coelioxys indica; one Osmiini, *Haetosmia circumventa*; and two Anthidiini, *Icteranthidium* n. sp. and *Pseudoanthidium ochrognathum*.

Megachile concinna, *M. minutissima* and *M. patellimana*, were all collected from flowers of Fabaceae (Mimosoideae); *M. concinna* and *M. patellimana* in addition from Apocynaceae (Asclepiadoidea), *Leptadenia pyrotechnica*; and *M. patellimana*, the most common species, in addition from Asteraceae, Boraginaceae, Brassicaceae, Fabaceae (Papilionoideae) and Zygophyllaceae but most commonly from *Heliotropium kotschy* at three sites and *Tribulus macropterus* at one of the same sites, none the less demonstrating broad polyphagy.

A female *Megachile patellimana*, captured carrying leaf pieces, was nesting in the sand beneath *Heliotropium kotschy* where *Coelioxys indica* was seen to be inspecting burrow openings. *Coelioxys indica* was visiting *Heliotropium kotschy* together with *M. patellimana*. As *Coelioxys* are known to be cleptoparasites of megachilids it is suggested that *M. patellimana* is a host of *Coelioxys indica*.

Megachile patellimana is represented in Namibia, where it has been collected from flowers of *Crotalaria podocarpa* DC (Papilionoideae) (Gess and Gess 2003).

No visits to flowers were observed for *Megachile maxillosa*, although it was nesting in trap nests, one bundle tied to a branch of *Calotropis procera* outside the drip irrigation area at Tawi Ruwyyan and the other on the trunk of a palm tree in the grove at the Camel Farm. This species was commonly collected visiting flowers in the semi-arid to arid areas of South Africa and Namibia (Gess and Gess 2003) where it was shown to be polyphagous, having been collected from flowers of Acanthaceae, Asclepiadoideae, Asteraceae, Brassicaceae, Fabaceae (Caesalpinioideae, Mimosoideae and Papilionoideae), Pedaliaceae and Polygalaceae, however, in Namibia it was most commonly visiting Papilionoideae, most notably species of *Crotalaria*.

Haetosmia circumventa was collected from three sites during five collecting events. All specimens were visiting flowers of *Heliotropium kotschy* (Boraginaceae), suggesting a preference for Boraginaceae, supported by Gotlieb et al. (2014) in which it is recorded that *H. circumventa* is oligolectic, specialising in collecting pollen from the flowers of *Heliotropium*, for which purpose the mouthparts are modified to extract pollen from narrow floral tubes.

Icteranthidium n. sp was observed during two collecting events at *Crotalaria aegyptiaca* to be the most common visitor to flowers of this plant. Furthermore, it was not visiting other flowers at the same or any other site, suggesting that it may specialize in visiting Papilionoideae, which taken together with its behavior and fit would suggest that it is a likely pollinator of *C. aegyptiaca*.

Pseudoanthidium ochrognathum was most commonly observed visiting flowers of Boraginaceae, *Heliotropium kotschy* and *Moltkiopsis ciliata*, suggesting a preference for Boraginaceae, however, one specimen was taken from *Aerva javanica* growing in close proximity to *M. ciliata*.

It would appear that in the DDCR, as in the semi-arid to arid areas of southern Africa (Gess and Gess 2004 and 2014) Megachilini are polyphagous but for some species of Osmiini and Anthidiini strong preferences are suggested.

Apidae

During the course of the present survey, remarkably few species of Apidae were observed visiting flowers: six species of Apinae, two Apini and four Anthophorini; and four species of Xylocopinae, two Xylocopini and two Ceratinini.

The two species of *Apis*, *A. (Micrapis) florea* and *A. mellifera*, are well known to be broadly polyphagous.

The two species of Anthophorini, *Amegilla bysina* and *Anthophora tenella*, and one of the two species of Melectini, *Thyreus hyalinatus*, were represented amongst the visitors to *Heliotropium kotschyi*. However, *A. bysina*, typically for *Amegilla*, is broadly polyphagous. In the DDCR it was represented in samples from, Asclepiadoideae, Asteraceae and Papilionoideae, in addition to Boraginaceae.

Anthophora tenella was taken not only from flowers of Boraginaceae but also of Mimosoideae. *Thyreus elegans* was uncommon, only one specimen, a single female, having been found visiting flowers of *Dipterygium glaucum* (Capparaceae). As *Thyreus* are nest parasites of anthophorines it was surprising that they were so uncommon.

The two large carpenter bees, *Xylocopa fenestrata* and *X. aestuans* were both commonly seen visiting *Calotropis procera* (Asclepiadoideae) at various sites. At Quarn Nazwa, where *C. procera* was not present, *X. fenestrata* was collected from flowers of *Centaurea pseudosinaica* (Asteraceae).

The two small carpenter bees, *Ceratina parvula* and *C. tarsata* were not represented in samples from *Calotropis procera*. In the dune enclosure at the Lucerne farm, where *C. procera* is well represented, *C. parvula* was visiting flowers of *Heliotropium kotschyi*, *Limeum arabicum* and *Tribulus macropterus*. *Ceratina tarsata*, represented by a single female, was taken in a sample of visitors to flowers of *Acacia tortilis* at a site east of the DDCR.

Conclusions

Although this first survey of flower visiting by wasps and bees in the UAE, with the DDCR as the focus of the study, was conducted over a limited period of time, during a dry spring, following seven dry years, it has provided sufficient data to draw some general conclusions.

- Most of the plants sampled attract visits from a complex of both wasps and bees.
- The flowers of some of these plants attract a wide range of wasps and bees but there were no flowers that were attractive to all available wasps and bees at any one site.
- Very few species of the wasps and bees encountered were specialists.
- The plants on which these specialist wasps and bees were dependent were not themselves dependent on these wasps and bees for pollination, however, some of the specialist wasps and bees are likely to be their most dependable pollinators.

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Appendix I

List of plants from the flowers of which aculeate wasps and bees were collected, with global distributions.

ACANTHACEAE: *Aerva javanica* (Burm. f.) Juss. ex Schult. – Northern Africa to southwestern Asia. Introduced and naturalised in northern Arabia (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

AIZOACEAE

Sesuvium verrucosum Raf. – native to the Americas, where it can be found in the southwestern quadrant of the United States (California, Oregon, Baja California, east to Utah, Kansas, Texas) and northern Mexico, it also occurs in southern Brazil. It is naturalized in the Arabian Peninsula (http://www.liflfe.com/Encyclopedia/SUCCULENTS/Family/Aizoaceae/28896/Sesuvium_verrucosum) Sampled in **DDCR**

APOCYNACEAE (Asclepiadoideae)

Calotropis procera (Aiton) W.T. Aiton – native to West Africa as far south as Angola, North and East Africa, Madagascar, the Arabian Peninsula, Southern Asia and Indo-China to Malaysia. Introduced and naturalized in Australia, many Pacific Islands, Mexico, Central and South America and the Caribbean Islands (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

Leptadenia pyrotechnica (Forssk.) Decne – Senegal, Mauritania to north of Nigeria, the semi-desert areas across Africa (Egypt, Sudan, Somalia, Chad, Libya, Algeria) to Western India (Pakistan and India) – (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

ASTERACEAE

Centaurea pseudosinaica Cerep. – Western Asia, Iraq, Iran, Arabian Peninsula, including UAE (<http://www.catalogueoflife.org/col/details/species/id/6a39f8876432e32027c6dcb108b5781f/source/tree>) Sampled in **DDCR**

Launaea procumbens (Roxb.) Ramayya and Rajagopal – Egypt, Iraq, Iran, Asia (Turkmenistan, Uzbekistan, Tadjikistan, Afghanistan, Pakistan, India, Nepal, Burma, China). Arabian Peninsula including the UAE (eol.org) Sampled in the **DDCR**

Rhanterium epapposum Oliv. – Western North Africa, Iraq, Iran, Arabian Peninsula, including UAE (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

BORAGINACEAE

Arnebia hispidissima (Lehm.) DC; *Heliotropium digynum* (Forssk.) Asch. ex Chr. – Northern Africa (Nigeria, Cameroon, Chad, Sudan, Egypt) to the Arabian Peninsula, northern India and Pakistan (<http://www.ddcr.org/florafauna>) **DDCR**

Heliotropium kotschy (Bge.) Gurke – Arabian Peninsula. Sampled in **DDCR** and also west of the DDCR

Moltkiopsis ciliata (Forssk.) I.M. Johnst. – Widely distributed in Mediterranean Region and Arabia including UAE (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

BRASSICACEAE

Farsetia linearis Decne. Ex Boiss. Arabian Peninsula, Yemen, Oman, UAE. Sampled in **DDCR**

CAPPARACEAE:

Dipterygium glaucum Decne. – Northern Sudan and Egypt east of the Nile through the Arabian Peninsula to the desert areas of North West India (Rajasthan, Gujarat and Pakistan) (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

CARYOPHYLLACEAE

Polycarpha repens (Forssk.) Asch. & Schweinf. – Mauritania, Niger, Chad, Libya, Tunisia, Algeria, Morocco, Sahara, Egypt, Iraq, Iran, Israel, Sinai, Arabian Peninsula (www.gbif.org) Sampled in **DDCR**

FABACEAE: Mimosoideae

Acacia tortilis (Forssk.) Hayne – Widespread in Africa from South Africa northwards to Algeria and Egypt, extending to Asia and southern Arabia. Cultivated in India and Pakistan (<http://www.ddcr.org/florafauna>) Sampled in **DDCR** and also east of the DDCR

Prosopis cineraria (L.) Druce – India, Pakistan, Afghanistan, Iran, Arabian Peninsula (<http://www.ddcr.org/florafauna>) Sampled in **DDCR**

FABACEAE: Papilionoideae

Crotalaria aegyptiaca Benth. – Egypt, Somalia, Iran, Arabian Peninsula (Saudi Arabia, Oman, Yemen, UAE), Jordan, Palestine, Israel (<http://www.ddcr.org/florafauna>)
Sampled in **DDCR**.

MOLLUGINACEAE

Limeum arabicum Friedr. – Saudi Arabia, Oman, Yemen, UAE (<http://www.catalogueoflife.org>) Sampled in **DDCR**

NEURADACEAE

Neurada procumbens L. – North Africa, East Mediterranean Region, Sinai, Sahara, Sudan, Ethiopia, Arabia to Indian Desert. (<http://eol.org/pages/6872917/overview>) Sampled in **DDCR**

POLYGONACEAE

Rumex dentatus L. – Europe, Mediterranean region, Arabia, Asia (<http://eol.org/pages/587351/details#overview>) Sampled to the west of the DDCR

SOLANACEAE

Solanum nigrum L. – native to Europe and western Asia, introduced in North America, Africa, Asia and Australia (<http://www.globinmed.com/>) and Arabia. Sampled to the west of the DDCR

ZYGOPHYLLACEAE

Tribulus macropterus Boiss. – Algeria, Libya, Egypt, Palestine, Arabia, Iraq, Iran, Afghanistan, Sudan (<http://eol.org/pages/5633281/details>) Sampled in **DDCR**
Zygophyllum qatarense Hadidi – Arabian Peninsula. Sampled to the west of the DDCR
Zygophyllum simplex L. – Africa, Madagascar, Arabia, Palestine, India (<http://eol.org/pages/5633281/details>) Sampled to the west of the DDCR

Appendix 2

List of aculeate wasps and bees collected in the DDCR and from the transect to the east and west coasts, with global distributions.

Chrysidoidea

Chrysididae

Undetermined, **DDCR**

Vespoidea

Vespidae

Masarinae

Celonites jousseaumei du Buysson, 1906, Algeria to Israel, southwards to Sudan and the Arabian Peninsula, including the UAE (Schmid-Egger, 2015) **DDCR**

Celonites yemenensis Giordani Soika, 1957, Arabian Peninsula including UAE, Ethiopia (Schmid-Egger 2015) in present survey found to the east of the DDCR

Quartinia nubiana Richards, 1962, Tunisia, Libya, Egypt and UAE (Schmid-Egger 2015) **DDCR**

Eumeninae

Delta esuriens esuriens (Fabricius, 1787), India through to Iran and the Arabian Peninsula, including UAE (Gusesenleitner 2010) in present survey found to the east of the DDCR

Rhynchium oculatum (Fabricius, 1781), Mediterranean Region to India, Arabian Peninsula including UAE (Gusesenleitner 2010) **DDCR**

Polistinae

Polistes watti Cameron, 1900, Arabian Peninsula including UAE to China (Gusesenleitner 2010) **DDCR**

Vespinae

Vespa orientalis Linnaeus, 1771, Southern Italy and Libya to India and Nepal, UAE (Gusesenleitner 2010) in present survey found east of the DDCR

Pompilidae

Pompilinae

Anoplius suspectus (Saussure, 1904), North Africa, Algeria, Egypt; Arabia, Yemen; Asia, India, Nepal, Pakistan, Laos, Thailand, Sumba (Wahis, 2006) in present survey found east of the DDCR

Gonaporus israelicus Wolf, 1990, Israel, UAE, **DDCR**

Telostegus argyrellus (Klug, 1834), North Africa, Algeria, Tunisia, Morocco, Libya, Egypt; West Africa, Mauritania, Niger, Senegal; Turkey, Jordan, Israel, Iran; Asia, Pakistan, Turkmenistan, Kyrgyzstan; Europe, Portugal, Spain (insectoid.info/checklist/pompilini/ and Gahari et al. 2014) UAE, **DDCR**

Ceropalinae

Ceropales krieckbaumeri Magretti, 1884, Burkina Faso, Nigeria, South Africa, Zimbabwe, Uganda (<http://www.waspweb.org/Vespoidea/Pompilidae/Ceropalinae/Ceropales/index.htm>), UAE, **DDCR**

Tiphiidae: Thynninae

In present survey one specimen of one species west of the DDCR

Mutillidae

To light in **DDCR**

Scoliidae

Campsomerinae

Campsomeriella thoracica (Fabricius, 1787), Sahel area of the Afrotropical Region, the Mediterranean area, Arabian Peninsula, including UAE (Schulten 2007) **DDCR**

Micromeriella hyalina (Klug, 1832), Sahel area of the Afrotropical Region, the Mediterranean area, Arabian Peninsula, including UAE (Schulten 2007) **DDCR**

Scoliinae

Scolia flaviceps Eversmann, 1846, Crete, Iraq, Tajikistan, Turkmenistan, Uzbekistan, Central Asia, Cyprus, Transcaucasia, Greece, southern France, Italy, Balkans to the eastern Mediterranean Region, including Egypt to the Caspian Sea, Turkey, Turkmenistan (Samin, Bağrıaçık and Gadallah 2014) **DDCR**

Apoidea - Spheciformes

Sphecidae

Sphecinae

Prionyx nigropectinatus Taschenberg, 1869, Libya, Algeria, Egypt, Israel, Mauritania, Tajikistan, Turkmenistan, Oman, Yemen, Iran (Pulawski 2016) **DDCR**

Sceliphrinae

Sceliphron madraspatanum pictum F. Smith, 1856, Mediterranean Region, Iraq, Arabian Peninsula including UAE (Schmid-Egger 2011) in the present survey found east of the DDCR (*Sceliphron madraspatanum* (Fabricius, 1781), India, Maldives, Malaysia, Thailand, Taiwan, Philippines, Japan, China, Kazakhstan, western Russia (Pulawski 2016)

Ammophilinae

Ammophila rubripes Spinola, 1838, widespread throughout Africa from north to south and west to east, Saudi Arabia, Yemen, Oman, UAE, Israel, Syria (Pulawski 2016) in the present survey found east of the DDCR

Crabronidae

Astatinae

Astata prosii Schmid-Egger, 2014, UAE (Pulawski 2016) **DDCR**

Crabroninae: Larrini

Gastrosericus moricei E. Saunders, 1910, North Africa (Algeria, Libya and Egypt), Arabia (Saudi Arabia, Oman and UAE), Israel, Sinai Peninsula, Sri Lanka, Uzbekistan, Tajikistan and Kazakhstan (Pulawski 2016) **DDCR**

Gastrosericus waltlii Spinola, 1839, South western Africa (Namibia), North Africa (Western Sahara, Algeria, Morocco, Libya, Egypt), south east Western Russia, southern France, Cyprus, Turkey, Israel, Iran, Arabia (Saudi Arabia, Kuwait, Oman, UAE), Sri Lanka, Central Asia, Tajikistan, Kazakh, Uzbekistan, China (Pulawski, 2016) in present survey found west of the DDCR

Prosopigastra globiceps Morice, 1989, Mali, Sudan, Egypt, Israel to Central Asia and northwest China, and Arabian Peninsula, including UAE (Schmid-Egger 2011) **DDCR**

Tachysphex erythropus (Spinola, 1839), Morocco, Libya, Spain, Portugal, Italy, Greece, Bulgaria, Turkey, Egypt, Saudi Arabia, Turkmenistan, Kazakhstan, Uzbekistan, Sri Lanka (Pulawski 2016) **DDCR**

Tachysphex micans (Radoszkowski, 1877), Morocco, Libya, Egypt, Turkmenistan, Tajikistan, Kazakhstan (Pulawski 2016) **DDCR**

Tachysphex quadrifurci Pulawski, 1971 = *brevipennis* Mercet, 1909, Spain, Portugal, Greece, Algeria, Morocco, Egypt, Turkey, Ukraine, Crimea, Kazakhstan, Turkmenistan, Iran, UAE, India, Zimbabwe, South Africa (Pulawski 2016) **DDCR**

Tachytes comberi Turner, 1917, Libya, Mauritania, Pakistan, Arabian Peninsula, including Saudi Arabia, Oman, UAE (Pulawski 2016) **DDCR**

Crabroninae: Oxybelini

Oxybelus lamellatus Olivier, 1811, From Southwest Europe and North Africa to Northwest India, southwards to Mali, Nigeria and Niger, Arabian Peninsula, including UAE (Schmid-Egger 2011), West Africa (Mauritania), North Africa (Morocco, Tunisia, Algeria, Libya, Egypt, Sudan, Eritrea, Ethiopia, Somalia), Mediterranean Europe (Spain, Italy, Greece, Cyprus), Turkey, Jordan, Syria, Iraq, Iran, Arabia (Saudi Arabia, UAE), Turkmenistan, Afghanistan, Pakistan, India, Uzbekistan, Kazakhstan, Tajikistan, China (Pulawski 2016), **DDCR**

Crabroninae: Palarini

Palarus bisignatus F. Morawitz, 1890, Central Asia, Saudi Arabia, UAE (Schmid-Egger 2011 and Pulawski 2016) **DDCR**

Palarus dongalensis Klug, 1845, North Africa (Egypt and Sudan), Iran, Saudi Arabia, Oman, UAE (Schmid-Egger 2011 and Pulawski 2016) **DDCR**

Palarus laetus Klug, 1845, North Africa (Tunisia, Morocco, Egypt, Djibouti), Iraq, Iran, Arabia (Kuwait, Oman, UAE), India (Schmid-Egger 2011 and Pulawski 2016) **DDCR**

Palarus parvulus de Beaumont, 1949, North Africa (Algeria, Egypt) Israel, Arabian Peninsula, including UAE (Pulawski 2016) **DDCR**

Crabroninae: Miscophini

Plenoculus vanharteni Schmid-Egger, 2011, Northeast Coast of UAE (Schmid-Egger 2011 and Pulawski 2016) **DDCR**

Bembicinae: Alyssontini

Didineis bucharica Gussakovskij, 1937, Uzbekistan, Kazakhstan, UAE (Schmid-Egger 2011 and Pulawski 2016) in the present survey found east of the DDCR

Bembicinae: Bembicini

Bembix arenaria Handlirsch, 1893, Tunisia, Egypt, Saudi Arabia, Turkey, Iran, Palestine, UAE (Pulawski 2016) in present survey found east of the DDCR

Bembix chopardi Berland, 1950, North west Africa (Niger), North Africa (Egypt), Arabia (Saudi Arabia, UAE (Pulawski 2016) in present survey found east of the DDCR

Bembix freydessneri Morice, 1897, North-west Africa (Mauritania, Chad), North Africa (Algeria, Libya, Egypt, Sudan), Arabia (Saudi Arabia, Yemen, UAE) (Pulawski 2016) **DDCR**

Bembix gazella Guichard, 1989, Oman (Muscat) and UAE (Pulawski 2016) **DDCR**

Bembix hameri Guichard, 1989, UAE (Pulawski 2016) **DDCR**

Bembix hauseri Schmid-Egger, 2011, Saudi Arabia, Oman, UAE (Pulawski 2016) **DDCR**

Bembix kohli Morice, 1897, Egypt, Iran/Baluchistan and UAE (Schmid-Egger 2011) **DDCR**

Bembix oculata Panzer, 1801, Europe (Germany, Austria, Portugal, Spain, France, Italy, Greece, Hungary, Croatia, Serbia, Bulgaria), Ukraine, Russia, North Africa (Western Sahara, Algeria, Tunisia, Libya, Egypt, Sudan), Cyprus, Albania, Turkey, Syria, Israel, Iran, Arabia (Saudi Arabia, UAE), Afghanistan, Turkmenistan, Kazakhstan, Tajikistan, China (Mongolia), (Pulawski 2016) in present survey found east of the DDCR

Bembix rochei Guichard, 1989, North-west Africa (Mali), North Africa (Algeria, Tunisia), Arabia (UAE), India (Pulawski 2016) **DDCR**

Bembix saadensis Guichard, 1989, Arabia (UAE) (Pulawski 2016) **DDCR**

Stizoides assimilis Fabricius, 1787, North Africa (Algeria, Morocco, Egypt, Sudan), Palestine, Israel, Arabia (Saudi Arabia, Yemen, UAE), India, Turkmenistan, Kazakhstan, Tajikistan, (Pulawski 2016) east of the DDCR

Eremiasphecini: Eremiasphecini

Laphyragogus sp. (a new species to be described by Christian Schmid-Egger) **DDCR**

Philanthinae: Philanthini

Philanthus coarctatus Spinola, 1839, North west Africa (Mauritania, Chad), North Africa (Western Sahara, Libya, Egypt, Sudan, Ethiopia), Italy, Turkey, Jordan, Israel, Iraq, Iran, Asia (Kazakhstan), Arabia (Saudi Arabia, Oman, UAE) (Pulawski 2016) **DDCR**

Philanthus pallidus Klug, 1845, North-west Africa (Mauritania), North Africa (Morocco, Egypt, Sudan, Ethiopia, Eritrea, Arabia (Saudi Arabia, Oman, UAE), Iran (Pulawski 2016) **DDCR**

Philanthus triangulum Fabricius, 1775, Widespread in Europe from north to south, Africa from north to south, Middle East, Arabia including UAE, Western and central Asia (Pulawski 2016) **DDCR**

Philanthinae: Cercerini

Cerceris albicincta Klug, 1845, North-west Africa (Chad), North Africa (Western Sahara, Algeria, Morocco, Egypt, Sudan) Palestine, Arabian Peninsula including Saudi Arabia and UAE (Pulawski 2016) **DDCR**

Cerceris chromatica Schletterer, 1887, North Africa (Algeria, Egypt) Israel, Arabia (Saudi Arabia, Oman, UAE) (Pulawski 2016) **DDCR**

Cerceris sp. **DDCR**

Apoidea – Apiformes

Halictidae

Halictinae

Halictus (Seladonia) lucidipennis (Smith, 1853), Southern Palearctic and Oriental Regions, including North Africa, Asia from Palestine, Arabian Peninsula, Asia Minor, Iran, Iraq, Central Asia to Mongolia and N China, south to Sri Lanka, Cape Verde Islands, northern part of Afrotropical Region, south to Kenya, Central Thailand, UAE (Dathe 2009) in present survey found east of the DDCR

Sphcodes sp. UAE, **DDCR**

Nomiinae

Nomia (Crocisaspidia) vespoides (Walker, 1871), Sudan, Eritrea, Iran, Pakistan, Oman, UAE (Distribution Map at www.discoverlife.org) in present survey found east of the DDCR

Pseudapis (Pseudapis) nilotica (Smith, 1875), North Africa to Pakistan (Egypt, Ethiopia, Sudan, Djibouti, Saudi Arabia, Qatar, Oman, UAE, Turkmenistan, Afghanistan) (Dathe 2009) **DDCR**

Nomioidinae

Ceylalictus (*Ceylalictus*) *punjabensis* (Cameron, 1907), Cape Verde Islands, North Africa, Arabian Peninsula, including UAE), Israel, Jordan, S Iran, S Afghanistan, Pakistan, NW India (Dathe 2009) **DDCR**

Ceylalictus (*Ceylalictus*) *variegatus* (Olivier, 1789), warm habitats in Central and Southern Europe, North Africa, steppes and deserts of western Asia to China, northern India and Mongolia, Saudi Arabia, Yemen, Oman, Bahrain, UAE (Dathe 2009) **DDCR**

Ceylalictus (*Meganomioides*) *karachiensis* (Cockerell, 1911), Mauritania, Oman, S Pakistan, UAE (Dathe 2009) **DDCR**

Nomioides (*Nomioides*) *klausii* Pesenko, 1983, North Africa, Arabian Peninsula (Saudi Arabia, Oman, UAE), SW Iran (Dathe 2009) **DDCR**

Colletidae

Undertermined, **DDCR**

Megachilidae

Megachilinae

Megachilini

Megachile (*Euchtricharea*) *concinna* Smith, 1879, USA, Azores, Spain, France, Corsica, Italy, Sicily, Slovenia, Greece, Morocco, Egypt, Sudan, Israel, Turkey, Yemen, UAE (Distribution Map at www.discoverlife.org) **DDCR** sub-species *leucostoma*

Megachile (*Euchtricharea*) *minutissima* Radoszkowski, 1876, Egypt, Eritrea, Saudi Arabia, Pakistan, UAE (Dathe 2009) **DDCR**

Megachile (*Euchtricharea*) *patellimana* Spinola, 1838, widely distributed in western Palearctic, particularly in the Mediterranean, Asia Minor, Egypt and UAE, also south-western Africa, Sudan, Niger and Mozambique (Dathe 2009) **DDCR**

Megachile (*Maximegachile*) *maxillosa* Guérin-Méneville, 1845, Senegal, Namibia, Botswana, South Africa, Zimbabwe, Malawi, Kenya, Sudan, Ethiopia, Saudi Arabia, Yemen (Distribution Map at www.discoverlife.org) **DDCR**

Coelioxys indica Friese, 1925, India, West Africa, East Africa, UAE (Distribution Map at www.discoverlife.org) **DDCR**

Osmiini

Haetosmia circumventa (Peters, 1974), Canary Islands, Morocco, Libya, Sudan, UAE (Dathe 2009) **DDCR**

Anthidiini

Icteranthidium n. sp. (to be described by Jessica Litman) **DDCR**

Pseudoanthidium (*Pseudanthidium*) *ochrognathum* (Alfken, 1932), Egypt, Israel, UAE (Dathe 2009) **DDCR**

Apidae

Xylocopinae

Xylocopini

Xylocopa (*Ctenoxylocopa*) *fenestrata* (Fabricius, 1798), Palestine to India, Iraq north to Bagdad, south coast of Iran, UAE (Dathe 2009) **DDCR**

Xylocopa (*Koptortosoma*) *aestuans* Linnaeus, 1758), SE Asia to Mediterranean (Morocco, Mauritania, S Sahara, Egypt, Turkey, Iran), UAE (Dathe 2009) **DDCR**

Ceratinini

Ceratina (*Ceratinula*) *parvula* Smith, 1854, Circum-Mediterranean (Crete), near East, Turkey, Turkmenistan, UAE (Dathe 2009) **DDCR**

Ceratina (*Pithitis*) *tarsata* Morawitz, 1872, Eastern Mediterranean (Crete), Egypt, Sudan, Ethiopia, Yemen, UAE (Dathe 2009) **DDCR**

Apinae

Anthophorini

Amegilla (*Micramegilla*) *byssina* (Klug, 1845), Desert areas from Algeria to eastern Arabia, including UAE, Egypt, Pakistan (Dathe 2009) **DDCR**

Anthophora (*Heliophyla*) *tenella* (Klug, 1845) Algeria, Egypt (Distribution Map at www.discoverlife.org) **DDCR**

Apinini

Apis (*Apis*) *mellifera* Linnaeus, 1758, Worldwide, **DDCR**

Apis (*Micrapis*) *florea* Fabricius, 1787, NW India to Borneo, Afghanistan, Iran, Oman, UAE (Dathe 2009) **DDCR**

Melectini

Thyreus elegans (Morawitz 1878), North Africa from Mauritania to Egypt, Palestine, Turkey, Pakistan, Central Asia, Saudi Arabia, UAE (Dathe 2009) **DDCR**

Thyreus hyalinatus (Vachal, 1903) Senegal, Mauritania, Nigeria, Chad, Egypt, Sudan, Eritrea, Djibouti, Tanzania, Israel, Saudi Arabia, Iran UAE (Distribution Map at www.discoverlife.org) **DDCR**